Advances in Science, Technology & Innovation
IEREK Interdisciplinary Series for Sustainable Development

Syed M. Ahmed · Paul Hampton ·
Salman Azhar · Amelia D. Saul *Editors*

Collaboration and Integration in Construction, Engineering, Management and Technology

Proceedings of the 11th International Conference on Construction in the 21st Century, London 2019

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Foreword

With my deepest gratitude and satisfaction, I write this Foreword to the Proceedings of the 11th International Conference on Construction in the 21st Century (CITC-11) London, United Kingdom, September 9–11, 2019.

CITC is an organization based in the Department of Construction Management at East Carolina University. Established at the dawn of the twenty-first century, Construction in the 21st Century (CITC) has lived up to its name and vision by truly representing the topical construction research issues over the past two decades. One only needs to see the breadth and depth of research issues covered in a series of these conferences to understand the shift in the research landscape over time. As one of the longest running peer-reviewed construction conferences, CITC brand has become synonymous to quality and relevance.

The CITC-11 conference was organized in collaboration with the University of Wolverhampton and supported by Auburn University, RICS, QSI, CIOB, CMAA, and Babcock University. As with previous conferences which include CITC-I in Miami of 2002, CITC-II in Hong Kong of 2003, CITC-III in Athens of 2005, CITC-IV in Gold Coast, Australia of 2007, CITC-V in Istanbul of 2009, CITC-VI in Kuala Lumpur of 2011, CITC-VII in Bangkok of 2013, CITC-8 in Thessaloniki, Greece of 2015, CITC-9 in Dubai of 2017, and CITC-10 in Sri Lanka of 2018, CITC-11 was also a tremendous success.

The 3-day conference brought together an international group of practitioners, researchers, and educators to promote a novel exchange of ideas in a multidisciplinary fashion through the delivery of 8 high-quality keynote presentations and 139 peer-reviewed papers. Over 100 delegates attended from 30 countries. As the world continues to become further complex and uncertain, it is through dialogue and mutual collaboration that we would be able to unravel its complexities. CITC-11 provided such a platform for dynamic collaboration and exchange of knowledge whereby new methods and techniques were carefully scrutinized and rigorously tested before implementation. Part of festivities of this conference included a fabulous river cruise down the Thames, with dinner and afternoon tea at iconic House of Common Churchill Room.

A special word of thanks is due to the conference organizers and sponsors for organizing yet again another successful conference.

Associate Professor Tayyab Maqsood
Associate Dean
RMIT University
Melbourne, Australia

Preface

While technology and innovation are shrinking, the distance between countries and industries and leadership and collaboration are actively shaping the construction industry, as well as guiding it towards success. Construction in the 21st Century (CITC) is an organization based in the Department of Construction Management at East Carolina University. The CITC-11 conference is being organized in collaboration with University of Wolverhampton and supported by Auburn University, RICS, QSI, CIOB, CMAA, and Babcock University. CITC organizes international conferences to bring together like-minded construction management professionals. The CITC-11 conference seeks to bring together an international group of practitioners, researchers, and educators to promote a novel exchange of ideas in a multidisciplinary fashion.

CITC-11 is a peer-reviewed conference that acts as a dynamic collaboration for the exchange of knowledge. New methods and techniques must be carefully scrutinized and rigorously tested before implementation, and CITC-11 plays an integral role in this process. As the industry moves forward in an ever-complex global economy, multi-national collaboration is crucial. Future growth in the industry will undoubtedly rely on international teamwork and alliance.

This September marks the eleventh CITC conference. Previous conferences include CITC-I in Miami of 2002, CITC-II in Hong Kong of 2003, CITC-III in Athens of 2005, CITC-IV in Gold Coast, Australia of 2007, CITC-V in Istanbul of 2009, CITC-VI in Kuala Lumpur of 2011, CITC-VII in Bangkok of 2013, CITC-8 in Thessaloniki, Greece of 2015, CITC-9 in Dubai of 2017, and CITC-10 in Sri Lanka of 2018. All conferences were tremendously successful. As with previous conferences, this effort has been greatly supported by our friends and colleagues across the globe. It is our pleasure to now present to you the Eleventh International Conference on Construction in the 21st Century (CITC-11, London). This three-day conference is being held in London at the RICS Headquarters. CITC-11 will bring together a diverse group of academics, professionals, government agencies, and students from all over the world to contribute to the future growth of the industry.

We gratefully appreciate your attendance and hope that you will support the future endeavors of CITC.

Thank you and kind regards,

Greenville, NC, USA — Syed M. Ahmed
Wolverhampton, UK — Paul Hampton
Auburn, AL, USA — Salman Azhar
Greenville, NC, USA — Amelia D. Saul

Appreciation

We appreciate the hard work and assistance of the following people in the organization of the conference:
Dr. Paul Hampton, *University of Wolverhampton*
Richard Ackroyd, *Royal Institute of Chartered Surveyors*
Aneeta Hazir, *University of Wolverhampton*
Johanna Nobel, *University of Wolverhampton*
Lauren Clarke, *University of Wolverhampton*
Suzanne Miller, *Quantity Surveyors International*
Chris Blythe, *Chartered Institute of Builders*
Caroline Gumble, *Chartered Institute of Builders*
Brenda Battle-Simms, *East Carolina University*
Taylor Wynn, *East Carolina University*
As well as those who assisted in the paper review process:
Dr. Amin K. Akhnoukh
Dr. Lincoln Forbes
Dr. Jodi Farrington
Thank you!

ECU COLLEGE OF ENGINEERING AND TECHNOLOGY

CITC-11 Themes

- Leadership in Engineering & Construction
- Architectural Management
- Building Information Modeling
- Automation and Robotics
- Lean Construction Practices
- 3D Printing
- Augmented and/or mixed reality
- Legal issues in Construction
- Value engineering
- Procurement Management
- Project and Program Management
- Quality and Productivity Improvement
- Risk Analysis & Management
- Sustainable Design and Construction
- Concrete Technology
- Construction Contracts
- Construction Equipment Management
- Construction Safety
- Construction Scheduling
- Cost Analysis & Control
- Cultural Issues in Construction
- Design-Build Construction
- Engineering & Construction Materials
- Ethical Issues in Engineering and Construction
- Information Technology and Systems
- Infrastructure Systems and Management
- International Construction Issues
- Innovative Materials (ultra-high-performance concrete, self-healing concrete, photocatalytic "self-cleaning concrete," etc.)
- Asphalt concrete (super-pave, etc.)
- Recycled and waste materials
- Fiber-reinforced polymers
- Curing compounds
- Nanomaterials in infrastructure projects
- Girder bridges with superior structural performance
- Road and bridge barrier design
- Arch bridges, suspension, and cable-stayed bridges
- Bridge construction systems
- Value engineering

Review Committee

We would like to express our sincere gratitude to the members of the International Scientific Committee, who participated in the review process for the CITC-11:

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Dr. Hamimah Adnan
Dr. Georgios Aretoulis
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A Special Thank You to Our Sponsor

CITC-11 is proud to be sponsored in part by The Royal Institution of Chartered Surveyors (RICS). RICS is a professional body that accredits professionals within the land, property, construction, and infrastructure sectors worldwide. For more information, please visit www.rics.org.

RICS is the global professional body promoting and enforcing the highest international standards in the valuation, management and development of land, real estate, construction, and infrastructure.

With offices covering the major political and financial centers of the world, RICS's market presence means they are ideally placed to influence policy and embed standards at a national level.

RICS works at a cross-governmental level, delivering a single, international standard that will support a safe and vibrant marketplace in land, real estate, construction and infrastructure, for the benefit of all.

RICS accredit over 130,000 qualified and trainee professionals and any individual or firm registered with RICS is subject to their quality assurance. RICS is proud of their reputation and guards it fiercely, so clients who work with RICS's registered professionals can have confidence in the quality and ethics of the services they receive.

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Information obtained from the RICS website: http://www.rics.org/.

A Special Thank You to Our Sponsor

CITC-11 is proud to be sponsored in part by The Chartered Institute of Building (CIOB). CIOB is the world's largest and most influential professional body for construction management and leadership. CIOB has a Royal Charter to promote the science and practice of building and construction for the benefit of society, and CIOB has been doing that since 1834. Their members work worldwide in the development, conservation and improvement of the built environment.

CIOB accredits university degrees, educational courses and training. Their professional and vocational qualifications are a mark of the highest levels of competence and professionalism, providing assurance to clients and other professionals procuring built assets. For more information, please visit www.ciob.org.

CIOB

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Information obtained from the CIOB website: https://www.ciob.org/.

Keynote Speaker

Prof. Geoff Layer Geoff Layer has been Vice-Chancellor of the University of Wolverhampton since August 2011. Before joining Wolverhampton, he was Deputy Vice-Chancellor (Academic) at the University of Bradford and prior to that, after years of teaching and researching in Sheffield Business School, he became the Professor of Lifelong Learning in 1996 and Head of Access and Guidance at Sheffield Hallam University.

Geoff has always been active regionally, nationally, and internationally. He is a Board Member of Advance HE, the Black Country Local Enterprise Partnership, and the Black Country Chamber of Commerce. He was Chair of the Department for Education's Disabled Students Sector Leadership Group and is currently Chair of the Student Loans Company Stakeholder Forum. He is also a governor for the Telford College Corporation and a Trustee of the Universities Association for Lifelong Learning.

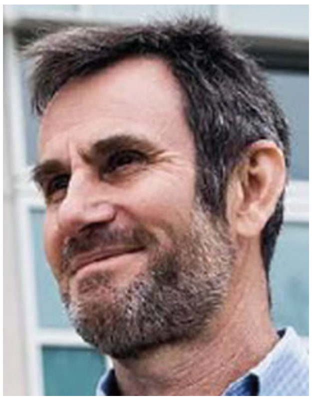
Between 2000 and 2006, he was the Director of Action on Access, an agency established to advise HEFCE on its Widening Participation Strategy. He was also Director of the HEFCE Innovations Co-ordination Team from 2000 to 2002 and has researched and published widely on Inclusive Education.

He is a Fellow of the Royal Society of Arts, a Principal Fellow of the Higher Education Academy, A Fellow of Leeds College of Music and was awarded the OBE for services to Higher Education in 2003.

Prof. Nazira Karodia Professor Nazira Karodia is Dean of the Faculty of Science & Engineering at the University of Wolverhampton and Professor of Science Education. Nazira's interests are diverse and include chemistry teaching and research in sustainable chemistry, school–HE transition, student engagement; the promotion of STEM across the education spectrum; and gender in science. She has published widely and supervises research students in chemistry, gender, and science education.

After her undergraduate studies at the University of Natal, South Africa, she moved, in 1992, to the UK to take up Ph.D. in Chemistry at the University of St Andrews, Scotland. She held postdoctoral fellowships at the Centre for Heterocyclic Chemistry, University of Florida, and with the catalysis group at the University St Andrews. Nazira was appointed as Lecturer at the University of Bradford in 1999. There her role morphed from teaching and research in Chemistry to Associate Dean, an active role in student recruitment and extending and enabling university opportunity to a wider group of students. She was Director of STEM at Bradford and led the regional spoke of a national initiative to promote STEM education.

In 2015, Nazira moved to the University of Wolverhampton as a Professor of Science Education; she is currently Dean of Faculty of Science & Engineering. She is a member of the RSC's Science, Education, and Industry Board, the RSC's Outreach Working Group, the Institute of Physics Schools Outreach Support Advisory Group. She is a Fellow of the RSC and one of its "175 Faces of Chemistry."



Prof. Richard Burt Professor Richard Burt trained and qualified as a Chartered Building Surveyor in the UK. He holds a Masters degree in Construction Management and a Ph.D. in Architecture from Texas A&M University. He is currently the McWhorter Endowed Chair & Head of the McWhorter School of Building Science at Auburn University in Alabama. His expertise is in construction history and the survey and documentation of historic buildings. He has worked on several building documentation projects in the US and France. He has published in numerous journals and conference proceedings and was a principal investigator in a multi-year federally funded project to investigate the building remains at the historic D Day landing site at Pointe du Hoc in Normandy.

He served as the chair of an American Council for Construction Education task force to develop learning outcomes-based standards for construction education and in this capacity he conducted data gathering workshops in conjunction with the Associated General Contractors of America. He currently serves on the Board of Directors of the AGC Education and Research Foundation and the Board of Trustees of the American Council for Construction Education. Dr. Burt also serves as the co-coordinator of the International Council for Building (CIB) Working Group WG089—Education in the Built Environment in this capacity he has organized workshops and paper sessions at conferences in England, Canada, United States, Finland, and Australia.

Construction Management Education—A Historical Snapshot from both sides of the Atlantic

Prof. Richard Burt
McWhorter School of Building Science, Auburn University, Auburn, AL

Abstract: What is the future for construction education? That was the original title for this keynote address. In making predictions about the future, it is important to understand what has happened in the past and how that has shaped the current environment. The early history of construction education particularly in the education of construction managers in the United Kingdom and the United States has not been formerly documented. The Second World War and the anticipated reconstruction programs on both sides of the Atlantic led to a focus on planning for educating managers for the industry. In the United Kingdom, various government reports with industry participation led to the majority of construction managers obtaining their education while in employment through part-time education at technical colleges. Up until the mid-1960s, there are minimal opportunities for students in the UK to study for a degree in "Building". In the United States, the situation is somewhat different with degree courses in subjects such as "Building Construction" and "Architectural Engineering" being offered at several universities before the Second World War. The anticipated construction activity after cessation of hostilities led to a growth in programs with an emphasis on "Light Construction"

in anticipation of the anticipated need for housing. A significant contribution to the establishment of these programs was made by Arthur A. Hood of the Johns-Manville company, who served on a wartime government committee. An understanding of the early history of construction education should allow us to better understand the current situation and make more informed decisions about the future.

Irtishad Ahmad Irtishad Ahmad has more than 30 years of experience in teaching, research, and curricula development in civil engineering and construction management. Prior to joining AUS, he taught at Florida International University, North Dakota State University, University of Cincinnati, and Bangladesh University of Engineering and Technology.

In 2016, the American Institute of Constructors awarded Dr. Ahmad the prestigious W. A. Klinger Construction Education Award. He has co-authored the book Quantitative Techniques for Decision Making in Construction. He served as the Editor-in-Chief of the Journal of Management in Engineering, published by the American Society of Civil Engineers (ASCE) from 2002 to 2008. He is a registered professional engineer and an elected Fellow of ASCE.

Digital Technology and Integration in Construction: The UAE Context
Irtishad Ahmad1 and Sameh El-Sayegh1

1 American University of Sharjah, P.O. Box 26666, Sharjah UAE irahmad@aus.edu

Abstract. Traditionally construction is a fragmented industry too slow in adopting new technology. As a result, the construction sector productivity continues to remain stagnant. Digital technology offers a great opportunity to improve productivity by integrating many entities and functions in construction. The paper argues that integration can be achieved to a large extent with the proper adoption of digital technology. Technology's transformational role in construction needs to be recognized and harnessed by the stakeholders. The transformations and potentials are evidenced in the construction sector of UAE, where the government is taking a proactive role in facilitating the adoption of digital technologies, such as Blockchain. A conceptual model that explains the push/pull relationship between technology and integration is presented in the paper. The main conclusion of the paper is that the construction industry at all levels—firm, industry, and government—must take proactive actions to foster and facilitate integration in its processes by adopting technology.

Mohan M. Kumaraswamy Prof. Mohan Kumaraswamy is now an Honorary Professor of The University of Hong Kong, having been based there from 1992 to 2013. He is also an Honorary Professor of the University of Moratuwa; and has previously been a Visiting Professor at the National University of Singapore and at Curtin University, Australia; and an Adjunct Chair Professor at IIT Madras, India.

His Civil Engineering Degree is from Sri Lanka, while his M.Sc., Ph.D., and D.Sc. degrees are from Loughborough University, UK. Before joining academia, he worked on designs, construction, and project management, and led consultancies funded by ILO, UNDP, and World Bank. He also served as a Consultant to the World Bank in 2014. He is also an Adjudicator and Arbitrator.

He has contributed to many professional bodies, e.g., the first Sri Lanka representative of CIOB (Chartered Institute of Building, UK) until 1992; Vice-Chairman of CIOB Hong Kong in 1996–97; Chairman of the Civil Division of Hong Kong Institution of Engineers in 1997–98. He is now a member of the Accreditation Board of the Institution of Engineers Sri Lanka.

He is the Founding Director of the 'Centre for Innovation in Construction & Infrastructure Development' (CICID), which he launched in Hong Kong in 2002. His international contributions include those as Coordinator of the international CIB Working Commission on 'Public Private Partnership'; and as the Editor-in-Chief of the 'Built Environment Project and Asset Management' journal.

UNSTABLE LINKS and UNTAPPED SYNERGIES between Academia, Construction Industry, Government & Society at large
Prof. Mohan Kumaraswamy
The University of Hong Kong & The University of Moratuwa

Much has been said about the imperative for deep collaboration between academia and industry in formulating and jointly pursuing R&D agendas, particularly in our domain of construction engineering and management. However, initiating and sustaining meaningful collaboration, yielding significant gains, has often proved difficult. Therefore, potential synergies from such latent linkages remain largely untapped. One approach to strengthen existing weak links and/or establish and nurture new linkages, has been to catalyze them with Governmental inputs, such as seed-funding and/or incentives including tax concessions. It is shown how such approaches could in turn be reinforced and sustained by engaging the end-users of construction outputs from the outset, while also factoring in the long-term net benefits and value additions to society at large. From another perspective, but along similar lines, it is shown how Government funding of academia could be more productive in helping target overall societal goals, by linking relevant representatives to develop and aim at long-term national developmental goals. From a third perspective, it is shown how Public-Private Partnerships that develop public built infrastructure need to be strengthened and stabilized by focusing on life-cycle value based on end-user needs. For this, it is suggested that relevant representatives of "People" should be embedded in Public-Private-People-Partnerships (4P), through "framework agreements" in suitable projects, albeit with necessary safeguards to minimize potential downsides. The above suggestions, with examples, are presented in the context of a quest for "breakthrough solutions" in developing operating and sustaining "smart, sustainable and best value" built infrastructure for society at large.

Peter Bolton-King Peter Bolton-King (FRICS FNAEA FIRMP) is the Global Director of Professionalism and Ethics at the Royal Institution of Chartered Surveyors (RICS), whom he joined in April 2012. Peter started to work in 1973 with a leading firm in the UK. After qualifying as a Chartered Surveyor, he became the firm's youngest ever partner.

In 2003, Peter was appointed Group Chief Executive of the National Federation of Property Professionals in the UK, a post he held for 10 years before RICS.

Peter currently holds a number of UK and Global Industry appointments on behalf of RICS. He is also a "Senior Visiting Fellow" at a UK University. He continues to influence Governments in the UK and globally for better standards in the industry and is Chair of the International Ethics Standards Coalition.

A large part of Peter's current workload involves leading a project, which is looking to understand the nontechnical risks to the reputation of RICS professionals.

What does being a professional mean in this day and age?
Peter Bolton-King
Royal Institute of Chartered Surveyors (RICS)

Abstract: The real estate profession, whether that be Land, Construction, Infrastructure, Property or related professionals is under pressure. To many, professionalism is a word that over the years has been dumbed down.
Peter will consider this issue and share some recent RICS research.

It is equally clear that our industry continues to become increasingly international. Many works in worldwide firms and we deal with large global end-users. Investors are often considering property and development schemes around the world. As our work changes and grows, so must our approach to developing and reinforcing professional ethics.

Peter will explain how global standards help to bring much needed transparency and re-assurance?

Andrea Rutledge, CAE
President & CEO
Construction Management Association of America

Association executive with 28 years' experience in association leadership, government, and higher education with a significant record of achievement as an innovative executive, strategic thinker, collaborative leader, and passionate advocate.

Before becoming President and CEO of CMAA, Andrea Rutledge spent 10 years as Executive Director of the National Architectural Accrediting Board, the sole agency authorized to accredit professional degree programs in architecture. Previously, she was Managing Director/Alliances at the American Institute of Architects.

CMAA

About CMAA

The Construction Management Association of America is an industry association dedicated to the practice of professional construction management. CMAA represents more than 16,000 members including federal/state/local government and private sector owners, construction consultants, technology suppliers, academia, and legal organizations all with a common goal: to improve our nation's infrastructure.

History of CMAA

CMAA was formed in 1982 to establish a set of professional standards for managing capital construction projects. One of CMAA's goals is to help the construction management profession further develop its own unique identity within the architecture, engineering, and construction industries. The organization's mission is to promote the profession of construction management and the use of qualified construction managers on capital projects and programs. For additional information, visit www.cmaanet.org.

Workshop
Managing Risks in Multi-Stakeholders' Projects

Description: This workshop highlights the main risks arising in managing construction contracts of multi-stakeholders. Key stakeholders in most common projects are three or four parties: Owner, Consultant/PM and Contractor. In multi-stakeholder projects, you may have around ten key stakeholders: Owner, Sponsor, Regulator, End User, Designer, Supervision Consultant, Project Manager, Main Contractor, Supplier/Vendor and other Specialized Sub-Contractor. Dealing with those stakeholders of different—and sometimes contradicting—perspectives, requirements, interests, and expectations would create high impact project risk/issues. This workshop presents analytical techniques for identifying, classifying, and engaging project stakeholders for the best outcomes in achieving project objectives. It will also identify the main risks/issues and proposes different strategies for mitigating them.

Topics: Overview of stakeholder management—Analysis, classification and engagement of stakeholders—Contradicting stakeholders' requirements—Main risks/issues related to stakeholders—mitigation strategies for project risks.

Date: Sept. 10, 2019 15:45–17:15
Session: 6
Location: Lecture Hall

Speaker: Dr. Mohamed El Agroudy, Ph.D., CCT, PMP, RMP, TRC, MCIArb, M.ASCE, PM Consultant and Visiting Professor, The American University in Cairo, Egypt.

Certificate:
All participants will receive 2.0 Professional Development Hours (PDH) certificate.

Speaker: Dr. Mohamed El Agroudy Ph.D., CCT, PMP, RMP, TRC, MCIArb, M.ASCE

Dr. Mohamed El Agroudy has decades of experience in construction engineering and management. He is a Certified Corporate Trainer (CCT), a Project Management Professional (PMP), a Risk Management Professional (RMP), a Transnational Referral Certified (TRC), and an International Arbitrator. He had his B.Sc. in civil/construction engineering, a Masters in contracts, and a Ph.D. in contracts and risk management. He is teaching Contracts/Risk Management at the American University in Cairo. He is a project management consultant for mega projects in the Middle East. Dr. El Agroudy has trained many professionals around the globe and has performed a lot of workshops and keynote speeches in more than 25 countries. His areas of expertize include: Contracts, Risk and Facility Management. He is an active member of Project Management Institute (PMI), International Facility Management Association (IFMA), Chartered Institute of Arbitrators (CIArb), American Society of Civil Engineers (ASCE), and board member of Green Building chapter at Saudi Council of Engineers (SCE).

Contents

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Inventory Management and Construction Project Delivery in Nigeria

Dubem Ikediashi and Godfrey Udo

Abstract

Effective management of inventories has been widely acclaimed as an important panacea for sustainable construction project delivery. This paper evaluates inventory management practices in the Nigerian construction industry. To achieve this, the specific objectives are to (1) assess inventory management practices in the construction industry and (2) explore the influence of inventory management on project delivery in Nigeria. A structured questionnaire was distributed to 110 construction companies in three strategic cities of Lagos, Abuja and Port Harcourt using purposive and stratified sampling techniques. Ninety (90) valid responses were retrieved giving a response rate of 82%. Data collected were analysed using descriptive and inferential statistics. Findings reveal that materials requirement planning (MRP) with a mean score of 3.972 was the top ranked technique for construction project management in the Nigeria. This is closely followed by warehousing management (WM) (3.961) at the second, first-in–first-out (FIFO) (3.880) at the third. Findings also reveal that the level of use of all the three inventory management techniques had significant influence on project delivery time and cost but not on quality. The paper recommends that contractors and industry associations should embrace the concept of inventory management to improve efficiency in terms of growth, turnover and sustainability. Besides, stakeholders should carry out advocacy and sensitisation to improve level of awareness while educational construction institutions should update their curriculum to incorporate sustainable and more innovative technologies into inventory management.

Keywords

Materials management • Project performance • Construction industry • Nigeria

1 Introduction

Inventory management has been described as a very critical management technique used by companies to manage inventories (Mukopi and Iravo 2015). It is defined by (Adeyemi and Salami 2010) as a framework employed in firms for controlling its interest in inventory. It includes the recording and observing of stock level, estimating future request and settling on when and how to arrange for more inventories. In the construction industry, construction materials which are the major inventories constitute the major cost component in any construction project. The cost of these materials may be 50% to 70% of the total construction cost (Kasim et al. 2005) which goes to indicate that consequence of mismanagement of these materials could be very colossal. Ineffective management of inventories result in either of two scenarios. Too much stock could result in funds being tied down, increase in landing cost, deterioration of materials in the storehouse, obsolescence and theft. However, shortage of materials could lead to interruption of supplies, disruption of construction programme and ultimately increase in cost overrun. According to (Donyavi and Flanagan 2009), material management is classified into five categories, namely, (1) measurement and specification, (2) procurement and purchasing process where the order is transmitted to the supplier, (3) delivery to site and logistics of checking the order, (4) offloading, and storing on site, and (5) administrative and financial process of payment. Proponents of inventory management also called materials

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management had argued that it maintains adequate control of demand and supply of materials, it ensures that the right quality and quantity of materials are appropriately selected, purchased, delivered and handled on site in a timely manner and at a reasonable cost, while there is reduced liabilities and loss on account of overstock.

In operations management research, the concept of inventory management has been extensively explored: inventory management practices (Song 2005; Navon and Berkovich 2006; Lu et al. 2011; Madhavi et al. 2013) and relationship between inventory management and performance ((Mukopi and Iravo 2015; Koumanakos 2008; Imeokparia 2013)). For instance, (Mukopi and Iravo 2015) observed that there is a strong relationship between four constructs of inventory system and performance of procurement option for sugar manufacturing industry in Kenya. Additionally, (Subramani et al. 2017) analysed inventory management practices and observed that ABC is one of the most conventional approaches used in India. Besides, improper handling and storage of construction materials on the site has made it difficult to effectively track construction materials. In Nigeria, (Olayeni et al. 2017) recently assessed the impact of logistics factors on material procurement for construction projects and observed that vendor qualities and competence of procurement officer were the most critical factors for effective materials management for construction projects in Abuja, Nigeria. (Okorocha 2013), however, established planning and handling as critical to effective material management of constriction projects in Nigeria. Although these and several other previous studies have provided insight into the concept of inventory management, and many of these studies have concentrated on sectors other than the construction industry on one hand and on the experiences of countries in Europe, Asia and USA on the other. Besides, the relationship between inventory management and project performance has been largely ignored as most studies have concentrated on relationship between inventory management and firm performance. This study fills the knowledge gap by employing more robust statistical tools applied to a recent sample of construction companies in three strategic cities of Lagos, Abuja and Port Harcourt of Nigeria.

Given the background above, the aim of this paper is to evaluate inventory management practices in the construction industry with a view to improving project delivery in the Nigerian construction industry. The specific objectives are to (1) assess inventory management practices in the construction industry and (2) explore the influence of inventory management on project delivery.

2 Literature Review

2.1 Inventory Management

Inventory management is the process of managing inventories with a view towards meeting the expectations of clients at the lowest possible disruptions and cost. In other words, it includes all activities of planning, forecasting and replenishment of stocks to minimise differences between customers demand and availability of items. The central theme is management of materials. (Donyavi and Flanagan 2009) observed that common problems associated with material management on construction site include failure to order on time which delays the projects, delivery at the wrong time which interrupts the work schedule, over ordering, wrong materials or error in direction of materials requiring re-work, theft of materials from delivery into production and double handling of materials. However, materials management systems are effective for fast-track projects delivery which is why there is need for an integrated material handling process from the design stage to the usage of materials on sites (Kasim et al. 2005).

2.2 Inventory Management Techniques

Literature has established inventory management as a veritable tool for sustainable project delivery in the construction industry apparently because it guarantees that balanced items of stock are sustained at the right quality, quantity and are obtainable at the right time and in the right place (Okorocha 2013). Some of the techniques used in managing inventories are discussed below:

2.2.1 Material Requirements Planning (MRP)

Material Requirements Planning (MRP) is a computer-based production planning and inventory control system and is concerned with both production scheduling and inventory control (Gallego 2017). It is a material control system that attempts to keep adequate inventory levels to ensure that the required materials are available when needed. It is applicable in situations of multiple items with complex bills of materials. It is, however, not useful for activities for which continuous processes are tightly connected. According to (Gallego 2017), the major objectives of an MRP system are to ensure the availability of materials, components and products for planned production and for customer delivery; maintain the lowest possible level of inventory; and plan manufacturing activities, delivery schedules and purchasing activities. In the construction industry, MRP includes all strategies, tactics and tools for managing the design and construction delivery processes and for controlling the key factors to ensure that the client receives a facility that matches their expectations and function as it is intended to function (Burt et al. 2003).

2.2.2 Always Better Control (ABC)

ABC is an inventory management tool in which materials are grouped into three categories depending on their perceived values. The first group known as "A" group comprises costly items that are 10 to 20% of total items in a store but account for 50% of total cost of all items. The second group known as "B" group comprises materials 20 to 30% of total stock but accounts for only 30% of total value of stock in the store. The third or "Q" group has 70 to 80% of total stock but accounts for only 20% of total value. This technique assigns items to three groups according to the relative impact or values of the items that makes up the group. Those thought to have the greatest impact, or value, for example, constituted the 'A' group, while those items thought to have a lesser impact or value were contained in the 'B 'and 'Q' groups, respectively (Coyle and Bardi 2003). It is a tool that, among others, ensures considerable reduction in the storage expenses. However, the technique can only be successfully deployed if there is proper standardisation of materials in the store. This is particularly challenging in the construction industry of developing countries such as Nigeria where infrastructure deficit challenge has tendered to hamper automation in construction methodologies.

2.2.3 Economic Order Quantity (EOQ)

According to (Arijeloye and Akinradewo 2016), EOQ is an inventory management tool used to ascertain the amount of orders that will minimise total variable costs required to order and hold inventory. In other words, it refers to the order sizing that will result in the lowest total of ordering and carrying costs for an item of inventory. The economic order-quantity model considers the trade-off between ordering cost and storage cost in choosing the quantity to use in replenishing item inventories. A larger order quantity reduces ordering frequency, and, hence ordering cost/month, but requires holding a larger average inventory, which increases storage (holding) cost/month. On the other hand, a smaller order quantity reduces average inventory but requires more frequent ordering and higher ordering cost/month. One of the most important problems faced by the purchasing department is how much to order at a time. Purchasing in large quantities involve lesser purchasing cost. But cost of carrying them tends to be higher. On the other hand, if purchases are made in smaller quantities, holding costs are lower while purchasing costs tend to be higher. This can be rectified with the help of EOQ.

2.2.4 Just-in-Time System (JIT)

JIT is an approach in inventory management that helps to make rational and appropriate order of materials available to each operating unit at the right time in the right quantity (Stock and Lambert 2001). It is a systematic concept consisting of JIT purchasing, JIT transportation and JIT production. These three elements combine to create a material handling system that avoids waste and minimises inventory investment. The technique has changed employees' belief, attitude, work habits and awareness of quality assurance. One of the strengths inherent in JIT is the fact that it makes production operations by manufacturers more efficient, cost effective and customer responsive. Thus, components and parts are proactively acquired before they are needed in the assembly line, thereby relieving manufacturers of the cost and burden associated with housing and managing idle parts. According to (Patil and Patil 2015), the philosophy behind JIT has a lot of potentials for managing movement of construction materials from manufacturing yard to construction site.

Several other techniques are found in the literature. These include purchasing of materials (Bell and Stukhart 1986), transporting of materials (Hira and Dozzi 1994), and materials handling (Tompkins and White 1984). Others are warehousing management (Bowersox and Closs 1996; Monczka et al. 2002) and vendor managed inventory (Claassen et al. 2007). Researchers are unanimous that these are variates of inventory management systems. This study explores their extent of use in the Nigerian construction industry.

2.2.5 Inventory Management and Project Performance

Researchers such as (Koh et al. 2007) and (Koumanakos 2008) have opined that inventory management which has been characterised by transaction approach techniques such as EOQ and management-oriented concepts such as JIT and MRP have effect on firm performance despite their perceived theoretical and practical shortcomings. (Koumanakos 2008) had observed that the higher the level of inventories persevered by a firm, the lower its rate of returns. In other words, the hypothetical assumption that efficient inventory management leads to improvement in financial performance was rejected by the study, although it has a limitation that the study was conducted in only chemicals sector of Greek manufacturing industry. In another study, (Mukopi and Iravo 2015) discovered that four variables of inventory management (leaninventory systems, strategic supplier partnerships, information technology and legal policies) have strong relationship with procurement function in a sugar manufacturing firm in Kenya. (Ogbo and Ukpere 2014) discovered that inventory control management by way of easy storage and retrieval of material improved sales effectiveness and reduced operational cost. (Agu et al. 2016) observed that inventory control significantly influenced productivity and concluded that inventory management is essential in the operation of any business. (Sahari et al. 2012) carried out an investigation on impact of inventory management on performance of Malaysian construction firms. The study concluded that there is correlation between inventory delays and company performance operationalised as return on assets and return on investment.

While these studies gave clear insights into relationships between inventory management and performance, few gaps exist which this study intends to fill. Most of the studies were based on sectors other than the construction industry while virtually all concerned carried to investigate performance of firms leaving out project performance. This study investigates the nature of relationship between inventory management strategies as independent variables and project performance as dependent variable.

3 Research Methods

To investigate inventory management practice and its influence on project delivery, taxonomy of variables was extracted from the literature review in the relevant domains. A pilot study was conducted through interview with academic and industry experts to improve the taxonomy prepared from the literature review. The final list of variables was chosen under two key constructs of inventory management techniques and project performance to reflect the theme of the research problem.

In line with quantitative survey adopted for the study, a self-completion questionnaire was sent to 110 construction companies drawn from the register of the Federation of Construction Industry (FCI), Nigeria, and who are domiciled in three strategic cities of Lagos, Abuja and Port Harcourt in Nigeria for the study was collected through a structure questionnaire. The questionnaire was divided into four parts. Section A captured the respondents' demographic data (job description, educational qualification, and location, etc.), section B solicited responses on inventory management techniques in use in the area, while section C was on influence of inventory management on 3 key project management variables of "timely delivery of materials", "reduced project cost" and "quality of completed projects". Target respondents were mainly project managers, purchasing officers and procurement officers who were conversant with on-going projects of their companies. Data collected were analysed using basic descriptive tools and Spearman rank correlation.

4 Results

4.1 Sample Characteristics

Majority of respondents were from Lagos (44%) while in terms of job description, they were almost evenly spread across the four groups used for the survey. For instance, 23% were project managers, 31% were purchasing managers, 32% were procurement officers, while store officers comprised 14% as indicated. In terms of years of experience, more than 50% of respondents have spent 10 years and above in their present positions. This is to indicate that responses are reliable since respondents are well grounded in inventory management and have spent reasonable time in their jobs to give valid responses to questions asked.

4.2 Level of Use of Inventory Management Techniques

To explore the level of use of inventory management in the construction industry, respondents were asked to rate the level of use of 11 inventory management techniques for construction projects using a five-point scale of 1 = never used, 2 = used rarely to 5 = used very frequently. The result of analysis is presented in Table 1.

It shows that MRP with a mean score of 3.972 is the top ranked technique for construction projects in Nigeria. This is closely followed by WM (3.961) at the second, FIFO (3.880) at the third and VMI (3.874) at the fourth. However, MTS (3.371), MH (3.544) and ABC (3.622) were the three least rated techniques. The top rating of MRP underscores its significance as a technique that simultaneously allows companies construction companies inclusive to ensure that construction materials are available for use on time at site and that projects are effectively delivered to clients at the agreed schedule of time and cost. It is instructive to note that all the 11 techniques used for the survey score are above 3 points which is to indicate that they are all used in the Nigerian construction industry but with varying degrees of implementation.

All the inventory management tools were also examined for potential outlier and normality. Normality of all the 11 attributes of inventory management was checked by significant test for skewness and kurtosis. According to (Chan et al. 2001), the observed values of skewness and kurtosis should be tested against null hypothesis of zero because values of skewness and kurtosis are zero when a distribution is normal. The test statistics result for skewness and kurtosis were within an acceptable range as most of the values are close to zero at $p < 0.01$, two-tailed test with the exception of ABC with a kurtosis value of 1.241 (Table 1), meaning that they are normally distributed.

Table 1 Results of analysis for inventory management techniques for projects

Inventory management tool	Mean	SD	Rank	Skewness	Kurtosis
Material Requirement Planning (MRP)	3.972	0.825	1	0.815	0.141
Warehousing Management (WM)	3.961	0.813	2	−0.408	−0.072
First-In–First-Out (FIFO)	3.880	0.870	3	−0.378	0.424
Vendor Managed Inventory (VMI)	3.874	0.945	4	0.081	−0.641
Recovery & Recycling (R&R)	3.866	0.857	5	−0.741	0.575
Material Tracking (MT)	3.755	0.824	6	−0.823	0.042
Economic Order Quantity (EOQ)	3.719	0.788	7	0.114	0.061
Just-in-Time (JIT)	3.703	1.092	8	0.004	0.031
Always Better Control (ABC)	3.622	0.822	9	0.161	−1.241
Material Handling (MH)	3.544	0.765	10	−0.674	−0.001
Material Transporting System (MTS)	3.371	0.902	11	0.112	0.578

Note SD stands for standard deviation

4.3 Influence of Inventory Management on Project Performance

In order to explore the influence of use of inventory management techniques on project performance, a hypothesis was postulated. It states that there is no significant correlation between the level of use of inventory management techniques and project performance. The decision rule is that the hypothesis is rejected for all values of $p > 0.05$ while it is accepted for all values of $p < 0.05$. The top three ranked techniques were correlated against three project performance indicators using spearman rank correlation. The results are presented in Table 2.

The results show that the level of use of all the three inventory management techniques had significant influence on two of the project performance indicators used for the survey. This is because p-values are greater than 0.05. For instance, MRP had strong correlation with improved project delivery time (p-value = 0.089), reduced project cost (p-value = 0.114). The hypothesis is, therefore, rejected. The correlation between MRP and improved quality of project output is, however, not significant at 5% Significance level (p-value of 0.024). Therefore, the hypothesis is accepted. This is a replica of all other techniques. What this implies is that the use of the three techniques has no influence on improved quality of construction projects as perceived by respondents. This is likely due to the fact that the use of inventory management may not have direct influence on quality of project output but definitely has indirect influence on the quality of projects at the long run.

Table 2 Results of correlation analysis between use of inventory management tools and project performance

Correlated variable	R-value	P-value	Decision
Material Requirement Planning (MRP)			
Improved project delivery time	0.448	0.089	Reject
Reduced project cost	−0.211	0.114	Reject
Improved quality of project output	0.102	0.001	Accept
Warehousing Management (WM)			
Improved project delivery time	0.092	0.158	Reject
Reduced project cost	0.244	0.499	Reject
Improved quality of project output	0.178	0.000	Accept
First-In–First-Out (FIFO)			
Improved project delivery time	−0.643	0.117	Reject
Reduced project cost	0.533	0.284	Reject
Improved quality of project output	0.281	0.024	Accept
Vendor Managed Inventory (VMI)			
Improved project delivery time	0.402	0.401	Reject
Reduced project cost	−0.034	0.054	Reject
Improved quality of project output	−0.521	0.012	Accept

Note R-value = correlation coefficient; p-value is significant @ $p \geq 0.05$

5 Conclusion

Based on questionnaire survey of 90 inventory management professionals, the study examined the concept of inventory management and its influence of project delivery from the perspective of the Nigerian construction industry. Data collected were analysed using descriptive statistics and spearman rank correlation.

Findings indicate that material requirement planning (MRP), warehousing management (WM) and first-in–first-out (FIFO) are the top most used inventory management techniques in the study area while the level of use of all the top three inventory management techniques had significant influence on two of the three project performance indicators used for the survey. The paper, therefore, concludes that inventory management is popular in the Nigerian construction industry but with varying degrees of implementation. However, its influence on project delivery is significant only in the areas of time and cost delivery.

The paper, therefore, recommends that contractors and industry associations should embrace the concept of inventory management to improve efficiency in terms of growth, turnover and sustainability. Besides, stakeholders should carry out advocacy and sensitisation to improve level of awareness while educational construction institutions should update their curriculum to incorporate sustainable and more innovative technologies into inventory management.

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Overview of Concrete Durability Evaluation Using Electrical Resistivity

Amin Akhnoukh

Abstract

The current quality control procedures for concrete production focus mainly on concrete compressive strength. Despite its relevance to concrete performance, compressive strength testing is poorly correlated to the long-term performance of concrete mixes, including the concrete ability to withstand chloride and sulfate attacks, and the concrete capability of protecting the steel bars and prestress strands against corrosion. This research presents an overview to the use of electrical resistivity testing technique as an alternative quality control procedure that is currently used in assessment of concrete long-term performance. Electrical resistivity testing conducted through surface resistivity (SR) and bulk resistivity depends on measuring the concrete porosity and pores connectivity within hardened concrete samples. The final resistivity measured in ohm-meter is inversly proportional to the pores ratio and pores connectivity. Thus, a higher resistivity is a good indicator to minimal and disconnected pores formation within the concrete, which leads to a better future performance of hardened concrete structural elements. The outcome of electrical resistivity is currently used by several state departments of transportation (DoTs) to improve concrete mix designs, and minimize the potential need to maintenance activities during concrete projects life span.

Keywords

Durability • Resistivity • Conductivity • Corrosion • Chloride diffusion

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1 Introduction

The current quality control procedures for concrete production focus mainly on concrete compressive strength. Currently, different codes and specifications consider the compressive strength of concrete as the main indicator to concrete quality. Different concrete characteristics as modulus of elasticity (MOE) and modulus of rupture (MOR) are calculated by empirical equations as a function of concrete compressive strength.

Despite its relevance to concrete performance, compressive strength testing is poorly correlated to the long-term performance of concrete mixes, including the concrete ability to withstand chloride and sulfate attacks, service cracking, freeze and thaw cycles, and the concrete capability of protecting embedded steel bars and prestress strands against corrosion. Currently, different research programs consider different testing techniques to assess long-term performance of concrete mixes. These programs focus on measuring the pore percentage within hardened concrete and the degree of pore connectivity. Larger pore percentage and sufficient connectivity are directly correlated to potential chloride ion infiltration, which accelerates the deterioration of the concrete section and expedite the corrosion of steel reinforcement. Current specifications permit the use of rapid chloride permeability testing (RCPT) in measuring the resistance of concrete to chloride ingress. The RCPT method (Whiting 1981) uses a 4 in. diameter core or cylindrical sample from the concrete being tested. The cylinder length is 2 in. and is treated according to AASHTO T277 (2007) or ASTM C1202 (ASTM 1202). The sample is exposed to a 60-volt potential for 6 h, with readings taken every 30 min. The amount of coulombs passing through the sample are calculated and correlated to chloride permeability according to specifications. RCPT technique is shown in Fig. 1.

While the RCPT test is widely accepted in construction projects within the United States, it is a time-consuming test, laborious, and expensive to conduct. To-date, different

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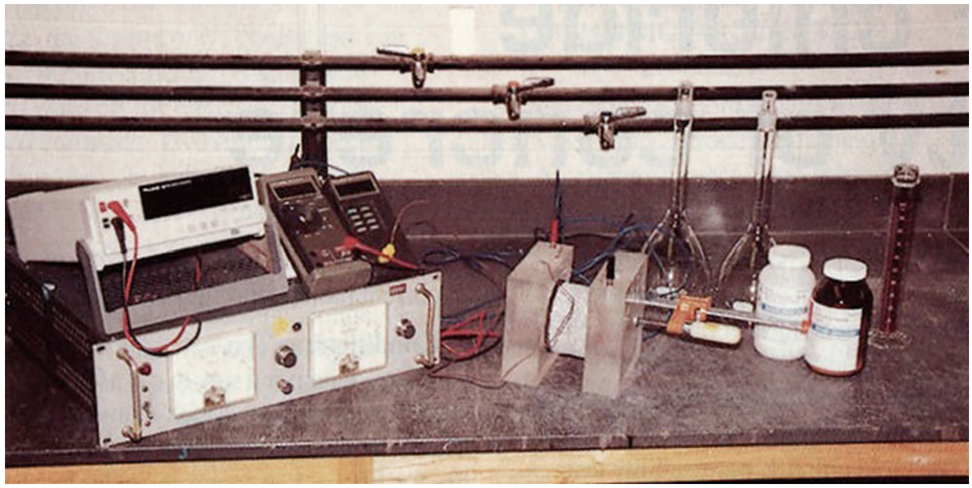

Fig. 1 RCPT technique used for concrete durability

research projects are being conducted to evaluate the potential of using bulk and surface resistivity of concrete specimens in replacement of RCPT method. Bulk and surface resistivity techniques are simple, easy-to-perform, and does not include complicated testing procedure. The investigation of electrical resistivity measurement is currently conducted to assess the potential use of electrical resistivity for the performance-based evaluation of mix designs, and to optimize standard mixes to attain a predetermined future performance by correlating the measured resistivity to the chloride diffusion co-efficient of concrete (Lu 1997).

2 Electrical Resistivity Measurements

Two different resistivity techniques are currently used in concrete durability evaluation, namely, surface resistivity and bulk resistivity. The two electrical resistivity techniques depend on simple measurement of a given size concrete specimen, using Ohm's law, to determine the electrical resistivity of concrete. The electrical resistivity measurements can be used to assess the quality of concrete, percentage of air voids, void distribution, and existence of good or poor conductive ingredients within the mix as steel fibers for good conductivity, and supplementary cementitious materials which block the air voids within the concrete mix, hence, reduce the electrical conductivity.

2.1 Surface Resistivity

The surface resistivity method as non-destructive testing was initially introduced by geologists to investigate the soil strata (Wenner technique). The surface resistivity method was considered by material engineers as a technique that could be successfully used in measuring the ability of hardened concrete to resist chloride ion penetration according to AASHTO T358-17 (2017). There are three advantages associated with the implementation of the surface resistivity method in long-term performance assessment of concrete: First, surface resistivity is a non-destructive testing method and could be performed on concrete cylinders poured for compressive strength testing. This results in minimal expenses for testing concrete. Second, the surface resistivity method assesses the quality of surface concrete that covers steel bars or prestress strands. This layer of concrete is the most important layer of the pour as all chloride and different adverse environmental conditions attack the concrete and steel from the outside. Third, surface resistivity technique is simple to perform, does not need special expertise, or complicated/expensive testing equipment. The simplicity of surface resistivity method enables construction personnel to conduct the test anywhere and at any time regardless to the nature of the project, including high-security buildings and nuclear power plants as no core are required to drill.

The Wenner method in surface resistivity measures depends on four electrodes situated in a straight line at equal distance (a). The two outer electrodes apply an alternate current (AC) with a predetermined frequency and the two inner electrodes measure the potential difference (V). The location of the four probes has to be accurately identified, and there should be a direct contact between the electrodes and the concrete specimen surface. The presence of any aggregates near the sample surface may result in misleading resistivity measurements. The Werner surface resistivity measurement device is shown in Fig. 2.

The electrical resistivity is measured using the aforementioned device, and the schematic representation of the electric current flow lines, equipotential line, and electrodes positioning is illustrated in the schematic drawing shown in Fig. 3.

The equation for measuring electrical surface resistivity according to Werner technique is shown in Eq. 1:

Fig. 2 Wenner device for surface resistivity measurement

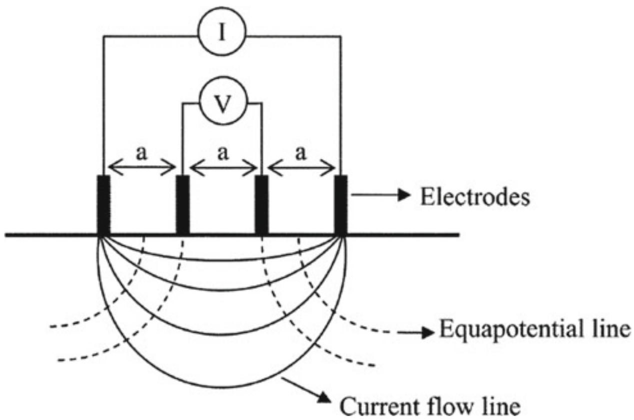

Fig. 3 Schematic representation of surface resistivity testing of concrete (Sengul and Gjorv 2008)

Fig. 4 Bulk resistivity measurement device

$$\rho = 2\pi a(V/I) \tag{1}$$

where
V, electrical potential (volts)
I, electrical current (ampere)
A, probe spacing (cm).

2.2 Bulk Resistivity

The bulk resistivity test is conducted according to the standard test method for bulk electrical conductivity of hardened concrete (ASTM C1760-12). The main advantage of bulk resistivity measurement is that the measured resistivity is assessed for the whole concrete sample and not a surface layer only. The bulk resistivity measurement can be conducted as a non-destructive test for concrete cylinders that will be used in measuring the compressive strength of the concrete at any given age. The bulk resistivity test setup is shown in Fig. 4.

The effect of the cylinder geometry on the final measurement of concrete resistivity is eliminated by calculating a shape factor (k) for the tested cylinder. The shape factor (k) is calculated as follows:

$$\mathrm{K} = \mathrm{A/L} \tag{2}$$

where
K, shape factor
A, cross-sectional area of the cylinder
L, the height of the cylinder (distance between the probes).

The electrical resistivity of concrete, using bulk resistivity testing technique, is calculated according to the following equation:

$$\rho = \mathrm{K.R} \tag{3}$$

where
ρ, electrical resistivity of concrete
R, resistance (=V/I of the electric source).

Despite the advantages associated with the bulk resistivity method, this electrical measurement technique might not be used in given construction projects if it is not possible to access an existing concrete structure from both sides to place the resistivity probes, or drill cores to obtain a sample to be measured in site or in any materials lab.

3 Factors Affecting Electrical Resistivity Measures

Electrical resistivity techniques are currently investigated as an alternative technique to the current RCPT method. Electrical resistivity of concrete is a direct indicator to the hardened concrete quality. Higher concrete resistivity indicates limited pores and lack of pores connectivity. Recent studies showed that the electrical resistivity of concrete is affected by different parameters as follows.

3.1 Moisture Content of Concrete

The increased moisture content of a concrete specimen results in a higher flow of electrical current within the tested specimen. This is attributed to the higher tendency of water to conduct electricity. Thus, higher water content due to higher water-to-cement ratio in the mix or increased water content of an existing concrete structure due to higher concrete permeability will resist in a lowered resistivity. The lowered resistivity indicates a potential reduced durability.

3.2 Effect of Concrete Cove

The concrete cover is detrimental to the accuracy of electrical resistivity measurement of any concrete sample. Intact concrete cover, with fewer cracks, results in a higher value of concrete resistivity due to the lower flow of moisture through the concrete cover. On the other hand, a low-quality concrete cover, low thickness and/or existence of hair cracks, results in a higher tendency of the concrete sample to permit the passage of electrical charge, which results in a lower concrete resistivity and implies a reduced durability.

3.3 Steel Reinforcement of Concrete

Reinforced concrete structures contain different percentages of steel bars for flexure reinforcement, shear reinforcement, and shrinkage compensation purposes. Bridge girders, and other prefabricated elements, may contain prestressing strands. New generation of concrete mixes with superior characteristics, known as ultra-high-performance concrete (UHPC), contains a higher percentage of steel fibers (ASTM 1760). The aforementioned different types of reinforcement bars results in a higher conductivity of concrete. The lower resistivity calculated due to steel bars embedment shows false measurement of long-term durability of concrete. The problems associated with steel reinforcement effect on resistivity reading are non-existent in new construction projects quality control as plain concrete cylindrical specimens are always used.

However, in existing projects, location of steel bars should be determined and avoided prior to the application of resistivity measurement techniques.

3.4 Concrete Temperature

The temperature of concrete specimen is crucial when electrical resistivity is measured. Simply, an elevated temperature allows for faster ionic transfer. So, an elevated temperature of concrete specimen will result in a lower resistivity, and implies a lower performance and reduced durability during the life span of the project.

4 Quality Control of Concrete Mixture

The quality control procedures followed during concrete mix design and production could affect the measured resistivity of concrete mixes. The quality control procedures include (1) proper mixing, which improves the hydration of the cement paste and minimizes the free moisture which reduces resistivity, (2) curing regimen, which reduces the concrete shrinkage and improves the concrete surface cover (Akhnoukh 2008).

5 Concrete Permeability and Voids Ratio

The percentage of concrete voids is highly dependent on the size and gradation of different granular materials, including coarse aggregates, fine aggregates, Portland cement, and supplementary cementitious materials as fly ash, micro-silica, and nano-silica incorporated in the mix. Recent studies showed that improved gradation of granular particles and resulting low voids ratio results in improved mix resistivity. These results match the findings of other research projects showing that concrete durability could be enhanced using micro- and nano-sized supplementary cementitious materials (Akhnoukh 2013, 2017).

6 Applications of Electrical Resistivity in Construction Industry

The interpretation of resistivity measurements of concrete and its potential correlation to chloride ion diffusion is currently used in the assessment of instantaneous properties of concrete, and potential long-term performance of concrete construction projects. The following represents a list of applications where electrical resistivity of concrete could be used:

1. *Estimate the concrete voids ratio*: which is an important measure that reflects the potential performance of concrete structures
2. *Detect concrete surface cracks*: which indicates potential risks associated with a concrete structure. Existence of cracks is a potential threat as it enables additional moisture to dissipate into the concrete, and results in corrosion of steel reinforcement.
3. *Ensure overall quality of concrete*: through the overall measurement of resistivity. Higher resistivity is a direct indicator of absence of cracks, lack of free moisture, and a higher packing order of cement and cementitious materials paste. Thus, a higher resistivity could be used as an indicator for performance-based design of concrete mix design and optimization.

The use of electrical resistivity in concrete durability evaluation or for performance-based design of concrete mixes has a positive impact on the construction industry in the United States, and on a global level. The successful implementation of electrical resistivity in concrete mix design optimization would result in concrete structures with fewer cracks and better long-term performance, which will increase the life span of construction projects, and minimize the expenditure required for maintenance, repair, and replacement of deteriorated sections. Concrete mix optimization and improved durability results in a lower life-cycle cost of construction projects, and improved national infrastructure.

7 Research Findings

Electrical resistivity measures were successfully used in the assessment of long-term performance of different concrete mix designs based on measuring the resistivity of concrete surface or bulk sample to the passage of electric current. The measured resistivity is affected by the following parameters:

1. Concrete paste design: as higher cement content or the inclusion of supplementary cementitious materials as fly ash, quartz flour, micro-silica, nano-silica, and carbon nano-tubes results in improved packing of granular materials, which increase the hardened concrete resistivity. This indicates a better long-term performance of the hardened concrete in the future.
2. Chemical admixtures: used in modern projects to attain special properties including early set, delayed set, high workability have a high effect on electrical resistivity of the mix. High chemical dosage results in an increased conductivity of the concrete mix, which reflects a lower long-term performance of hardened concrete.

8 Summary and Conclusion

Current projects are shifting to performance-based specifications. According to this recent change, concrete mixes are being optimized by material design engineers, batch plants, and precast facilities to attain predefined short- and long-term performance criteria. The main long-term performance criteria specified for concrete mixes is durability. Currently, RCPT is used to assess the long-term performance of hardened concrete by estimating the concrete capability of resisting chloride ingress. Despite its successful implementation, RCPT has multiple disadvantages as being a time-consuming and laborious technique. Current research projects indicated that concrete electric resistivity can be successfully used in long-term performance assessment of concrete. Two main electrical resistivity techniques are presented to the industry professionals, namely, the surface resistivity and bulk resistivity. Electrical resistivity technique correlates the measured concrete resistivity for electric current and the amount of pores and pores connectivity within the hardened concrete surface. Electrical resistivity measurement is affected by different parameters as mix constituents, voids ratio, curing regimen, and duration. To-date, several state DoTs implement the electrical resistivity technique in their concrete quality control procedure to attain optimized mix designs with superior long-term performance and minimize future maintenance expenditure.

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An Assessment Tool to Measure the Lean Construction Maturity Level

Ahmed Helmy Mohamed

Abstract

The past two decades have witnessed a rapid increase in construction projects within developing countries in the Middle Eastern Gulf region. Despite this, construction companies still face many challenges, including completing projects on time and within budgets. The negative impact of these challenges has been confirmed through (1) data collected from documents concerning completed construction projects in which the author has been professionally involved; (2) the author's experience in the field of construction project management in the Middle East and risk management in particular; and (3) extensive study of the literature in this domain. To that end, the objective of this study is to create a Lean Construction Assessment Tool. To achieve this objective, the research work (a) investigates the linkages between Lean and risk management; (b) reviews the concept of Lean and its application to the construction industry in developing countries (c) analyses the barriers and success factors; and (d) identifies the benefits of Lean Construction within construction organisations in developing countries. Among the main findings of this research is the lack of future strategic plans for the construction industry in terms of managing waste and risks in general and specifically in developing countries. It is hoped that the outcomes of this research study will have theoretical and practical significance for successful Lean implementation in construction organisations in developing countries.

Keywords

Developing countries • Lean construction • Mega-Construction • Risk management

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1 Introduction

Prior to a successful Lean implementation, a Lean assessment should be conducted to identify gaps in knowledge that need to be addressed. The Lean implementation assessment consists of all the observed categories of Lean implementation. The researcher believes that Lean assessment should be applied before implementing the Lean Construction method. The researcher considered two tools for conducting Lean assessment: (1) The Lean Enterprise Self-Assessment Tool (LESAT) and (2) The Highways Agency Lean Maturity Assessment Toolkit (HALMAT).

2 Proposed Lean Construction Assessment Tool (LCAT)

The researcher proposes a Lean Construction Assessment Model to evaluate the level of Lean awareness in organisations which can measure the gap between their current state of maturity and the position they want to reach. The researcher reviewed some of the previous assessment tools and adopted two approaches, LESAT and HALMAT, as guidance and then tailored an assessment tool to be adopted for assessing the level of Lean awareness in construction companies in the Middle East. The rationale behind choosing these two tools is that the two approaches are easy to use and will be relevant to the Middle East construction industry. Highways England (2012) developed a step-by-step route to completion, and abiding by the following steps is highly recommended 46 (Highways England 2012).

2.1 Lean Construction Assessment Steps

The researcher mainly followed the steps of the assessment tool mentioned in the HALMAT section because, from experience, it is more applicable to construction projects.

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The road map has been created to implement an actual assessment for the organisation that undertakes the management of the ongoing Mega-construction project (Massachusetts Institute of Technology 2012). The following are the steps that should be abided by and followed by the road map (see Fig. 1):

Step 1 Decide the limit of the assessment, whether to include a whole organisation, a particular division or a department of an organisation.

Step 2 Determine individuals qualified to participate in the assessment process.

Step 3 Appoint a facilitator
Explanation: A facilitator should have sufficient knowledge of Lean principles so as to be able to guide participants on interpretation, should be an independent individual; and should not be one of the leaders of the organisation, in order to avoid any conflict of interest.

Step 4 Determine the mission, vision, value, and strategic aims of the organisation. Explanation: The Company's mission, vision, value, and strategic aims should be considered in the questions posed to assess the level of company awareness regarding Lean.

Step 5 Hold an initial meeting to set the ground rules of the assessment.
Explanation: (1) Ensure that the participants fully understand the assessment tool as well as the application method (2) Confirm that they understand the limits of assessment clearly; (3) Arrive at an agreement on the timetable for completion and collation of individual scores; (4) Set a date for the assessment meeting.

Step 6 The assessment form is filled in by selected participants

Step 7 Facilitator gathers results that determine areas of strong agreement.

Step 8 Conduct an assessment meeting where consent is given and the facilitator analyses the results.

Step 9 Facilitator determines the level of Lean awareness of the company based on collected scores from the review.

2.2 Areas of Coverage of the Assessment Tool

Before developing the assessment tool questions and determining the key assessment elements, the researcher held a brainstorming session with the workers involved in the selected ongoing Mega-Construction project. This session aimed to tackle the main Lean Construction principles as well as the quantitative evaluation of such principles within

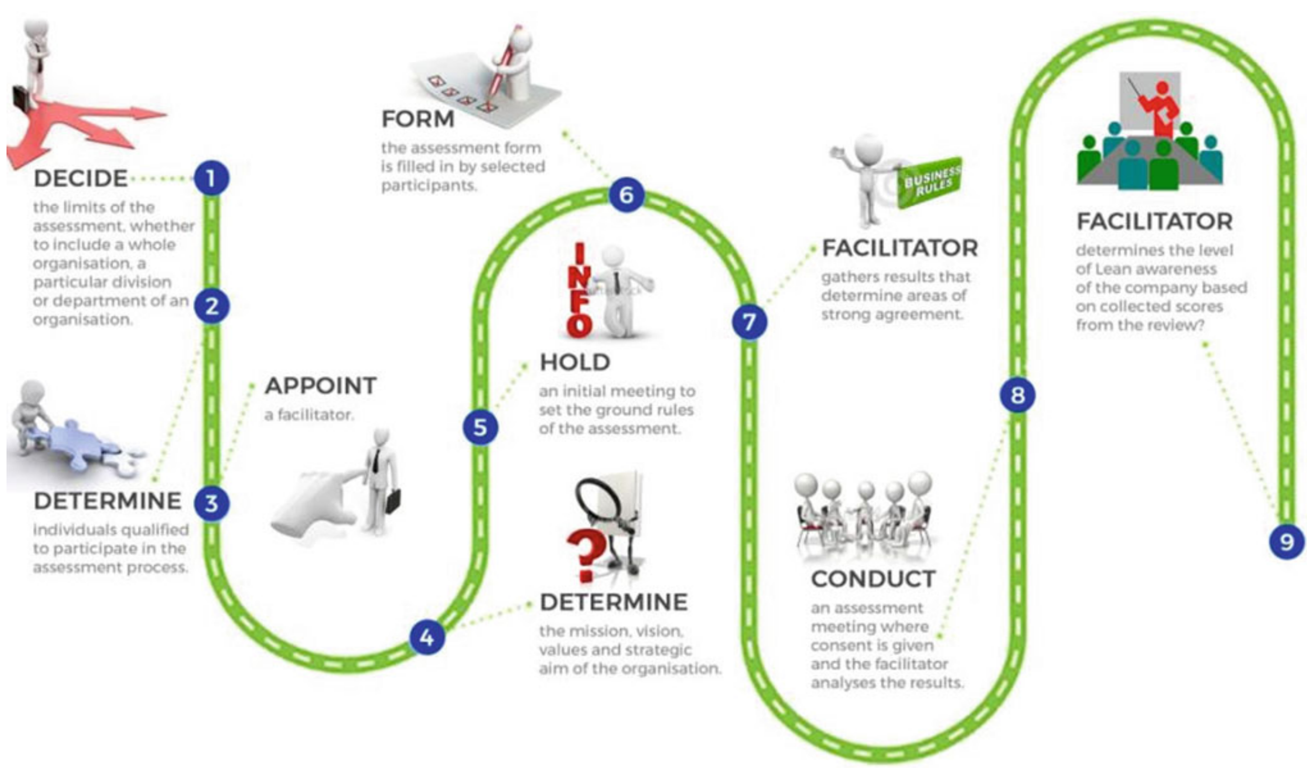

Fig. 1 Lean construction assessment roadmap

construction projects through site visits. Attempting to cover all Lean Construction aspects, the researcher chose the following assessment elements based on the reviewed literature and previous assessment tools, as well as key findings from data collected from both the conducted survey and the researcher's experience in developing countries (Casey 2007). These areas of coverage are verified in the validation process, and if any other area is suggested by the participants, the research will consider it:

- Lean policy and strategy: this element identifies the extent of Lean principles incorporated in the strategic and planning processes of organisations and assesses the company policy deployment in order to determine the company's position in the future.
- Lean philosophy: this element identifies the scope of an organisation's target for creating more value for customers and focuses on its key processes to continuously increase it.
- Lean leadership and structure: this element indicates how the organisation's leaders are active in encouraging and mentoring the introduction of Lean and examines the companies' degree of structuring their organisations to maximise team working and employee empowerment (Engineers Australia 2012).
- Lean principles and drivers: this element evaluates the organisation's usage of the five principles of Lean and ensures that companies are following the overall organisational strategy and that they are constantly and consistently delivering value to their customers through the constant review of their processes.
- Eliminating waste and continuous improvement: this element identifies the organisation's plan for defining and managing the generated waste in order to achieve continuous improvement.
- Lean techniques and tools: this element aims at evaluating the usage of the Lean techniques and tools to support the adoption of Lean principles.
- Delivery of value: this element identifies the level of value maximisation in the organisation through the analysis of the key processes which deliver end customer value.
- Built-in quality: this element identifies whether the organisation avoids quality issues through the quality assurance processes.
- Process flow: this element assesses the degree to which processes are being designed to encourage flow and balance resources.
- Lean impact (barriers and success factors): this element identifies the organisation's understanding of Lean's impact on its performance and defines the process of assessing the impact of Lean on final project success (Massachusetts Institute of Technology 2012).

2.3 Assumptions for Assessment Tool

The researcher made two assumptions for proposing the assessment tool: (1) LCAT weighting and overall scoring system; (2) evaluation of the outcome of the assessment tool (reading results). The main basis for those two assumptions was an expert's judgment, reviewed literature, and the researcher's experience in the Middle East.

In order for the researcher to develop the tool, a brainstorming session with four of the selected participants, two from top management (the CEO and Project Management Office Director) and another two from site workers (project manager and construction manager) was held to discuss the main Lean Construction principles and how they can be quantitatively evaluated within construction projects in the Middle East.

The researcher considered the HALMAT scoring spreadsheet developed by the Highways Agency (2012) as a basis for the first assumption (weighting and overall score system). The questions' weights are given, tailored to the company's areas of weaknesses and strengths (2012). Therefore, the researcher and experts during the brainstorming session agreed to weight the twenty (20) questions provided in the assessment tool equally at 5% each and have a minimum score (1) and maximum score (5).

The second assumption is the outcome/results of the assessment tool which will be used to calculate an overall weighted score for the organisation's Lean maturity.

2.4 LCAT Weighting and Overall Scoring System

The adopted maturity levels for the development assessment are based on the approach of Nesensohn et al. (2014).The researcher applied a scoring system based on a 5-point scale for each question. Ratings are in whole numbers only (no decimal ratings). The assessment tool is based on a numerical scoring system on a scale that ranges from 0 to 4, where 0 represents the state of Uncertainty and 4 represents the Challenging state. The researcher used the same maturity levels utilised for the maturity assessment. Table 1 identifies the maturity levels used for Lean Construction assessment (Nesensohn et al. 2014).

Table 1 Maturity level definitions

Level	Maturity level	Definition
0	Uncertain	Knowledge about the system is present but there is lack of interest in implementing it
1	Awakening	System is present but lacks concentration and guidance in the implementation
2	Systematic	System is implemented and company is adjusting to the system
3	Integrated	System is implemented and company is reaping the benefits while adjusting to new challenges encountered during the process
4	Challenging	Knowledge about the system is present but there is lack of interest in implementing it

Lean Construction principles were presented in questions applicable to the reality of construction sites. However, the Lean principles included in the assessment tool were split into ten main categories, covered by 20 questions, for applicability reasons. These ten main categories are (1) Lean policy and strategy; (2) Lean philosophy; (3) Lean leadership and structure; (4) Lean principles and drivers; (5) waste elimination and continuous improvement; (6) Lean techniques and tools; (7) delivery of value; (8) Built-in Quality; (9) process flow; and (10) Lean impact (barriers and success factors). Each of the 20 questions has an equal weighting, with a rating value that ranges from 0 to 4. Table 2 illustrates the weighted scoring for each section and subsection (questions).

Table 2 Weighted scoring system—assumptions

	Subsection	Subsection weighting	Section weighting	Min score	Max score
1 Lean Policy and Strategy	*1.1*	5.00%	15%	1.00	5.00
	1.2	5.00%		1.00	5.00
	1.3	5.00%		1.00	5.00
2 Lean Philosophy	*2.1*	5.00%	10%	1.00	5.00
	2.2	5.00%		1.00	5.00
3 Lean Leadership and Structure	*3.1*	5.00%	10%	1.00	5.00
	3.2	5.00%		1.00	5.00
4 Lean Principles and Drivers	*4.1*	5.00%	10%	1.00	5.00
	4.2	5.00%		1.00	5.00
5 Eliminating Waste and Continuous Improvement	*5.1*	5.00%	15%	1.00	5.00
	5.2	5.00%		1.00	5.00
	5.3	5.00%		1.00	5.00
6 Lean Techniques and Tools	*6.1*	5.00%	10%	1.00	5.00
	6.2	5.00%		1.00	5.00
7 Delivery of Value	*7.1*	5.00%	5%	1.00	5.00
8 Built-In Quality	*8.1*	5.00%	5%	1.00	5.00
9 Process Flow	*9.1*	5.00%	5%	1.00	5.00
10 Lean Impact (Barriers and Success Factors)	*10.1*	5.00%	15%	1.00	5.00
	10.2	5.00%		1.00	5.00
	10.3	5.00%		1.00	5.00
Weighting check		100%	100%	*20.00*	*100.00*

3 Evaluation and Outcome of the Assessment Tool

There are several necessary prerequisites for conducting the application of the LCAT adequately. Project and company information should be gathered beforehand in order to provide time for the assessment, which is conducted through an interview and needs to be well prepared through a site/company visit. In order to reduce bias and to facilitate observation and questioning, site visits and interviews should be conducted with ten or more people. The evaluation model should not be filled out during the site visit and questioning, in order to provide better observation and maintain confidence between the facilitator and interviewee. In order to rate the project or company according to the LCAT, based on a trial that has already been conducted, the researcher asked two of the participants to fill in/answer the assessment questions prior to the actual assessment. It has been found that one hour of site visit is considered enough. The results of the assessment are then compared, discussed, and merged in order for the interviewers to agree on a final version. For the sake of gaining more experience and a clearer rating notion, the same researchers are advised to apply the LCA-Tool to as many projects as possible. This will also help in minimising bias.

The reading of results is based on the overall score of the ten categories of the assessment. The results are considered to be the company's level of Lean Construction awareness; this is represented as a score between 20 and 100. The researcher has assumed a weighting score system such that the minimum score for each question is 1.0 and the maximum is 5.0, whereby results are based on the overall score of the ten categories of the assessment. It is assumed that the score range represents each level of maturity (Nightingale and Mize 2002).

INITIATION (score range: 20.0–30.0): your company urgently needs to improve these aspects.

PLANNING (score range: 31.0–45.0): your company needs to address the gaps in its knowledge.

EXECUTION (score range 46.0–60.0): your company has moderate capability and maturity and scope for improvement.

MONITORING AND CONTROLLING (score range 61.0–75.0): your company has high capability and maturity

CLOSING (score range: 76.0–100): your company needs continuous improvement.

4 Conclusions

The development of an assessment tool was employed to allow construction companies in the Middle Eastern Gulf region to assess the maturity level of Lean Construction prior to implementing the Lean Construction method. The nine steps of Lean Construction Assessment and the ten areas of coverage of the assessment tool are provided. The ten areas have 20 questions to help organisations evaluate the level of awareness of the Lean Construction method among their workers. Based on the conducted process of the validation of the assessment tool. Fifteen participants (100 per cent) agreed that the proposed Lean Construction Assessment Tool could assess the awareness of Lean in construction organisations/projects. In addition, the experts interviewed also gave positive comments on the overall assessment tool, such as 'the proposed assessment tool is really well-designed'. Moreover, an assessment tool was employed to allow construction companies in the Middle East to assess the maturity level of Lean Construction prior to implementing the Lean Construction method.

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Best Management Practices in Design, Construction, and Maintenance of Mechanical Systems in Data Centers

Prabha Sharma, Scott Kramer, and Junshan Liu

Abstract

The purpose of this research study is to evaluate the challenges faced during the project definition, design, construction, and maintenance phase of mechanical systems projects for new Data Centers or existing Data Centers. Construction industry professionals, design professionals, data center management, and engineering personnel were surveyed. The survey questionnaire comprised of 27 questions and focused on the following themes: general information and respondent's area of knowledge and experience, overall management challenges in data centers, challenges specific to data center mechanical systems, standard management practices and processes employed in data center mechanical projects and recommendation and suggestions to arrive at best management practices in mechanical systems projects for data centers. The results of the survey were evaluated to arrive at best management practices to better assist in building reliable data centers.

Keywords

Data centers • Mechanical systems • Best management practices

1 Introduction

Data centers are mission critical facilities that typically contain thousands of data processing equipment, such as servers, switches, and routers. In recent years, there has been a boom in data center usage, leading their energy consumption to grow by about 10% a year continuously. The heat generated in these data centers must be removed to prevent high temperatures from degrading their reliability, which would cost additional energy (Alkharabsheh et al. 2015). Data center owners and operators face high stakes challenges, as poor decisions can lead to difficulties that must be dealt with for decades (Data Center Challenges n.d.).

Failure of any mission critical system due to the disability in equipment, software, process results in the failure of business operations. It is not rare for a data center power outage to happen. According to a survey that is conducted by the Emerson Network Power and Ponemon Institute in 2010, 95% of the data centers have unplanned outages. The outage can cost a business an average of $300,000 in just 1 h ($5,600 per min). Respondents averaged 2.48 complete data center shutdowns over a two-year period, with an average duration of 107 min. The root cause analysis shows that among the top seven causes of unplanned outage are insufficient cooling, load capacity issues, and heat-related/computer room air conditioner (CRAC) failure.

2 Research Objective and Data Centers

The objective of this study is to identify factors and challenges associated with mechanical systems projects in data centers and to establish best management practices that would focus on a dynamic and collaborative approach involving all stakeholders in delivering a data center that would meet the desired needs, thus eliminating the need for redesign or upgrade in a couple of years. Whether one is planning to build a new data center, leasing capacity in a collocated data center, or retrofitting an existing data center to expand its capacity, careful planning, coordination, and collaboration need to happen among all stakeholders to understand the requirements. This is the backbone to laying the foundation of success for mechanical system in data centers.

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3 Data Center Design Requirements

3.1 Tier Classifications

There are four levels of a data center, based on the infrastructure requirements. The simplest is a Level 1 data center, which is basically a server room. The most stringent level is a Level 4 data center, which is designed to host the most mission critical computer systems, with the ability to continuously operate for an indefinite period during power outages (Data center tier classifications n.d.).

Tier 1 Basic—Per TIA-942-A (2014 edition), the HVAC system of a Basic facility includes single or multiple air-conditioning units with the combined cooling capacity to maintain critical space temperature with no redundant units. If a generator is provided, all air-conditioning equipment should be powered by the standby generator system. Associated with less than 28.8 h of downtime/year.

Tier 2 Redundant Components—The HVAC system of a Redundant Component facility includes multiple air-conditioning units with the combined cooling capacity with one redundant unit (N + 1). Air-conditioning systems should be designed for continuous operation 7 days/24 h/365 days/year, and incorporate a minimum of N + 1 redundancy in the Computer Room Air-Conditioning (CRAC) units. The computer room air conditioners (CRAC) system should be provided with N + 1 redundancy, with a minimum of one redundant unit for every three or four required units. All air-conditioning equipment should be powered by the standby generator system. Associated with less than 22 h of downtime/year.

Tier 3 Concurrent Maintenance—The HVAC system of a Concurrently Maintainable facility includes multiple air-conditioning units with the combined cooling capacity to maintain critical space temperature and relative humidity at design conditions, with sufficient redundant units to allow failure of or service to one electrical switchboard. This level of redundancy can be obtained by either furnishing two sources of power to each air-conditioning unit, or dividing the air-conditioning equipment among multiple sources of power. The piping system or systems are dual path, whereby a failure of or maintenance to a section of pipe will not cause interruption of the air-conditioning system. Redundant computer room air-conditioning (CRAC) units should be served from separate panels to provide electrical redundancy. All computer room air conditioners (CRAC) units should be backed up by generator power. Refrigeration equipment with N + 1, N + 2, 2 N, or 2(N + 1) redundancy should be dedicated to the data center. Associated with less than 1.6 h of downtime/year.

Tier 4 Fault Tolerant—The HVAC system of a Fault Tolerant facility includes multiple air-conditioning units with the combined cooling capacity to maintain critical space temperature and relative humidity at design conditions, with sufficient redundant units to allow failure of or service to one electrical switchboard. If a water-side heat rejection system serves these air-conditioning units, such as a chilled water or condenser water system, the components of these systems are likewise sized to maintain design conditions, with one electrical switchboard removed from service. This level of redundancy can be obtained by either furnishing two sources of power to each air-conditioning unit, or dividing the air-conditioning equipment among multiple sources of power. The piping system or systems are dual path, whereby a failure of or maintenance to a section of pipe will not cause interruption of the air-conditioning system. Associated with less than 0.4 h of downtime/year (Use Best Practices to Design Data Center Facilities).

3.2 Energy Consumption

The energy consumption of the data centers has accounted for 1% of total electricity consumption. Today, data centers are facing soaring energy prices, coupled with increased energy consumption due to increases in server processing power and a greater demand for cooling (DiRamio 2008). Power has become a major expense and therefore, energy efficiency is now a top concern. In 2005, 1.2% of the total U. S. energy consumption was attributed to the server-driven power usage (Li and Kandlikar 2015). Of this usage, the energy consumption by the electronic components of the IT made up about 50%, and cooling systems about 40%. In simple terms, 1 kWh of energy consumed by the IT equipment requires another 1 kWh of energy to drive the cooling and auxiliary systems.

3.3 Efficiency and Total Cost of Ownership

The data center industry uses the measurement PUE, or power usage effectiveness, to measure efficiency (Designing a Very Efficient Data Center). A PUE of 2.0 means that for every watt of IT power, an additional watt is consumed to cool and distribute power to the IT equipment. A PUE closer to 1.0 means nearly all the energy is used for computing (Data Centers—Google n.d.).

A data center is one of the most financially concentrated assets of any business. The capital and operational costs for the physical infrastructure may be comparable to, or larger than all supported IT assets. Sometimes, decision-makers just focus on the upfront costs but are not aware about the long-term costs, especially the operating and maintenance costs (ASME n.d.).

Predicting TCO for your physical data center infrastructure is essential to return on investment (ROI) analysis and other business decision processes. Over a 20-year lifespan of the 50 million USD facility, you would spend three to five times the capital costs on operational expenses, with as much as half of that cost—the single largest element on energy. As a result, energy-related electrical and mechanical systems may account for approximately 60 percent of the data center's capital cost and 50 percent of the ongoing operational cost (QLW).

So, it is essential that a close cooperation between your information technology (IT) and facilities team, designer of record, builder, and operations team is a start to assuring that the appropriate trade-offs between capital investment and operating costs are met over the life of the facility, while supporting the budget, growth requirements, and green data center goals.

3.4 Cooling Process

The sole purpose of data center cooling technology is to maintain environmental conditions suitable for information technology equipment (ITE) operation. Achieving this goal requires removing the heat produced by the ITE and transferring that heat to some heat sink. In most data centers, the operators expect the cooling system to operate continuously and reliably (Heslin 2015). For decades, computer rooms and data centers utilized raised floor systems to deliver cold air to servers. Cold air from a computer room air conditioner (CRAC) or computer room air handler (CRAH) pressurized the space below the raised floor. Perforated tiles provide a means for the cold air to leave the plenum and enter the main space—ideally in front of server intakes. After passing through the server, the heated air is returned to the CRAC/CRAH to be cooled, usually after mixing with the cold air. The primary benefit of a raised floor, from a cooling standpoint, is to deliver cold air where it is needed, with very little effort, by simply swapping a solid tile for a perforated tile.

3.5 Factors Affecting Mechanical Systems in Data Center Projects

Heat Load—The most significant factor affecting mechanical system data center projects is heat load. This includes the total heat to be rejected and the density of that heat. Traditionally, data centers have measured heat density in watts per square foot. The construction cost of the data center can be significantly affected by the design power density and the level of reliability (Kurkjian and Glass 2005). Design professionals should carefully determine heat loads, and consider developing phased plans for the installation of mechanical and matching cooling equipment to meet IT requirements, so that it makes the most cost-effective sense, requiring infrastructure costs only to be expended when required. Technology Changes—Data center managers will replace servers three times before they replace cooling systems, so the design must be flexible enough to accommodate several technology changes during the life of the facility and must ensure that infrastructure technologies will be able to scale to support future needs (IBM n.d). Owners, designers, IT data center managers, and operators should also take into consideration that during the initial start-up and first year of operation the data center could require the mechanical systems to operate with little or no computing equipment load (Plant Engineering n.d). Airflow—Careful consideration should be given to airflow produced by the cooling system to meet the ITE requirement (Data Center Best Practices n.d). Of the numerous ventilation schemes, the team should be able to choose which one is the best for cooling the ITE requirement and minimize airflow distribution problems (Schmidt and Iyengar 2007). Site Location—Climatic Conditions, Temperature, and Humidity. The team will have to determine what the temperature and humidity should be in the space as it affects the operation of the ITE. For new data centers, site location and climatic conditions will also need to be evaluated (Data center design n.d.).

4 Research Methodology and Analysis

To better understand mechanical systems projects in data centers, a survey questionnaire was distributed via a web-based service called SurveyMonkey™ (http://www.surveymonkey.com) to 96 executives. The survey population consisted of IT Managers, Mechanical Designers, Construction Contractors, Facility Engineers, Operations and Maintenance Personnel, and Project Managers representing different phases of project cycle for data center projects. The questionnaire comprised of 27 questions and was divided into 4 sections: General Information and

Respondents area of knowledge and experience, Overall Management Challenges in Data Centers, Challenges Specific to Data Center Mechanical Systems Projects, and Organization Approach/Management Practices. The Questionnaire survey was open for 21 days. Approximately 30% of the 96 respondents completed the online survey.

4.1 General Information and Respondents Area of Knowledge and Experience

In Sect. 1, questions 1–5, respondents were asked to provide information regarding their domain knowledge and area of experience, preferred acquisition, cause, and impacts of budget constraints. Majority of the respondents were Mechanical Designers (43%), followed by Construction Personnel comprising Project Managers, Builders, CM at Risk, Project Engineers, Construction Quality Control Representatives (36%), Facilities Engineering, and Operations Personnel (18%).

Design-Build was considered the most appropriate acquisition strategy by 45% of the respondents as requirements can be better defined. 38% of respondents chose Design-Build for delivering projects faster. Similarly, 75% of the respondents surveyed indicated that budgets constraints affected their projects. This was attributed to lack of deep-domain expertise of mechanical systems during the assessment phase which resulted in poorly defined requirements and poorly allocated budgets.

4.2 Overall Management Challenges in Data Centers

In Sect. 2, respondents were queried on management-related issues. Questions 6–8 validated the need for better project definition during the assessment and planning phases. Most respondents believed poorly defined requirements (undersized cooling and load requirements, not being able to predict capacity and future needs) were the major challenges facing the data center industry. Almost 96% of the respondents confirmed the need to have all stakeholders engaged during the assessment and planning phase. However, when queried whether their team involved all stakeholders during the assessment phase, only 55% confirmed in the affirmative.

4.3 Challenges Specific to Data Center Mechanical Systems

In Sect. 3, respondents were asked a total of 13 questions which helped identify challenges specific to Data Center Mechanical Systems projects. Poor Capacity Planning, Efficiency, Reliability, Redundancy of equipment, failure to consider exiting conditions, project constraints, space constraints and colocation, failure to plan for future growth/over engineering, failure to address airflow issues, and failure to address temperature and humidity issues were some of the major challenges identified and are shown in Fig. 1.

In this section, respondents emphasized the need to evaluate current technological trends, especially where legacy systems (ITE and Mechanical) were involved, as stakeholders were less likely to consider new technology for renovations/upgrades of such systems. On an average 70% of respondents confirmed, in such projects careful consideration must be given to technological advances and changes, energy modeling, energy and water conservation measures, redundancy of equipment, temperature, and humidity control. Similarly, use of engineering resources to meet industry standards and manufacturing guidelines, and Building Automation Controls in such projects was

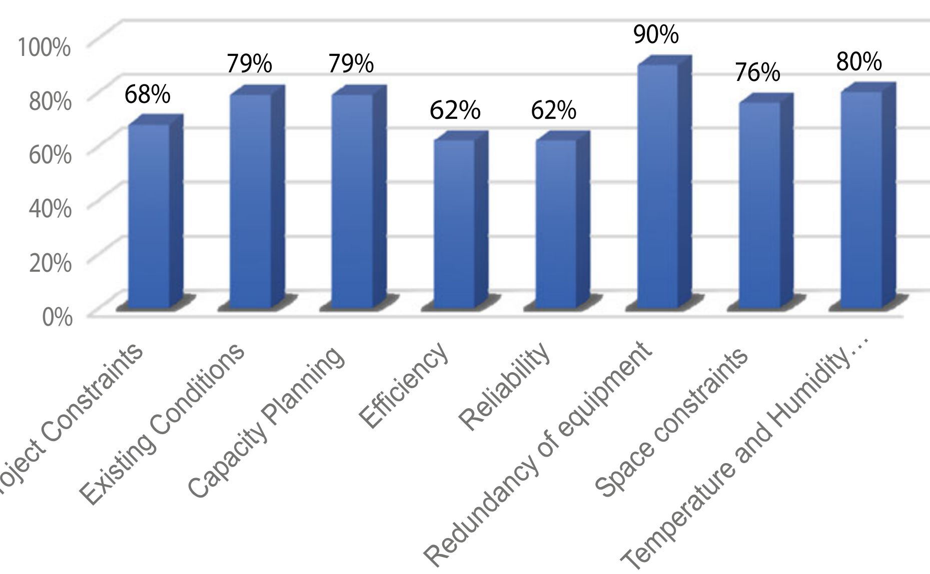

Fig. 1 Major challenges associated with mechanical system in data centers

encouraged. Respondents also identified the need to plan for commissioning on critical components of mechanical systems during assessment phase and then performing integrated testing/commissioning during the execution phase as critical element. Respondents indicated that commissioning should be routinely performed during the maintenance phase. 48% of respondents stressed the need to focus on Maintenance Planning, be it load balancing, maintaining the cooling system, or simply ensuring that data center stays clean and well-managed to ensure uptime. Even though, only 18% of respondents felt the need to evaluate Total Cost of Ownership (TCO), careful consideration should be given as this would eventually help better predict capital and operational expenditure costs, resulting in validated budgets.

4.4 Organizational Approach and Management Practices

The last set of questions gave an insight into the organization approach and management practices. Understanding the culture of an industry or an organization is the key to establishing practices that will lead a team to successful projects and to getting it right the *First Time*. Overall, 88% of the respondents indicated that their organization and management was committed to establishing processes and practices that would result in project success. An area of concern that was noted is that only 58% of the respondents believed that management was committed to self-improvement and allocated enough funds for training.

5 Conclusions

Based on the analysis, some best management practices have been identified.

Organization and Management: Organizations and Management should support strategic planning to achieve flexibility and scalability and reliability in a data center. Management should support innovation, promote stakeholder engagement, self-improvement initiatives by providing sufficient training opportunities.

Team Identification: As soon as a requirement becomes known, it is imperative that all stakeholder groups are on board. All stakeholders should collaborate, communicate, and be actively engaged in visualizing every aspect of the data center requirements.

Assessment/Project Definition: Assessments provide all stakeholders with a baseline at which to start. The goals of these assessments are to capture weaknesses in the facility, define requirements and to assist in controlling operational expense (OPEX) or arrive at building and investment costs (CAPEX) and be aware of the total costs of ownership to make a selection that best fits the need of the data center.

Design: From stakeholder management perspective, ensure that everyone is participating in the selection of the architecture and engineering firm that will provide the design. The first step in designing the cooling and air management systems in a data center is to look at the recommended operating environments for equipment set forth by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). Another important rule is to always design for flexibility and scalability and design an integrated system that optimizes space allocation, power, and mechanical systems. Build additional capacity into the main electrical components, such as patch panels and conduits, and use higher gauge electrical wire to accommodate future growth in electrical demand. Data centers often over cool and over control humidity, which results in no operational benefits and increases energy use. Care should be taken to address this issue. Another objective would be to ensure optimal configuration of the data center equipment for improved airflow management, and reduce operational costs. Site selection and climatic trends should be analyzed to invest in systems which would reduce cooling costs. These efforts should be implemented during the definition and design phase. The system should be designed to only support the level of redundancy required to meet requirements. At a minimum, a monitoring system should be installed to determine operational efficiency and to diagnose operational problems.

Commissioning/Training/Operations/Maintenance: Integrated Commissioning and Training prior to closeout routinely during the operation and maintenance phase should be adopted. There is always a need to have a deep-domain expertise in all the systems that comprise the modern data center, but there is also a need for cross training on the technology of operations across all stakeholder groups. An IT data center manager, a facility engineer, a designer, a builder, or a data center owner should have some working knowledge of every aspect of the project life cycle to include assessment, definition, design, construction, commissioning, turnover, operations, and maintenance. This is important, due to the need to work together as a cohesive group across all phases of the project life cycle. This approach will help deliver an efficient reliable and a scalable mechanical system that will meet the current and future needs of a data center.

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Antecedents of Client Loyalty in the Construction Professional Services Sector: A Qualitative Study

Nick Williams, Paul Hampton, Nii Ankrah, and Ezekiel Chinyio

Abstract

While a limited amount of research has focused on client loyalty in wider professional services, none has been carried out specifically in respect to construction professional services (CPS). A review of the wider professional service literature identified a number of key candidate loyalty antecedents. Thematic analysis was undertaken on semi-structured interview data obtained from 20 client and CPS supplier participants operating in the West Midlands (UK). The results were used to refine a literature-derived model of CPS client loyalty. Several modifications were made to themes and sub-themes in the light of empirical data. The results obtained will form the basis for a future quantitative phase of research which will determine the extent to which the findings of this qualitative research generalise to the wider population.

Keywords

Construction professional service firm • CPS • Loyalty

1 Introduction

Construction professional services (CPS) comprise occupations such as "architects, quantity surveyors, surveyors (other), building services engineers, civil and structural engineers, planners (town planners), project managers and multidisciplinary practices" (CIC 2008). CPS firms make a substantial contribution to the construction industry and wider economy. In the financial year 2005/2006, they generated £13.9 billion worth of revenue. The market for specialist architectural and quantity surveying services alone was worth £4.1 billion in 2011 (DBIS 2013). The importance of client loyalty to the CPS sector cannot be overstated. Retaining clients can lead to maintaining or even increasing sales and customer share, lower costs and reduced client price sensitivity. The loyalty of an existing client base is important to CPS suppliers, given that they tend to treat marketing as either unimportant or a necessary evil (Sawczuk 2010). It is even more important for those operating in business-to-business markets as they have a smaller number of customers, each making a larger contribution relative to turnover. Most professionals operate within a framework of professional and ethical obligations which constrain more ruthless aspects of selling and opportunism. Furthermore, they are required to adhere to technical codes, having only a limited ability to differentiate their service offerings (Sweeney et al. 2011). Despite this, the amount of research investigating client loyalty in professional services is modest (Broschak 2015). None has been carried out specifically with respect to CPS. A key strategic goal for CPS firms should be to retain and benefit from their key accounts, hence the interest in understanding client loyalty.

The problem addressed by this academic paper is addressing the question: what are the key service-related antecedents of client loyalty to CPS firms operating in business-to-business markets? Furthermore, on what level (key contact employee and/or firm) do these antecedents influence CPS client loyalty? This paper does not aim to present a holistic model of all the factors that can influence CPS client loyalty given that there are a wide range of pull and push factors involved (Naumann et al. 2010). While external influences, contractual arrangements and client characteristics are undoubtedly influential, this research is restricted to the study of service-related antecedents impacting on loyalty, specifically those which CPS firms can influence.

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2 Methodology

A literature review was carried out to develop a conceptual model of CPS client loyalty. Qualitative research was then carried out to refine the model using empirical data gained from 20 semi-structured interviews with a mix of clients and service professionals, all working in the West Midlands, UK. Purposive sampling was initially carried out, selecting participants with experience of either having been a CPS client or service provider. After the initial interviews, sampling moved to a snowballing strategy with contacts and suggestions sought from interview subjects. The data was transcribed and analysed in NVivo using thematic analysis (Braun and Clarke 2013). The data was initially coded to pre-determined themes based on the literature review while also searching for emergent candidate themes. From these, their component sub-themes were developed, based both on extant research and emergent findings. The theme and underlying sub-theme structure were refined during the qualitative analysis based on the evidence obtained from the participants. Once the themes and their sub-themes were sufficiently developed, pattern analysis was undertaken on the data to identify any associations between the themes and their sub-themes with loyalty.

3 Defining Loyalty

A succinct definition which summarises the conceptualisation of loyalty used in this paper is "a favourable attitude […] that results in intentions to repurchase and recommend" (Yeh et al. 2016, p. 247). The repurchase aspect is referred to in this paper as behavioural intentions loyalty (BIL), whereas the propensity to recommend the CPS to others is referred to as positive word of mouth (PWOM). There is an empirical argument for considering PWOM to be a desirable relationship outcome distinct from BIL when operationalising loyalty (Watson et al. 2015), hence the conceptualisation adopted in this paper.

3.1 Service-Related Loyalty Antecedents of Loyalty

Commitment has been positioned as the central explanatory construct of business-to-business service loyalty. It has been conceptualised as having three different facets reflecting the different psychological states that bind the individual to the target; specifically calculative commitment (attachment due to instrumental reasons); affective commitment (attachment due to liking and identification); and normative commitment (attachment due to felt obligations). A succinct description of calculative, normative and affective commitment can be expressed as "need to", "ought to" and "want to" motivations, respectively (Allen and Meyer 1990, p. 3). Expanding this conceptualisation, it has been argued that calculative commitment can have separate "locked-in" and "value-based" dimensions (Sharma et al. 2011, p. 69). While the former is consistent with its traditional constraint-based operationalisation, the latter is more positive, arising from the expectation of gain arising from the relationship by way of profits, efficiencies and other successes.

Being able to *trust* construction professionals is vitally important for clients (Carr et al. 2002). Poor CPS performance is of high consequence to the client with a risk of adverse outcomes, such as buildings failing, design requirements not being met or projects exceeding budgets. In common with other professional services, having confidence in the capability, honesty and integrity of the CPS provider are likely to be of fundamental importance to the client and a key determinant in their decision to continue the professional relationship.

Sixty per cent of CPS firm respondents considered service quality to be their major source of competitive advantage (Jaafar et al. 2008). The service quality scale developed for quantity surveying services measured attributes of tangibility, reliability, responsiveness, assurance and empathy (Akinsiku 2016). The service quality model adopted in this paper conceptualises two distinct aspects, specifically "technical quality" (relating to what is delivered) and "functional quality" (relating to how it is delivered) (Grönroos et al. 1984, p. 38). Technical quality has been operationalised in professional service studies using the perceived quality of advice provided and the degree to which the service provider helps achieve the client's goals. Functional quality has been operationalised by measures such as responsiveness and flexibility (Sarapaivanich and Patterson 2015).

Communication quality has been operationalised in the literature by communication frequency, understanding client's needs and accessibility, keeping the client informed of progress, providing sufficient information and explaining concepts meaningfully 106 (Sarapaivanich and Patterson 2015; Sharma and Patterson 1999).

A further aspect to account for is the influence of individual employees versus the firm as a whole in developing client loyalty. The term "key contact employee" (KCE) used in context with the individual client-facing employee is deemed to be intuitively understandable (Bendapudi and Leone 2002, p. 84), hence, its adoption in this paper. Although relationships in business-to-business professional services are more commonly conceptualised as being between firms, interpersonal relationships and human factors play a significant role. A client's association with the employee and firm are separate facets within an intermingled relationship. Clients can and do make independent judgements and purchase decisions influenced by the KCE versus the firm (Anaza and Rutherford 2014). These findings led to the development of the model shown in Fig. 1.

4 Results of Qualitative Analysis

In line with the approach of Braun and Clark (2013) in this paper where the term "most" is used, this refers to fifteen or more of the 20 interview participants. Where the term 'many' is used, this refers to between 10 and 20 of the participants. Where the term "occasionally" or "some" is used, this refers to less than half. Emergent themes and sub-themes were included in the client loyalty model on the basis of supported evidence found in many or most of the participants' accounts.

Evidence from many of the participant's accounts supported the association between most of the theory-derived antecedent themes and BIL. The exception to this was normative commitment. With the exception of locked-in commitment and normative commitment, evidence was also found in many of the participants accounts that antecedent themes were associated with PWOM. The lack of evidence for normative commitment in CPS–client relationships may be because obligation-based exchange relations are more strongly associated with collectivist business cultures such as those in Asia as opposed to individualist cultures such as the UK (Sharma et al. 2006). The analysis findings also demonstrated that only locked-in commitment, affective commitment and trust operated on both KCE and firm levels. A new sub-theme associated with the technical quality of CPS services was 'meticulousness' not found in extant conceptualisations within the literature (Tables 1 and 2).

Due to weak evidence for the existence or impact of normative commitment, it was excluded from the refined model. Due to the lack of evidence for value-based commitment, functional quality, technical quality and communication quality operating on both employee and firm levels, they were collapsed into single level-neutral themes during the thematic analysis. Sufficient support was found for the remaining themes for them to be included. The initial 16 antecedents were reduced down to a total of eleven antecedents in the refined model shown in Fig. 2.

Fig. 1 The literature-derived model of CPS–client loyalty

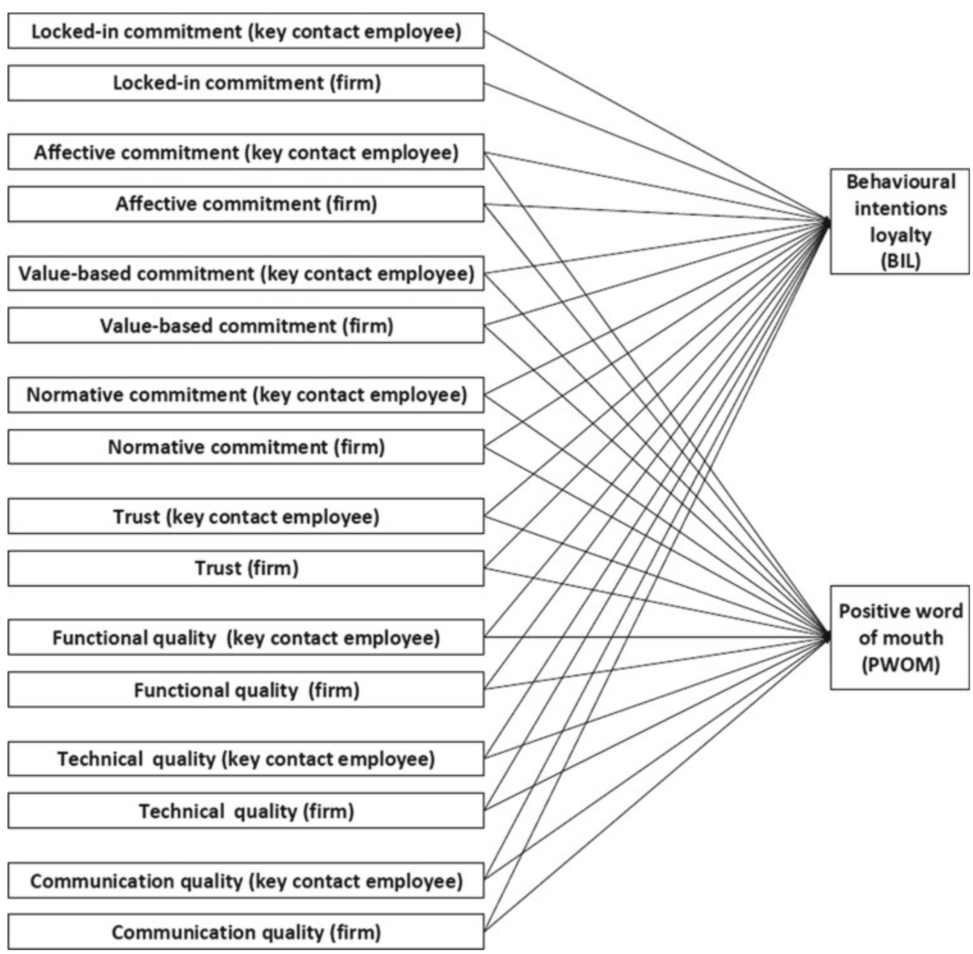

Table 1 Loyalty themes and underlying sub-themes resulting from the thematic analysis

Antecedent themes and associated sub-themes	Participant sources	Occurrences (total)
Locked-in commitment	(out of 20) 20	60
Lack of alternatives who understand unique requirements	12	27
Lack of alternatives with right skills and attributes	11	19
Risks, time and costs of switching	10	14
Affective commitment	20	80
Identification	8	9
Likeability	11	25
Rapport	18	46
Value-based commitment	15	39
Benefits exceed costs associated with relationship	15	39
Normative commitment	7	9
Guilt associated with switching	2	2
Obligation	6	7
Supplier expectation	0	0
Trust	20	251
Client's interest at heart	16	44
Confidence	17	46
Integrity	16	79
Expertise	20	46
Reliability	13	36
Functional quality	19	100
Flexibility	12	15
Responsiveness	19	85
Technical quality	19	130
Helps me achieve my goals	15	32
Meticulousness	15	38
Understands my needs	15	60
Communication quality	19	99
Explains pros and cons	10	15
Explains things meaningfully	10	36
Keeps me updated	18	48

Table 2 Analysis of the association between antecedent themes with BIL and/or PWOM

	Participant sources (out of 20)	Occurrences (total)
Affective commitment (firm)—BIL	15	38
Affective commitment (firm)—PWOM	10	14
Affective commitment (KCE)—BIL	18	69
Affective commitment (KCE)—PWOM	10	15
Communication quality—PWOM	15	16
Communication quality—BIL	20	121
Functional quality—BIL	18	65
Functional quality—PWOM	16	26
Locked-in commitment (firm)—BIL	17	35
Locked-in commitment (KCE)—BIL	12	25
Normative commitment (firm)—BIL	5	8
Normative commitment (firm)—PWOM	0	0
Normative commitment (KCE)—BIL	5	6
Normative commitment (KCE)—PWOM	0	0
Technical quality—BIL	20	132
Technical quality—PWOM	17	34
Trust (firm)—BIL	18	80
Trust (firm)—PWOM	15	33
Trust (KCE)—BIL	19	100
Trust (KCE)—PWOM	15	26
Value-based commitment—BIL	18	66
Value-based commitment—PWOM	13	19

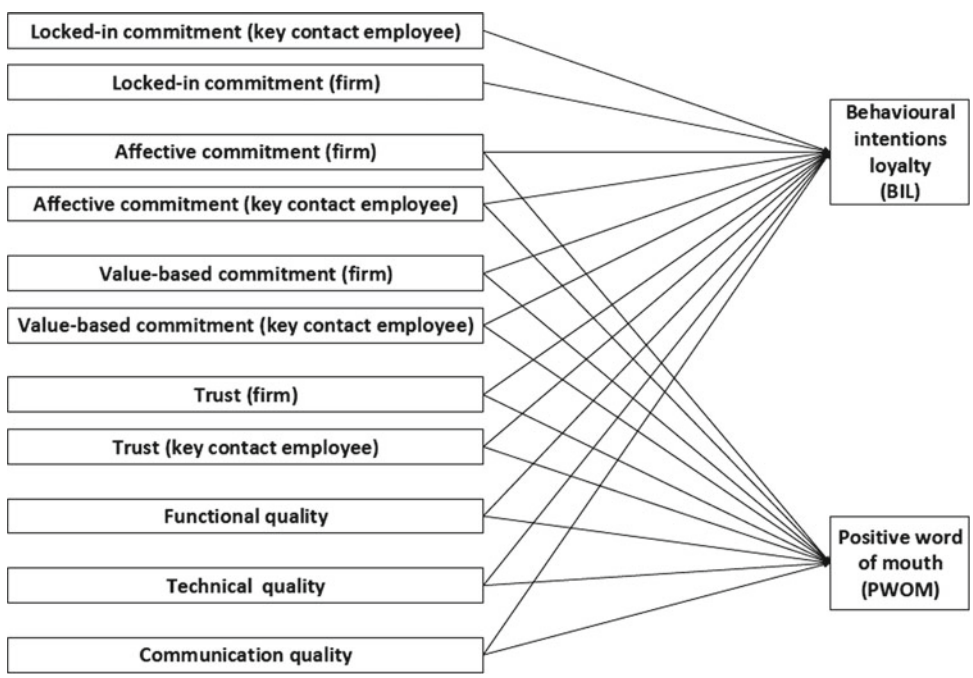

Fig. 2 The refined model of CPS–client loyalty

5 Conclusions

Qualitative analysis demonstrated that most (but not all) of the antecedents identified in the extant professional loyalty literature appear to be similarly influential in CPS–client service relationships. Furthermore, it was necessary to refine the sub-themes for certain antecedents, such as CPS technical quality based on the emergent findings. The next planned phase of research is to quantitatively test the proposed relationships between the themes shown in Fig. 2 and determine the degree to which these findings generalise within the wider CPS client population.

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Reducing Our Energy Usage and Reliance to Mechanical Air Conditioning Through Passive Cooling: Can It Be Done at Home Today?

Junshan Liu, Scott Kramer, and Marisol Cho

Abstract

Today more houses are being built to rely solely on air conditioning as the only means of cooling a home. This research study explored methods available that may help minimize energy consumption and reduce reliance on mechanical cooling through passive cooling while focusing on retrofit options for existing residential buildings and energy-saving considerations for new residential construction in the United States of America. The data of this research was collected through literature review, a combination of an online survey and interviews on individuals' experiences with air conditioning, and an interview with an electrical energy provider managing weatherization home improvements.

Keywords

Air conditioning • Energy • Insulation • Natural ventilation • Passive cooling • Residential construction

1 Introduction

Today, nearly most of a person's day is spent comfortably sheltered in an air-conditioned box. Air conditioning has become our way of life, it has changed the type of air we breathe, the way we design our homes and has redefined our tolerance to surrounding temperature according to a modern standard of living. For some of us, it is the only life we know. So, what happens when our air conditioning system suddenly fails, when there is a power outage, or when it becomes necessary to shut off the only cooling system our home was built to work with? In most cases, the inside temperatures become too uncomfortable to withstand. The one place we call home can suddenly become inhabitable.

Before air conditioning, most homes were built to provide people comfort according to the climate and geographic location. They were built using vernacular building methods. Today, the ability to keep a home cooled mostly naturally with near-zero energy consumption is referred to as passive cooling (Oropeza-Perez and Østergaard 2018). Consisting of different non- mechanical methods and some new energy-efficient technologies, setting up an existing or new construction home for passive cooling, can improve home energy efficiency, can be something to fall back on when a break from air conditioning is inevitable, can redefine our current standard of living and mostly, it can help minimize the negative impact of air conditioning on the environment.

However, most buildings today and especially the mass number of housing developments emerging every year are designed and built to depend on an air conditioning system for the most part of the year. Featuring operable windows is almost always part of residential construction, but is that enough to cover our cooling needs during a power outage or at least cuts back on air conditioning usage during parts of the year?

According to the U.S. Energy Information Administration (U.S. Energy Information Administration 2018), the demand for electrical power was expected to increase in the summer of 2018 alone by 1% with an estimated 3% spending increase. With energy resources depleting and demand growing annually, the increase in prices will continue to follow. This tendency also continues to impact the environment. The building sector is currently the thid largest contributor to greenhouse gas emission. By 2030, if the industry continues the trend of building with energy-consuming systems, the building sector will earn the spot as the second largest contributor to greenhouse gas emissions (Oropeza-Perez and Østergaard 2018). As seen in Fig. 1, there is an upward increase of air conditioners being installed in all new homes in all four geographic regions of the Contiguous United States. Regardless of the years of

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research, studies and awareness did on the impact of the environment, people continue to move forward with buildings constructed to comfortably house them on the condition that the air conditioner is running. With this upward increase of new buildings equipped with air conditioning, comes an upward increase in energy consumption, energy costs, and greenhouse gas emissions. So, it has never made more sense to finally adopt alternatives methods to cool a home such as those offered through passive cooling that can help offset these increases in energy consumption. The purpose of this study is to explore the options available that may help minimize energy consumption and reduce our reliance on mechanical cooling for homes through passive cooling. Some passive cooling methods are more feasible than others, some may require a new perspective of comfort or can only be applied under certain climate or site conditions.

2 Passive Cooling

Passive cooling involves the use of the natural environment to cool a building with no electrical supply. Unless you are using a wind turbine, solar or a water mill to produce electricity, passive cooling options can include using natural breezes, landscapes, thermal masses, insulation, wind towers, and other permanent architectural features such as deep overhangs and sunshade devices. During some parts of the year such as the summer season, eliminating the use of electricity all together for cooling purposes may not be a realistic option, but minimizing it with the assistance of passive cooling systems can reduce the cooling load which will allow for minimal energy consumption. The application of mechanical air conditioning systems in this form would be included as a supplement during these intense hot days.

The effectiveness of these passive cooling options varies by climate, time of year, and geographic location, but the methodology of passive cooling in respect to combating heat gain and heat rejection can be applied the same regardless of these conditions. The site selected for new construction or where an existing home is already built includes its own unique climate, location, site features, or other special conditions which are all context-sensitive elements that will drive the selection of passive cooling options appropriate for the site. Considering how each of these passive cooling options varies is crucial as no one site with building combined is ever the same.

There are two key functions that make up passive cooling and help accomplish its goals: (1) heat gain preventive measures and (2) heat rejection corrective measures. Keeping as much heat out as possible and keeping existing cool conditions in, allows for more sensible cooling levels. Heat energy flows through the envelope of the building from outside. A building gets heat energy through radiation and convection, and can also generate heat energy inside through convection. Passive cooling options are more effective if there are efforts taken to try to keep heat energy out of a building. This is also an important factor to consider for a building constructed to solely depend on an air conditioning system. If more effort is taken to prevent heat flow into a building, air conditioners would have to work less, thus consume less energy and cost less. So, the first key function is to prevent (or minimize) heat energy from accessing or generating inside. Second, once heat energy is generated or has entered from outside sources, the key is to get as much of that heat energy out. Heat energy flows into a home and then out of the home, and if more heat is coming in than what is being taken out, then the difference will generate uncomfortable room conditions.

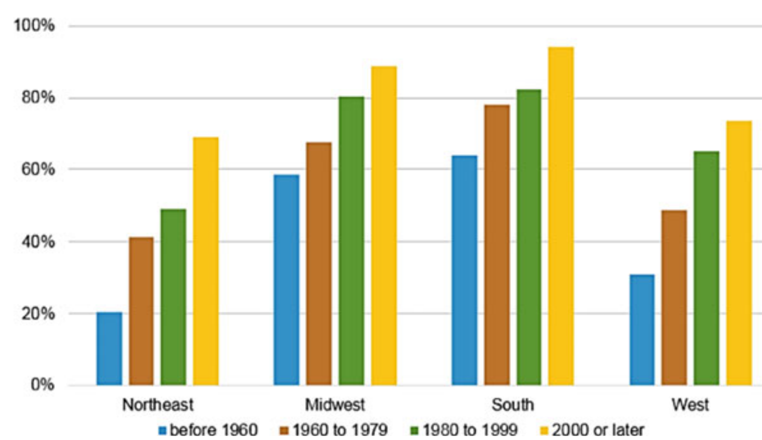

Fig. 1 Most newer homes have central air conditioning. Percentage of homes by year built with air conditioning. 2015 Residential Energy Consumption Survey (U.S. Energy Information Administration 2018)

2.1 Heat Gain Preventive Measures

To get a better understanding of how to prevent heat flow, first consider where this heat comes from. Heat can come from the following:

- Conduction through building envelope.
- Solar heat gains. Accounts for 75% of the cooling load in a residential building that occurs through windows, doors, and other exterior glazing wall systems.
- Air infiltrations. Can include natural air ventilation during peak summer temperature.
- Internal gains. Accounts for about 25% of the cooling load in a residential building normally generated by appliances, lights, and human body temperature

1. *Insulation and Thermal Mass*: One of the passive cooling methods that effectively helps keep heat energy out is the application of building envelope insulation. "Many older homes have less insulation than homes built today, but even adding insulation to a newer home can pay for itself within a few years (Energy.gov. (n.d))." Today, for the sake of initial cost savings, homes can be designed and constructed to meet just the bare minimum heat resistance (R-Value) insulation standards provided by the International Energy Conservation Code (IECC) or other enforced building codes. Initiatives are taken by the owner or designer to increase these values during design appropriate to the climate and geographic location, increase the insulating effectiveness. Increasing the R-Value will slow the flow of heat into a building, but higher R-Values do have their limits subject to diminishing returns. The effectiveness of a properly insulated wall and attic is critical in preventing heat gain thus minimizing energy usage that now even energy companies have taken the role of providing insulation services to low-income residents with a goal of increasing their home's energy efficiency.

Electrical companies are now offering programs that either assist homeowners to improve their home's energy efficiency or reward them for installing qualifying energy-saving improvements. City Public Services (CPS) in San Antonio, Texas, for example, includes a program, Casa Verde (3,000 Homes Weatherized Through Casa Verde SA Program (n.d.)), which offers an estimated $5,000 in energy efficiency upgrades to each qualifying home amounting to an average savings of 25% in annual energy consumption for each home. These upgrades include attic insulation, wall insulation, air sealing measures, duct sealing, replacing incandescent bulbs with LEDs and other minor repairs that may be needed to make a home safe once its building tightness limit (BTL) has been improved. For wall insulation, for example, CPS will conduct an energy and safety evaluation of the home to assess needed energy improvements and send a contractor to make small openings between each wall cavity on the interior side of perimeter walls and install R-19 loose cellulose installation as seen in Fig. 2. After interviewing CPS Casa Verde Weatherization Program Manager, Frank Kostusyk, it was interesting to find that nearly 90% of homes that participated in the program had to receive attic insulation as they did not have any. He explained that they begin with a baseline of R-0 for a home that does not have insulation and increase as needed targeting R-19 for walls and R-30 for attics. For an attic with a lower R-Value, such as the one shown in Fig. 3, additional insulation was added on top of existing batt insulation so that the R-30 can be met. Casa Verde is a program within CPS Energy's Save for Tomorrow Energy Plan (STEP). Based on their annual reports on residential energy improvements, it is determined that envelope measures are the largest contributor to total gross program impacts with attic and wall insulation bringing the largest energy impacts per home. A homeowner that participated in this program was also interviewed and explained that he has noticed a significant difference in his home. Since adding insulation into both the walls and attic of his home, he has had to run the air conditioner a lot less (3,000 Homes Weatherized Through Casa Verde SA Program (n.d.)).

Prior to building insulation as we know it today, thermal mass or Trombe walls (Mazen et al. 2017) were used to slow the flow of heat entering a building. While the R-Value of a concrete wall alone is less than that provided by polyurethane or fiberglass insulation, these methods can be added on to an existing building or new construction to assist with keeping heat from entering a building. A Trombe wall works by absorbing heat energy from the heated outside air during the day as a heat sink and then expelling the collected heat out at night either through manual or automated controlled vents, or windows.

2. *Shading:* Another important factor in passive cooling preventive heat gain is through proper shading. Shading can be provided through systems built directly on the building or through landscape near the home. It will provide both protection from the sun's rays and allow for cooler ambient air to surround the building. With heat energy flowing through the building roof, exterior walls, and window, shielding these surfaces before direct solar radiation contact can minimize the impact of radiated heat entering the building. "Controlling solar heat gains is a matter of keeping the sun out of the building and off the exterior surfaces" (Abrams 1986). Before mechanical cooling, buildings were built with deep overhangs, deep

Fig. 2 CPS Wall Insulation installed at a residence's home

Fig. 3 CPS Attic cellulose insulation on top of existing fiberglass insulation (Danner 2012)

porches, and windows strategically placed for ventilation and according to the sun's path. Compared to an exterior wall or roof, windows are impacted the most due to their lack of thermal mass and greater emphasis needs to be considered when protecting them from the sun rays. Whether single or double glazed, their thermal mass is much less than that provided by the rest of the building envelope.

Figure 4 provides an example of a sunshade device that can also be added to an existing house that may have originally been designed and constructed with minimal or no shading in mind. A retractable device such as this one allows for it to be lowered and raised according to the location of the windows in relation to their cardinal orientation which depending on their location will receive dissimilar angles of the sun during certain parts of the day and time of year.

Other retrofit options of utilizing shading could include the addition of a deep porch at the front entrance of a house, on the side of the house that is most vulnerable to the sun, or a wrap-around porch for full protection of the first-floor level. Before air conditioning, wrap-around porches were a common part of southern architecture serving multiple purposes from protecting the lower level windows from the sun to providing a cool shaded outdoor living/dining space. This option, while providing consistent shading, can end up costing more than individual window sun shading devices, but as a permanent structure, can also add value to a house.

In addition to heat gain acquired through outside conditions, are those generated through inside sources such as human body heat, appliances, and light fixtures. While it may appear as minor, replacing incandescent bulbs with CFL bulbs or even better, LEDs, also helps minimize heat gains. An incandescent bulb for example emits more heat and consumes more power. A 100-W incandescent bulb will produce 10% of that into light, and the rest, 90% into heat. The CFLs on the other hand will produce 15% of that into

Fig. 4 An example of Retractable Window Shading Device mounted to a wall (Top Inspiration Idea Outside Window Shades With Exterior Regard To Outdoor And Blinds Remodel Great Best 25 Ideas On Pinterest Diy Inside Remarkable Sun Regarding Plan Prepare—Puppify.info. 2018)

light, and the rest, 85% into heat and will last longer than an incandescent. LEDs, while much more expensive, are 90% more efficient than incandescent, producing less heat and cool to the touch, using less energy and lasting longer than both the incandescent and CFL bulb (GES 2018).

2.2 Heat Rejection Corrective Measures

The second key function of passive cooling includes implementing corrective measures through heat rejection. That is, removing heat gains. The preventive measures discussed earlier are key as they help reduce heat gains, keep existing cool conditions in, and reduce the required cooling load, but for any heat gain that does occur despite these preventive measures, using corrective measures to immediately expel them will help maintain conditions inside a house that can be comfortable enough to live in without air conditioning use or to minimize its use.

Some of these heat rejection measures include the following:

1. Natural ventilation through outdoor breezes and density differences
2. Natural ventilation with supplemental mechanical support (ceiling exhaust fan)
3. Mechanical cooling combined with passive cooling methods (Hybrid of the two)
   (a) *Natural Ventilation:* Cooling a house using natural ventilation is accomplished by allowing outside air to supply and remove inside air and creating a constant movement of airflow throughout a house without mechanical means. The idea is to use the outside atmosphere as a heat sink under the condition that the interior temperature is already warmer than the outside temperature. To fully take advantage and get the most of natural ventilation, creating a constant airflow can involve more than simply opening a window or two. Strategically sized and placed windows along with an open internal wall layout can help create a cross flow of air that will aid in displacing warmer indoor air with slightly cooler outdoor air. A channel of openings must exist within the house to allow uninterrupted airflow. For an existing home, this can be done by opening doors inside or through planned demolition of nonstructural walls creating a more open layout. To further accentuate this process, the implementation of a wind tower, ceiling to roof ventilation or any type of vertical chase with an opening terminated at the highest point of the house, can assist with displacing heat not captured by the horizontal flow of air brought by only using windows. Warmer air will rise to the top due to it being less dense than the air surrounding it. Combining this thermal phenomenon with open windows and a vertical chase, it creates a vacuum like force with a natural upward airflow motion referred to as the stack effect. As warmer air rises towards the highest exit point of a house, it pulls in outside or cooler air in Fig. 5 shows a design sketch of a Natural Ventilation System for a building.
   (b) *Combined Efforts:* To further boost the flow of air inside a home for ventilation and cooling purposes,

Fig. 5 Natural Ventilation System for a building including windows and skylights (Wu et al. 2018)

force ventilation provided by fans, exhaust fans, and whole-house fans can also be considered to lessen the use of the air conditioner. The inside of an attic if improperly insulated, can easily measure up to 150° on a 100° day thus acting very much like a furnace or a heating pad radiating heat directly into the interior spaces of a house. If insulated, the temperature is reduced, but combining it with a solar exhaust fan can further reduce the attic temperature by removing the hot air normally trapped on the highest point near the ridge of the roof structure. For an existing house built without a vertical chase such as a chimney for the purposes of the stack effect, a whole-house fan can be installed at the highest ceiling point of the interior space open to the attic space (DeBlois et al. 2013). As required with natural ventilation, with open windows, and an open interior wall layout, the flow of air would be continuous providing a cooling effect and removing warmer air with cooler outside air provided it is less warm outside. Other systems that can also be integrated depending on the climate can include evaporative cooling in dry–hot climates or dehumidification in hot–humid climates.

The conditions can vary as the second law of thermodynamics states that heat will naturally flow from a high-temperature area to a low-temperature area until both areas are balanced. If the conditions outside are too hot to bear, it would probably not make sense to displace interior air with it. There are parts of the year when ventilation alone can provide plenty of cooling without mechanical means. It is during this time of the year, that taking a break from the air conditioner and letting passive cooling methods take over should be considered. During the summer peak, the time of the year when the temperature outside is significantly greater than it is inside, or during extremely hot and humid conditions, supplemental mechanical support such as dehumidifiers, evaporators, and finally air conditioning, may then be needed.

Natural ventilation can be feasible for most part of the year. According to Paula Melton (Melton 2014; Melton and Yost 2018), the three primary reasons to design a building using natural ventilation is for energy savings, occupant satisfaction and indoor air quality. Also, being realistic, she makes note that there are also many reasons why not to. These reasons can depend on the geographic location, current outside air quality conditions, humidity levels and other factors that can impact the comfort level provided using only natural air ventilation and other passive cooling methods. These factors alone should not be a reason to deter from designing and constructing a building with passive cooling systems. The idea again is not to eliminate mechanical systems entirely, but to reduce it instead and create a balance or harmony between available advanced technology and natural systems that have also progressed as a result of this technology.

Giving up air conditioning altogether is unlikely to happen any time soon. Combining passive cooling preventive measures to lower the cooling load and lessening air conditioning use during parts of the year when the outside temperature is acceptable, will help minimize energy consumption.

With more buildings continually being built to depend on air conditioning for cooling means, and energy consumption and cost increases as a result, what options do we have to provide relief? The different options and methods available are not new. People have used and relied on these options long before electricity. Many have experienced them, and others simply have not. Transitioning from a sole air-conditioned home regardless of a person's experience with it would likely require accepting, adapting and adopting a new lifestyle and understanding how the system works.

3 Research Data and Analysis

A survey for this research concerning individual experiences with air conditioning and methods of keeping cool was conducted through social media. The data gathered on past experiences with air conditioning is based on individuals from different geographic locations including all regions of the United States, and various locations in Central America and Southern America with most of the respondents now residing in the Southern United States.

According to the survey results as shown in Fig. 6, only 14% of participants say they grew up with air conditioning compared to the 73% that did not grow up with it. With 100% of the respondents now relying on air conditioning, their non-air conditioning methods of staying cool have also changed. Before air conditioning was prominent, 68% used natural methods of cooling such as opening windows and letting breezes in. 82% of the respondents also used fans, with most of them sharing through individual interviews that they combined natural breezes and fans together to boost ventilation and air movement in their homes. Now that all respondent use air conditioning, the data reveals that natural cooling methods have decreased with only 14% of respondents cooling their homes with natural breezes and 36% still using fans. More is focused on simply controlling the thermostat as a method of lessening air conditioning while still trying to keep their home cool. Seeing how each respondent has moved away from natural methods of cooling and now rely on air conditioning, the question about how they felt growing up without air conditioning was asked. 82% of the respondents felt the conditions at that time were acceptable. Also provided in the survey were individual statements revealing why they feel they have no choice but to use air conditioning today and how hard it would be to go back to natural cooling. Within most of the statements provided, respondents explained the homes they grew up used materials that felt cooler to the touch. Many explained how they didn't know any different, survived with the bare minimum and were fine with it while slowly acclimating to living in air conditioning over time attributing it to new home construction and/or climate change.

4 Conclusion

It may be easier, cheaper and faster to design and build a house that is cooled entirely by mechanical means and repeat that process again until thousands more of the same are built without considering the context surrounding them. Consisting of different non-mechanical methods and some new energy efficient technologies, setting up an existing or new construction home for passive cooling, can help it be more energy efficiency. This can be something to fall back on when a break from air conditioning is inevitable. This can also redefine the current standard of living and mostly, it can help minimize the impact on the environment. It is also understood that some climate conditions may not allow for natural passive cooling during parts of the year. In that case, efforts in combining some parts of the passive cooling system with mechanical systems can ease the cooling load demand and lessen the energy consumption. Some of these systems will be more energy efficient than others and some will be better suited for extreme conditions that may require air conditioning during parts of the year. Some of these systems can include natural or forced ventilation for cooling, fans for cooling, evaporative cooling, air conditioning, and radiant cooling. While it may seem minor, making changes to an existing home or adding passive cooling measures to

Q #	Questions	Response				
1	Nearly everyone today has an air conditioner at home which wasn't the case for everyone growing up. Did you grow up with air conditioning?	Yes	No	Experienced Both		
		14%	73%	14%		
2	Whether or not you grew up with or without air conditioning , if you experienced it in some form or fashion such as visiting family or a friend, how would you describe your experience growing up without it from a comfort standpoint?	Fine, Comfortable Enough	Too Hot, Uncomfortable			
		82%	18%			
3	*What methods did your family use to stay cool before air conditioning?	Natural Breezes (Open Windows)	Fans	Watercoolers	**Building Components	***Other
		68%	82%	27%	27%	36%
4	Are you familiar with passive cooling or any methods like it?	Yes	No	No Answer		
		32%	64%	5%		
5	*What methods do you mostly use today to lessen the use of your air conditioning?	Natural Breezes (Open Windows)	Fans	Control Thermostat	**Building Improvments	Other
		14%	36%	41%	9%	14%

* Sum does not equal to 100%. Surveyors were given the option to select more than one method of staying cool or lessening use of air conditioner.

** "Building Components/Improvements": Consist of taking advantage of house architectural systems such as overhangs, insulation system, porches, high ceilings, occupy only 1st floor since 2nd floor is hotter, thermal mass, concrete walls, cool ceramic floors, specifically placed windows, attic fan, etc. Or the installation of any of these listed for building improvement purposes. Items in this list were items provided by those surveyed and were not provided as options to select.

*** "Other" included visiting public spaces, staying outside, pools, clothing selected, acclimating to the heat, or ice blocks added to swamp coolers.

Fig. 6 Survey result summary

new construction, may make a world of a difference and lessen air conditioning dependency.

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Enhancing Innovativeness in the Construction Sector: A System Dynamics Analysis

Emiliya Suprun, Rodney Stewart, Oz Sahin, and Kriengsak Panuwatwanich

Abstract

The construction industry has often been criticised for its lack of innovation and commitment to R&D. Using a systems approach, this study examined a number of construction innovation system scenarios and policy interventions within the context of four future plausible Russian construction industry transition scenarios. A system dynamics (SD) model was developed to incorporate the main actors of the construction innovation process, namely industry, government and academia. The SD model provided insight into the complexity and inherent dynamics of innovation processes caused by multiple feedback loops, nonlinearity and time delays in decision-making. The SD model also addressed the challenges of transforming Russia's construction industry into a highly developed sector by providing an understanding of how government policies and supportive programmes could encourage industrialists to innovate, promote research and transfer technology. The transition scenarios were developed by considering the variation of two factors driving innovation in the construction sector, namely: (1) the conditions and level of government financial support; and (2) demand for innovation related to market expectations, largely dictated by traditional versus progressive procurement processes. One key finding was that the Russian construction industry preferences imitation-oriented innovation development.

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Keywords

Construction innovation • System dynamics modelling • Transition scenarios

1 Introduction

It is generally accepted that the construction industry worldwide does not have a coherent model of innovation development and shows a conservative attitude towards mass inclusion of cutting-edge technology into construction processes (Blayse and Manley 2004; Orstavik and Dainty 2015; Ozorhon et al. 2010; Ozorhon and Oral 2017). Nevertheless, a high level of innovation performance is extremely important for the industry's growth and the development of a country economy. According to Seaden and Manseau (2001), the innovation process is complex involving governmental and other institutional actors that interact by jointly and individually contributing to the development and diffusion of innovations. From this perspective, the innovation performance of the industry depends not only on how individual firms perform in isolation but on how they interact with other actors. Hence, the current study is founded on the innovation system approach (Lundvall 1992; Malerba 2002; Nelson 1993; Uriona Maldonado and Grobbelaar 2018) which stresses that understanding the relationships among the actors involved in the innovation process is the key to the improvement of innovation performance of an industry. Moreover, a systems modelling approach is applied for capturing dynamics within the construction innovation system.

A robustly developed system dynamics (SD) model assists in understanding how government policies and supportive programmes can encourage industrialists to innovate, promote research and transfer technology, which will ultimately improve industry productivity and competitiveness.

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The overarching goal of this paper is to understand the mechanisms of innovation development in the context of four plausible scenarios of the Russian Federation construction industry. The built SD model integrates the concept of a construction innovation system with the notion of macroindustry transition pathways (Geels et al. 2016; Kubiszewski et al. 2017; Li et al. 2015; Moallemi et al. 2017). The transition scenarios were developed considering the variation of key driving factors: (1) the conditions and level of government financial support; and (2) demand for innovation related to market expectations largely dictated by procurement processes.

2 Background

The Russian construction sector has been facing various challenges which hinder innovation processes. The industry's unwillingness to implement innovative technological advancements is primarily caused by a lack of innovative capabilities as a precondition for application of new building materials, structures, design methods and construction methods (Suprun and Stewart 2015). In the majority of cases, there are inadequate financial resources for contractors to support their innovative activities. In addition to weak investment activity, there are excessive administrative barriers, inappropriate technical regulation and variance of construction norms and codes to international standards. Another top challenge in innovation integration is procurement methods based on price competition that lead to declining productivity and quality of construction works. It makes innovative companies hard to compete due to innovative solutions expansiveness at the initiation stage. Moreover, the 'cost over quality' purchasing practise may be a reason for the growth of corruption in the sector. The problem of significant underinvestment in R&D also holds true for the Russian construction innovation system. The conducted study (Suprun and Stewart 2015) indicates weak interest in R&D on the side of the industry. Despite the promising scientific and research potential of research institutions and universities, the transfer of innovative laboratory ideas to the practical environment is only possible with the industry readiness to implement the results of R&D. Sufficient government incentive mechanisms would invoke firms to make long-term innovation investments and move away from only short-term profit considerations.

As mentioned above, the developed SD model integrates the concept of a construction innovation system with the notion of transition scenarios, i.e. a set of plausible 'futures' that ultimately incorporate different policies along with the industry views in a simplified way. The following scenarios emerge by crossing two influential and uncertain driving forces to illustrate represent four futures:

- 'Business as usual' (BAU) scenario. In this scenario, industry development and growth occur at a rate similar to today's. Namely, incremental performance improvements and innovation processes are hindered by tight financial situation, limited incentive schemes, outdated legislation, excessive administrative barriers and inappropriate technical regulation; financing for necessary R&D is restricted and scientific and human potential is scarce. The culture of 'lowest bid' takes place that forces contractors to focus on initial cost, but not on the life cycle costs and the value of design, on order to win a tender (Suprun and Stewart 2015).
- 'Market forces' (MF) scenario. In this scenario, innovativeness is mostly market-led and competition-driven under tight financial conditions. As the main client, the government can significantly motivate decision-makers at construction firms to consider higher investment in innovation with driving demand for path-breaking processes and products (e.g. through procurement and tender policies). By following the multi-criteria tender evaluation procedure, construction companies are required to meet a range of criteria, such as overall projects' whole-life value, safety and quality, to name a few. However, financing for incentive schemes and science is restricted.
- 'Conservative development' (CD) scenario. Government is in control of the industry development in this scenario. The high rate of public investments, emphasis on incentive mechanisms and improvement of regulations, standards and legislation stimulate innovation diffusion. Nevertheless, the industry is still cost-competitive. Only well-established leading organisations can support R&D. Thus, despite government's efforts to enhance innovativeness through additional investments, firms prefer to stay conservative and choose an imitative strategy which is far less costly and labour intensive.
- 'Innovation power' (IP) scenario. In this scenario, the government drives and supports change by enforcing sustainable regulations and heavily investing in innovative infrastructure. At the same time, alternative procurement and tendering processes that aim to promote performance-based integrated delivery, induce companies to generate radical changes in creating know-how ideas; to invest a lot in R&D; to develop a variety of solutions in order to keep up with high demand for innovative products and processes. Overall, a strong will of both government and industry is necessary to ensure a successful transition.

3 Research Methodology

This research employed an integrated participatory systems modelling (IPSM) approach that is detailed in Suprun et al. (2018). This paper focuses on the scenario analysis derived from a comprehensively developed SD model that captures the complexity of the interactions between government, academia and industry within the construction innovation system. In general, SD modelling is a methodology that represents a set of conceptual and numerical methods that are used to examine and analyse the structure of a complex system and behavioural relationships between certain variables over time (Sterman 2000).

Active stakeholder engagement facilitated the formulation of the SD model. The study participants included researchers and academics specialising in construction management; civil and structural engineers; designers, project managers and directors of construction companies; and public servants with roles related to the construction industry and innovation development. Stakeholder consultations also resulted in the formulation of four future industry transition scenarios for this study, with each one attempting to encapsulate its relevant innovation conditions (e.g. government policy and incentives) and causal outcomes (e.g. innovation and R&D intensity). The simulation outcomes explore the system's behaviour in the context of different plausible futures on the horizon in 2045 to shed light on the transformation of the Russian construction sector based on different sets of assumptions.

Considering the specifics of this research, lack of empirical data, highly qualitative nature of the modelled system and participatory nature of the implemented modelling approach, the following steps were implemented to evaluate the model: (1) engaging stakeholders throughout the modelling process via stakeholder workshops and expert consultations in order to achieve an agreed final model; (2) examining model parameters to check whether they had real-world equivalents, and if not whether they were acceptable and acknowledged in theory; (3) performing sensitivity analysis to calibrate key input parameters and determine the importance of certain assumptions in order to generate a range of possible outcomes; (4) testing if the model confirmed the system boundary and the model behaviour was consistent with the real world; and (5) testing if the model behaved realistically under extreme conditions.

4 Results and Discussion

4.1 System Dynamics Model

The model is focused on the investigation of technological innovations (e.g. energy-efficient, soundproofing materials, BIM, off-site fabrication). According to the study previously conducted by the authors (Suprun and Stewart 2015), the proportion of construction companies implementing technological innovations is less than 3% of the total market size compared to other sectors of Russia's economy such as energy (22%) and biomedical (29%) industries. The duration of the analysis is from 2015 to 2045. In 2015 the Russian government set national targets to facilitate innovative development of the industry by designing an "Innovative development strategy for the construction industry in Russia for the period up to 2030" (2015). Undoubtedly, a number of systematically targeted strategies and rational policies are required in order to achieve the set of government goals and shape the successful transition of the construction sector in the innovative future. Hence, it was chosen to set the model time bound at 30 years to explicitly capture the long-term impact of various government policies on construction innovation performance.

The model distinguishes between two types of innovative companies: imitators and innovators (Orstavik and Dainty 2015; Yusof et al. 2017). Imitators represent construction firms that introduce and implement technological innovations by adopting ideas from others and slightly improving construction materials, techniques, technologically advanced production methods, products and services. Such firms mainly implement innovations known as incremental.

Innovators represent companies that implement technological innovations as a result of collaborative R&D. Such companies are constantly involved in R&D and implement newly introduced construction materials, techniques, goods and services. Considered as radical, these innovations are new or significantly different from those inherent in earlier products in the case of field of application, performance characteristics, features and design performance. The SD model (Fig. 1) was developed in Vensim software (Vensim et al. 2019). Blue arrows labelled '+' point out causal influences that cause changes to an influenced variable in the same direction, whilst red '-' labels dictate changes in the opposite direction. The double lines across the arrows are a delay symbol which indicates that an effect would take longer to appear. It is noted that the representation of the stock and flow diagram is simplified in this paper, and only the main variables and parameters are presented.

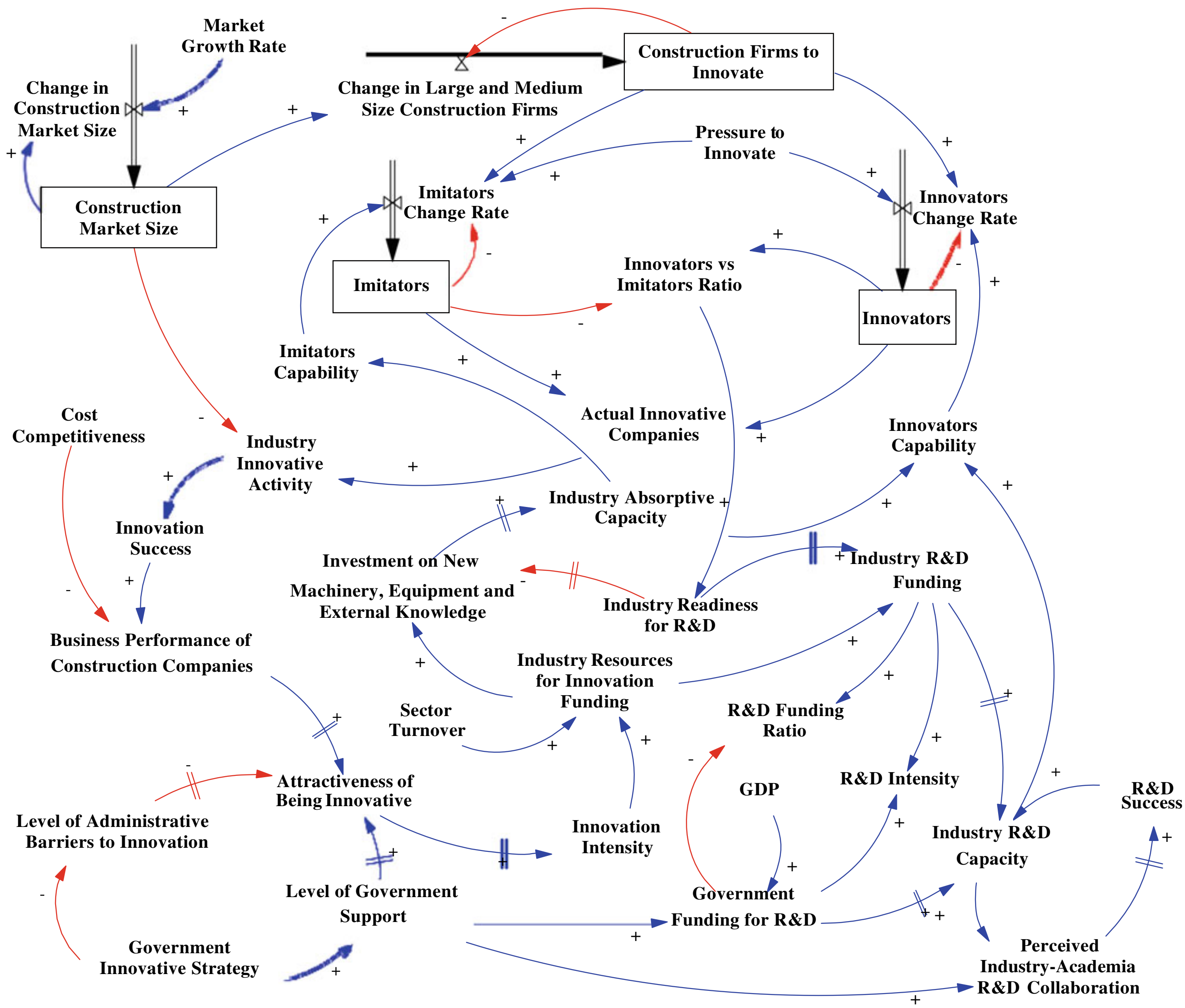

Fig. 1 Overview of the stock and flow diagram

4.2 Scenario Analysis

Four scenarios were considered for the simulations to reveal insights about the construction innovation performance along with future transition pathways. The base case scenario represents business as usual (BAU) conditions, i.e. the continuation of current trends in the Russian construction sector. The base run was calibrated through sensitivity analyses and qualitative analysis in collaboration with stakeholders to reach relevant numbers and generate behaviours consistent with reality. Outcomes arising from simulations of the other three alternative scenarios are compared to the baseline scenario in which no policy interventions applied. We estimated the implications of the aforementioned scenarios and policy assumptions for a 30-year time period, from 2015 to 2045. The impacts in changes of key parameters on the dynamic behaviour of the outcome variables were studied in every simulation run.

Figure 2 illustrates the future growth trend for a number of innovative firms accompanied by the distribution between innovators and imitators across four scenarios until 2045. Fractions indicate the ratio between innovators and imitators, measured as a proportion of innovators in the total amount of innovative construction companies which include both innovators and imitators. Figure 3 shows the level of industry innovative activity as a proportion of companies that implement technological innovations.

The industry grows steadily but very slowly under the BAU scenario, with no visible improvement in its innovative performance over time. In contrast, innovative activity shows faster dynamics under MF and CD scenarios. Yet, this happens after almost a decade of the simulation horizon. It

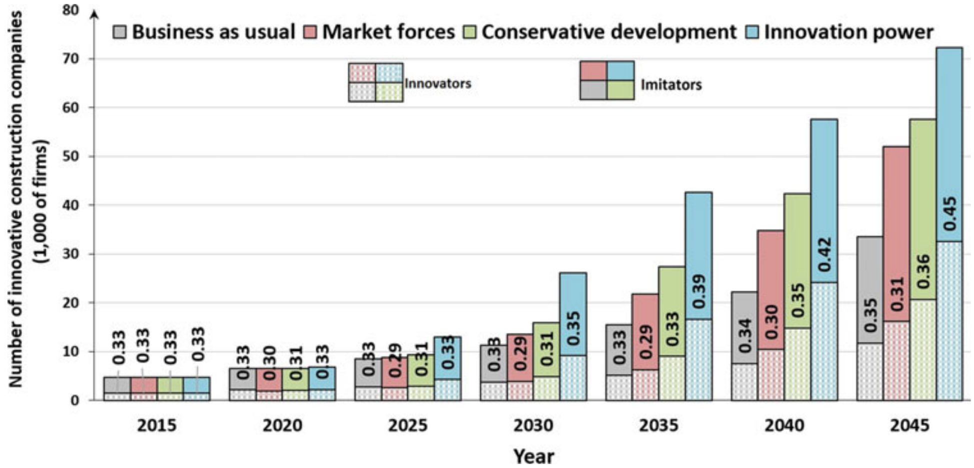

Fig. 2 Scenario results for cumulative innovative construction companies

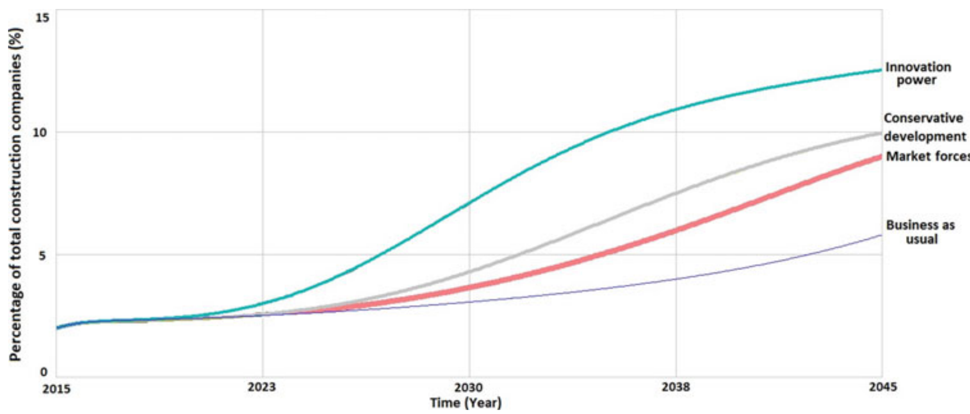

Fig. 3 Scenario results for the percentage of companies that implement technological innovations

explains the necessity to accumulate enough capabilities to not only be involved in innovative projects successfully but also to encourage industrialists to consider investments in innovations in the long run.

Finally, under the IP scenario, the sector grows rapidly up until 2040 and then slows down by reaching its steady-state level of 12.5% by 2045, which is twice as high as in the BAU simulation (5.8%). It corroborates the main assumption of the scenario, i.e. priority in promoting R&D, investing more in cutting-edge ideas and eventually transforming the sector into a high-tech sector that is capable of supporting science and research. Even though the fraction of innovators almost equals the fraction of imitators in this scenario (0.45 and 0.55, respectively), it is apparent from the figures, in the simulated state of the construction sector in 2045, the industry will remain imitation-oriented under any circumstance. Moreover, under a market-driven scenario, companies give priority to maintaining the competitive advantage by trying to improve their absorptive capacity, i.e. investing primarily in new equipment and providing training to their personnel, but not collaborating with universities and research centres to develop new solutions. Thus, only 31% (approximately 16,000 firms) of innovative companies are innovators, which is even lower than those in the reference case. In other words, the mechanism of learning-by-using supersedes learning-by-searching, i.e. innovations are well diffused within the industry but developed to a very limited extent. It is consistent with the fact that the Russian economy is unprepared for the market-led regime to be able to compete worldwide (RSCI 2017; TASS 2019). Therefore, this finding can be interpreted as the necessity to consider significant government support of the industry and academia in order to improve domestic R&D and science, in addition to policies targeting the growth of the construction industry itself. However, as can be seen in Fig. 2 and 3, providing financial incentives to boost innovative processes under the CD scenario is still not going to lead to the same results as when successful incentive schemes are accompanied by quality competitiveness driving the market.

5 Conclusions

Effective strategies are required to overcome the challenges of transforming Russia's construction industry into one which is progressive and innovative. Nevertheless, innovation is only likely to occur if there is sufficient support for increased collaboration within the innovation system and research into new materials and technologies. In this paper, an SD model was developed as part of the IPSM approach to provide understanding of how construction innovation would evolve in the context of four plausible transition pathway scenarios of the Russian construction industry. Specifically, the research sought to explicitly capture the impact of various government policies, provide a deeper understanding of how construction companies would behave in the context of different plausible 'futures', and enable decision-makers to design rational policies to improve the chances of better futures actually occurring.

Various stakeholders with diverse backgrounds were involved in the SD model development, calibration and testing processes. The complex multi-actor nature of the system under investigation justified the IPSM approach for modelling the innovation processes and studying the dynamic behaviour of the key parameters under different scenarios. The scenario analysis was performed with the notion of transition pathways to evaluate the possible futures of the Russian construction industry with regard to innovation development and diffusion.

One key finding was that the Russian construction industry preferences imitation-oriented innovation development. The innovation power transition pathway does produce more truly innovative companies than the other scenarios, but even in this scenario, it takes time to develop a sufficient proportion of them. Overall, simulation results under alternative scenario settings revealed that industry transformation requires sustained and coordinated innovation diffusion strategies that engage all innovation stakeholders. The versatility of the SD model allows for refinements to be made and new modules to be included in order to investigate the aforementioned research topics.

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Urban Planning in the Context of Seatropolis City Through the Public–Private Partnership Scheme

Mohammed Ali Berawi, Van Basten, Timothy Edwin Muljono, and Gunawan Gunawan

Abstract

The rapid demand for goods shipping and increasing role of sea transportation services make countries that have sea territory developed sea transportation infrastructure. They do not only develop for transportation, exploitation of marine products, and tourism but also make seafront areas as the potential development of the new city of Seatropolis. This research used the qualitative and quantitative method through literature studies to identify parameters as a minimum requirement for the development of marine areas that can support the development of advanced new cities. After that, through a case study on the country of Indonesia which is a maritime country with the largest area of the sea obtaining the size of the initial investment cost of a city with the concept of Seatropolis. In the final stage of this research was in-depth interviews for validating the results of data analysis results. The results of the case study identify potentials in developing eco-town in the coastal area such as commercial area, residential, power plant, and industries through sustainable development concept. The total initial cost to develop Seatropolis cities was US$ 1,974,070,053.85. This research observation divided the operational costs into three phases of construction development. Each phase of 2023, 2025, 2027 consisted of US$ 18,888,781.62, US$ 33,872,403.81, and US$ 51,974,650.82. The government should include in the financing scheme for the initial cost of 59.38% and invest in operation and maintenance around 31.74% with obtained revenue of 33.96%. This scheme generates optimum IRR of about 15.41%.

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Keywords

Port-City • Public–Private partnerships • Urban development • Life cycle cost

1 Introduction

One of the major drivers that will lead to the increasing need for sea transportation is the Asean Economic Community (AEC). With the agreement between the countries in Southeast Asia, the elimination of tariffs and trade restrictions will be carried out in the Southeast Asian region. This will cause (1) the increase in the number of goods entering and leaving in Asean Country and (2) the availability of low-paying workers and highly skilled workers (Sriyanto 2018). With the increasing movement of people and goods, some of the developing countries will respond to effectively utilize this potential.

The concept of coastal city planning is important, given the dependency relationship between ports and cities in coastal areas. Studies show that effective planning and implementation of policies will have a positive impact on cities and ports, where ports will enjoy increased volume while cities will enjoy economic growth (Merk 2014). Successful coastal cities can be formed with the existence of three main factors, namely (1) competitive ports, (2) ports become the economic drivers of the city, and (3) by mitigating the negative impacts of ports. Competitive ports will improve their status to reach part of the global supply chain. By achieving these three critical factors, the coastal city will achieve sustainable growth. In order to achieve these three factors, then in urban planning can be implemented from three main economic policy models for coastal cities: maritime clusters, industrial development, and urban waterfronts.

The maritime cluster is an area that has a role as a supporting port, where this cluster can provide great added

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value to the city and the area around the port. Maritime clusters are very sensitive to local needs, in terms of compiling these clusters, consideration must be given to local needs. Industrial development in the area around the port will also lead to increased economic relations. Finally, urban waterfront is the use of the area around the sea as an area with various functions to make the economy effective. For example, areas that can be developed include beaches, recreational areas, and restaurants that must first be approved by the stakeholders involved. As an island nation, Indonesia still places a low priority on its maritime capabilities. Based on the World Bank's Logistics Performance Index released in 2010, Indonesia has a lower value for port infrastructure than those in ASEAN countries and Australia, China, India, Japan, New Zealand, and Korea South. Indonesia is fifth ranking in ASEAN and fifty-third ranking in the world in terms of logistics performance.

Based on the above problems, the problem formulation in this study can be defined as (1) answering the modeling needs of the development of the Dumai city area as a Seatropolis, (2) determining the initial cost needed to achieve the realization of this concept, (3) determine operational and nursing costs, and (4) determine a sustainable payment scheme in achieving the realization of this concept.

2 Literature Review

2.1 Port-City

The concept of the port city itself has existed from the beginning of civilization. Many major cities began development from the port. With the existence of the port, the development of the city is driven by trade and economic activity which encourages rapid and modern development (Merk 2014). This can be seen from some of the world's largest cities, such as Shanghai and Osaka-Kobe which are large metropolitan areas and have ports which are among the largest ports in the world. Based on the types themselves, the port city can be classified based on shipping traffic in this port and the size of the city (Ducruet and Lee 2006).

The benefit of the port area is that the first port becomes a facilitator of trade, where regions with well-functioning ports will enjoy products at lower prices. For example, a study shows that an increase in maritime transportation costs of 10% will cause a decrease in product value by up to 8% (Radelet et al. 1998). The second advantage is adding value. The added value due to ports and industrial port activities has substantial value. For example, the added value of the Rotterdam port area per 2007 is EUR 12.8 billion, which contributes to 10% of regional Gross Domestic Product (GDP). In brief, there are four impacts of the existence of ports, namely direct, indirect, induction and direct impact of the port. The direct impact is the work and income earned due to the construction and operation of this port. Indirect impacts are work and the direct impact of suppliers of products and services. The induced impact is work and income derived from worker expenditure.

The impact of ports is income generated from ports as a driver of growth in productivity and attractiveness of new companies. The next positive impact is the creation of new jobs. The port area, along with the industry, requires local workers. The greater the existing port and the surrounding area, the greater the number of jobs produced. With the entry of the automation era, the port area did not absorb very high numbers of jobs. Aspects that can absorb higher numbers of employment are industries that are around the port and from the added value aspects that arise as a result of the port. With companies building infrastructure and observation points in the port area, this will lead to the creation of new jobs (Merk 2013).

2.2 Public–Private Partnership

Based on the International Monetary Fund (IMF), the definition of public–private partnership (PPP) is an agreement where the private sector provides a supply of assets. On the other hand, the government provides conventional services. Beyond this, there are two important characteristics of PPP, namely (1) there is an affirmation in the provision of services, and investment from the private sector; (2) the government transferred significant risks to the private sector. The characteristics of the infrastructure built affected the spectrum of PPP.

If infrastructure approaches pure private nature or can generate profits, like an airport and port, the model used is build–own–operate–transfer. As for infrastructure that is at the center of these two needs, for example, schools and universities, the model commonly used is design–build–finance–maintain contracts. For infrastructure that approaches pure public or does not generate profits, such as pedestrian bridges and roads, the model used is build-transfer-operate. Many countries began to use PPPs because the government was unable to build with traditional methods. In addition, accelerated development with the PPP scheme will also encourage the availability of funds from existing infrastructure (Arvis et al. 2012).

3 Methodology and System Development Framework

A four-phase methodology as shown in Fig. 1 was used to develop the proposed Seatropolis City Development. The methodology is based on both quantitative and qualitative

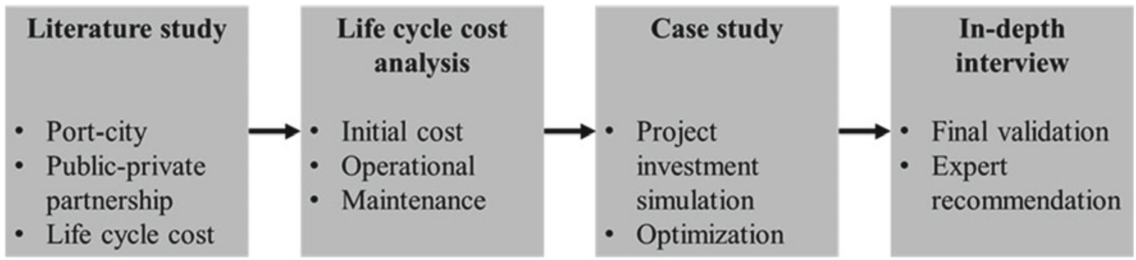

Fig. 1 Research framework

methods. Calculation of investment costs in the case study is part of quantitative and qualitative methods is a method for conducting final validation of calculation results through in-depth interviews with experts in infrastructure development in Indonesia (Basten et al. 2018). In the early stages of the research, review the literature to obtain variables that are a measure of the feasibility of developing a port city. In addition, researchers also conducted a search of the models of the public-private partnership scheme that existed before. There are two main variables in this study, namely urban planning and forms of PPP funding collaboration. Whereas the dependent variable which is the result of financing simulation is the funding provider scheme and the value of Internal Rate of Return (IRR), while the variable can change the simulation conditions or moderate variable, Weighted Average Cost of Capital (WACC).

The area for this case study is limited to Dumai City, Riau Province, Indonesia. The calculations carried out are the initial investment, operational and maintenance costs for the development of the Dumai City area. The payment scheme that is the scope of this study is the Public-Private Partnership scheme (PPPs). Dumai City's Medium Term Development Plan (RPJMD) used is the period 2016–2021. The Indonesian Maritime Policy used in this study follows Presidential Regulation Number 16 of 2017. The PPPs considered in this study follows the Public–Private Partnerships Book 2017 by the Ministry of National Development Planning (Bappenas). The inflation rate used is the average inflation rate of 2009–2016, which is 5.12%. Calculation of average economic growth will follow in 2010–2017. This study does not consider the regional regulations that apply to the Dumai city area which is related to the PPP scheme due to the absence of policies related to this matter.

Based on the research strategy, data validation will be carried out in this study to ensure that the research that has been carried out is a valid result in the expert's view. Experts are chosen based on their abilities in their fields and their relevance to the research being carried out. In this study, researchers will validate data to experts from PT. Sarana Multi Infrastruktur with interview method. In this case, the method used is a manual interview to synchronize the model proposed in this study with the views of experts regarding the theoretical possibilities and possible realization of this model in the long run. In considering an investment, a balanced comparison is needed to ensure that there are no incorrect estimates. In this study, all values that will appear in the future will be compared with the current value, namely by using the Net Present Value method (Latief et al. 2017). The present value can be simply defined as the value that must be invested at this time to obtain the value expected in the next period (Sandker et al. 2010).

4 Results

From the design of the area that has been carried out, it is necessary to review the existing area for other port cities in the world. In previous studies, it can be seen that the division of components does not have certain patterns or rules, but follows the needs of the existing region. For example, in the HafenCity, the public space and residential areas and offices have the widest contribution area. This is due to the location of the HafenCity which is in the developed urban center area. In Dumai Seatropolis, this development has also been carried out with consideration of the city to be built. In the case of Dumai city, this can be illustrated in Fig. 2.

From the illustration above, it can be seen that the port will not take up extensive land, with open green space and public space as the dominant area, especially with the use of the eco-town concept in this study. This results in an area with wide public space. This makes the Dumai Seatropolis region in accordance with other regions where public space has high importance. With the existence of a wide public space, the negative impacts that generally arise as a result of the port will be negated. This has been applied to the Dumai city area. From the zoning design, it can be seen that the existing Dumai Seatropolis area will be close to the existing Dumai city area, so this area will act as a supporting area for the existing area.

The overall value of this new area is the US $ 866,964,296.30. In its construction, this area will be estimated to be built in 5 years, with a start time that coincides with the port area. In this development period, inflation will occur in the value of development, with an increase that

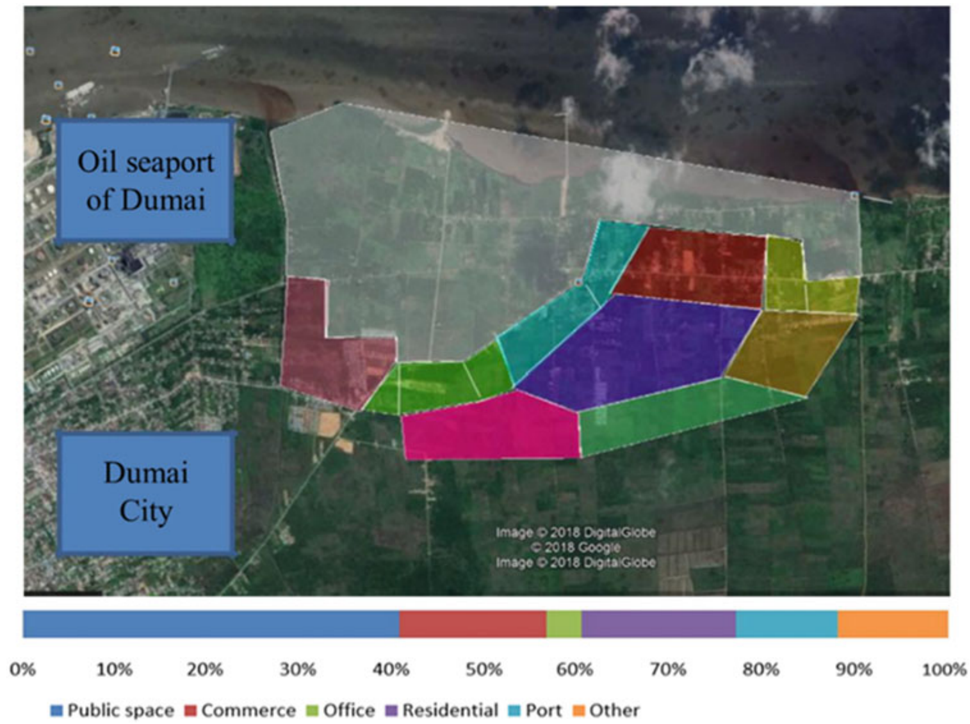

Fig. 2 District of territory in the case study of port cities design

follows inflation which has become a reference in this study. Then, for the operation and maintenance values in the Seatropolis area, it will follow the initial assumptions described earlier. The total operational and maintenance costs are the US $ 27,826,173.33 per year and will continue to increase following the reference inflation rate in this study, which is 5.12%.

Based on the design combination, the IRR value before the institutional scheme is 10.37%, this scheme is not attractive to the private sector. So, the financial scheme is needed to obtain an ideal PPP scheme to the design Dumai Seatropolis. After the redesign process in this research, an attractive design has the potential to obtain higher values if applied to PPP schemes. One area that boosts the IRR value is industrial estates, especially in oil palm areas with relatively large incomes. With the capacity of the city of Dumai as a palm oil-producing region, this has encouraged the palm oil industry to continue to grow and generate large revenues and contributions to the region. Preparing institutional schemes is necessary to first compare with the standards held by Bappenas as an institution that gives approval and status for PPP projects in Indonesia. Furthermore, arrangements will be made to approach the standard ready-to-offer or scheme that is ready to be offered to the private sector.

The first thing to do is to analyze the scenarios that can be done in this study. Conducting financial analysis is necessary to consider the IRR value that would be considered appropriate or attractive for the private sector in entering the PPP scheme in Dumai Seatropolis. The Weighted Average Cost of Capital (WACC) is used considering equity, debt, and the debt ratio of a company (Berawi et al. 2014). The WACC value of the industrial, chemical, real estate, and health sectors, respectively, is 10.51, 11.51, 11.10, and 10.31%. The results of simulations and validations conducted at IIGF show that the private sector will bear 40.62% initial costs, while the government will 59.38%. In the operation and maintenance of infrastructure, the private sector is responsible for 68.26% and the government is 31.74%. The acceptance of the management of Seatropolis will be accepted by the private sector amounting to 66.04%, while that of the government is 33.96%. The simulation shows the IRR value in the P3 scheme which is 15.41%.

5 Discussion

PT Dumai Seatropolis is a Regional Owned Enterprise that acts as the coordinator of Seatropolis development from this region. The government will build the area in accordance with the institutional scheme and the distribution of predetermined components. In this region, PLN (national electricity company) is a state-owned company that responds to energy management. In the port area, PT. Pelindo is the representative of government in port management. In plantation areas, the institutional scheme states that the government will have 30% of the total value of the oil palm industry. In this case, the government and the private sector will not build the similar factory, but the government will build a smaller capacity plant through PTPN (National Plantation Company) as a government entity that has rights and responsibilities for government-owned oil palm plantations.

Indonesia Infrastructure Guarantee Fund (IIGF) is a State-Owned Enterprise that acts as a bank that can provide loans to infrastructure. In this area, IIGF will be primarily a supporter of the government to meet debt needs in infrastructure development. In addition, IIGF can also provide loans to the private sector on infrastructure-related developments. Finally, Bank lenders are banks that will provide loans to the private sector in developing areas around the port and in industrial estates. In the operational phase, the institution that builds the existing area will also act as an operator and has a fee for operating, selling, and leasing from this region. The researchers conducted in-depth interviews with relevant parties to determine how to improve existing conditions and encourage PPP schemes compiled in this study to become more attractive to the private sector and the government with good validity. The following analysis results are obtained that the first involvement of IIGF in the PPP scheme will have an impact felt significantly in the PPP scheme carried out on a regional scale, with BUMD as the coordinator of this scheme. In projects carried out on a national scale or by national governments, IIGF guarantees will not give a significant impact. The second, IIGF will generally be a complement of banks, increasing bankability, or the willingness of banks to provide loans, especially to the private sector. The third, the tenants or private parties with large-scale business entities in industrial areas, will increase the interest of other potential investors to be involved in this PPP scheme. The last, industrial, ports, and their supporting area development should be carried out simultaneously. By the completion of these three facilities together, the private sector will get the benefit from the proximity to the port, besides that the port will get benefit from the operation of the port in the region.

6 Conclusions

Urban waterfront design that has been carried out in accordance with the ecotown design, achieves optimal design to ensure that existing designs meet the literature standards. The concept of Seatropolis in this study fulfills eco-town standards where the concept of a solid city with high comfort and an environmentally friendly city. This eco-friendly concept design is implemented through the use of wind power plants in this region. In addition, this area will have occupancy for people from various classes. This design shows a strong relationship between the city and the port, eliminating the negative impact on the surrounding area, and providing mutually supportive relations between the city and the port area. In this study, the ARCADIS Construction Cost Handbook 2018 standard was used, which is a standard reference obtained from the costs of development carried out in the Greater Jakarta area and major cities in Indonesia. In this study, the Construction Expansion Index (IKK) was used for the Dumai city area, so that the construction standards per m^2 were obtained for existing buildings.

The amount of operational and maintenance costs and income from Dumai Seatropolis. This will be done by a different method. In determining the number of operational costs in existing buildings and facilities, the researcher will use the standard from the Ministry of Public Works. This will result in operational and maintenance costs in the form of a percentage of the initial cost. From the determined values, simulation is carried out through the application, taking into account the increase in costs, both due to inflation and the appreciation of property values that occur in Indonesia as a reference. In addition, consideration is also given to the occupancy rate of property that refers to national data. By doing this, it will not be assumed that the existing property will be occupied by 100% so that an accurate income can be obtained from this region.

The Weighted Average Cost of Capital (WACC) simulation scenario is a moderate variable. From the IC, OM, and R components that have been simulated, the initial IRR value will be obtained which has a value below the WACC. From this value, the financial model is engineered, before the most favorable scheme is chosen, where the value of IC, OM, and R between the government and the private sector will be divided. From the research carried out, an institutional scheme was produced with the division of IC, OM, and R with an IRR value of 15.41% which is a higher IRR value than the WACC in Indonesia in other schemes. This is evidenced by the achievement of this IRR value with a different scheme than in general, whereas the division of IC, OM, and R, the IRR value achieved still exceeds the WACC value commonly used in Indonesia.

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Exploring the Working Conditions of People in Construction

Fidelis Emuze and Lesiba Mollo

Abstract

The working condition concept is an essential topic in the construction industry where management must provide a workplace that is free from hazards and risks that might cause accidents. Site management, in particular, must maintain working conditions that are safe and healthy for the workforce. This is, however, not the case in reality as injuries and fatalities are often linked to working condition factors in construction. This paper thus reports on the factors causing poor working conditions on construction sites in the central region of South Africa. This study adopted an ethnographic research approach to conduct 12 semi-structured interviews. From the findings, it was discovered that most of the construction workers are exposed to the dangerous working environment, which may harm their health, safety and well-being (HSW). The paper further highlights the lack of proper housekeeping as an area of serious concern in this context. The influence of lack of housekeeping frequently contributes to injuries and accidents in the construction sites. Therefore, a measure to improve housekeeping and other working condition factors should be deployed on-site with management tools such as the 5S (Sort, Set, Shine, Standardize and Sustain).

Keywords

Construction • Housekeeping • Working conditions • South Africa

1 Introduction

Safety is an essential element for improving the well-being of people in construction. Over the past decades, safety has become a persistent problem for people in construction (Golizadeh 2018). For example, management pursuit of labour productivity improvement at the expense of other performance parameters often increases the complexity of the working conditions. The working conditions on construction site are mainly influenced by site safety factors such as management commitment, safety rules and procedures, housekeeping, safety equipment and supervisors and co-worker's safety perceptions (Chen 2018). Failure by management to control and monitor the site working environment could result in situations where hazards are activated to become a risk with potentials to injure or kill people. Since people in construction should respect and obey the safety regulations and create friendly working conditions that will eliminate or reduce injuries or accidents in the workplace, safe work is critical in the construction industry due to the occupational accidents that could be traced to either the working conditions or the behavioural characteristics of workers (Mohammadi 2018).

In addition, the outcomes of occupational accidents affect the health, safety and well-being (HSW) of the workers negatively, just as productivity, profitability and organizational image also suffer (Van Heerdan et al. 2018). According to van Heerdan et al. (2018), due to the high number of accident reports in the industries, most countries worldwide has compelled the construction professionals to comply with the safety regulations to improve safety regulations. For example, the Department of Labour of South Africa enforces the health and safety regulations on sites to create a conducive working environment (Department of Labour 2014).

According to Guo (2015), researchers and practitioners continue to investigate how to improve safety performance in the construction industry because of pervasive problems

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such as poor working conditions. The question that is reported in this paper is grounded on the basis that the working conditions on the construction sites often cause risks and hazards that might cause injury or accidents to people in construction. To solve this reported problem of working conditions, the authors empirically addressed poor working condition causation factors on construction sites because it is reported that to solve problems under investigations, one needs to understand the root causes of the difficulties (Stilesa 2018).

2 Literature Review

The construction industry is regarded as a labour-intensive industry that is dominated by general workers (Ghodrati 2018). The general workers are exposed to high risks factors because of the nature of the construction works. As highlighted in the previous section, the construction industry is known as one of the most dangerous sectors due to the high number of accidents which are experienced worldwide (Van Heerdan et al. 2018). More so, the outcomes of the construction safety had reflected negatively on the state of the well-being of a given society, since occupational accidents would incur various losses to the injured workers and their families, employers and society (Mohammadi 2018). This statement is corroborated by Bowen and Govender (2017) in the South African context where they argued that the lack of safety compliance has negatively influenced the well-being of the workers in the construction industry.

According to Ghodrati (2018), management commitment to improving productivity on sites affects the HSW targets of construction projects. Hence, it is argued that safety management in the construction industry is a form of institutional work and that safety activity is as much as a ritual, routine and dramatic performance as it is goal-directed (Rae and Provan 2019). Therefore, most researchers have investigated the causes of poor safety performance. Mohammadi (2018) discovered the six top safety factors influencing performance negatively on Indian construction sites. The six safety factors include maintaining safe working conditions, establishing safety training, educating workers and ensuring that supervisors have good safety habits, effective control of the subcontractors' contractor by the main contractors, maintaining close supervision of the workers and assignment of responsibility for all levels of management and workers.

The above-mentioned factors imply that a proper HSW planning is essential for the construction professionals to enforce regulations that workers must obey on sites (Rahim 2014) because the HSW-related problems such as stress, diseases, injuries and fatalities target for eradication in the construction industry (Hall and Coward 2010). The unsafe working conditions are described as hazardous physical conditions or circumstances that have the potential to cause injury or death to an individual's (Hamid 2008). As indicated, the working conditions are one of the most concerned issues in construction, and it is caused by a lack of housekeeping, among other factors. This is because most of the workers in the construction industry neglect or ignores housekeeping practice (Lumens and Spee 2001). Effective housekeeping on sites is a very critical aspect of workplace safety, and it helps to prevent or reduces workplace hazards (Siu 2003). Poor housekeeping practice creates unsafe conditions, which cause accidents in the workplace (Hamid 2008).

3 Research Methodology

To answer the research question, 'what are the factors contributing to poor working conditions in construction?' The authors used an ethnographic research approach on construction sites (Schensul 2013). Ethnographic research is defined as a systematic approach designed to investigate the social and cultural life of communities, institution or a specific group of people (Schensul 2013). The adoption of an ethnographic research approach helped the research to collect qualitative data by interacting and sharing knowledge with the interviewees about their working conditions as illustrated by Fife (Fife 2005). The participants in the study are construction professionals working on construction sites in Bloemfontein, South Africa. The data were collected between August and September 2018. The qualitative data were collected through semi-structured interviews conducted with 12 construction professionals (Table 1). The interviewees were visited on their construction sites and were approached to do this exploratory study about working conditions. An open-ended question was designed and used as a guideline to help the researcher to structure face-to-face interviews. The researchers ensured that the interviewees covered all relevant topic areas during the interview sessions. The benefit of the qualitative approach is that the interviewees could express their opinions and lived experiences on the issues around working conditions. After that, the data were analysed thematically. The purpose of the thematic analysis is to help the researcher to summarize the key features of an extensive data set to produce a clear and organized final report of the collected data (Nowell 2017).

4 Results and Discussions

It is discovered that construction workers are exposed to poor working conditions that might influence their HSW negatively on various visited construction sites. Therefore, it can be concluded that indeed HSW is very critical in the

Table 1 Profile of interviewees

Code	Interviewees	Number	Percentage (%)
1	Site agent	1	8.0
2	Site engineer	1	8.0
3	Site foreman's	3	25.0
4	Student supervisors	2	17.0
5	Artisans (bricklayers)	5	42.0
	Total	**12**	**100.0**

construction industry due to working conditions that could harm people (Mohammadi 2018). It is also reported by some interviewees (1, 2 and 4) that the general workers are the one who is exposed to high level of noise created by machines or plants in operations. They are also exposed to the dust generated by moving vehicles and the wind. This negatively affects the HSW of the workers, and they are infected, in certain circumstances, with diseases such as tuberculosis (TB). More so, some interviewees (5) comment on the well-being of the workers on construction sites by saying:

> The construction industry must ask questions such as why are the construction workers, especially the labourer and artisans being the victims of poor health conditions than professional engineers and managers who are working on the site.
>
> This is because most of the time the professional engineers and management are spending most of the time in their site offices and are not exposed to hazards which might put their health in danger.

Therefore, it can be argued that the construction organizations must protect the workers and promote a safe working environment for the workers. Some interviewees report that most of the construction organizations are excelling in improving the HSW of the workers. This is because most of the construction organizations have adopted a safety standard to provide full personal protective equipment (PPE) to the workers working on sites. Also, site visitors are compelled to undergo a site induction before they can be permitted to enter the site work.

Regarding housekeeping, Interviewee 1 had a similar response to one of the interviewees three where they argued that housekeeping is the responsibility of everyone working on sites, not only for the workers. They contend that if management does not promote good housekeeping, the worker will also not support good housekeeping. The effect of poor housekeeping can lead to slips, trips or fall in the walkway. This explains the statement of Sui (2003) that housekeeping in the construction industry is a very critical aspect of workplace safety and it helps to prevent or reduces the causes of accidents.

For the research to analyse housekeeping perceptions, the 12 interviewees were asked to indicate how they observe and practice housekeeping in construction. Table 2 shows the opinions of the participants on housekeeping. The participants were asked to answer with either a 'Yes' or 'No'. Table 2 indicates that only four interviewees agreed that they always practice housekeeping, then five of them responded that they often practice housekeeping, and while three of them disagreed that they do not practice housekeeping.

Some of the interviewees' comments on housekeeping include:

> Yes, my team always practice housekeeping. This is because our experience has taught us that poor housekeeping can cause injuries and accidents to our workers. So, good housekeeping helps out organizations to prevent hazards which might cause injury and accidents to our workers.
>
> Yes, my team often practice housekeeping. This is because after every three weeks we are audited by the safety managers. Good housekeeping put our books in good standing and our organizations will not be penalized for poor housekeeping by the safety manager.
>
> No, my team do not always practice housekeeping. This is because housekeeping practice makes my team lose production target and we as a subcontractor are getting paid based on the work we deliver to the main contractor.

From the findings, it was discovered that it is difficult to eliminate all injuries and accidents on construction sites without paying attention to housekeeping matters. As it is highlighted by Bowen and Govender (2017), South African construction constitute a high-risk working environment. Several interviewees stated that it is difficult to eliminate

Table 2 Perceptions of the participants on housekeeping in construction sites

The perceptions of housekeeping	Yes	No
My team always practice housekeeping	4	–
My team often practice housekeeping depending on how busy the team is working on their activities	5	–
My team do not still practice housekeeping	–	3

accidents on construction sites due to natural factors which cannot be controlled by a human being. For example, it is difficult for people in construction to monitor the effects of natural weather (heavy rain, winds and hot suns) that could produce a poor working environment. More so, an interviewees 2 and 4 argued that during the summer period, workers are exposed to work in extremely hot weather. Because of the warm weather, workers are forced to drink lots of water, which makes them not as productive as expected. Such a situation leads to the decision to take shortcuts to meet production targets. This illustration by the interviewees suggests that injuries and accidents should be blamed on the unsafe acts created by the workers. For instance, management may enforce regulations consistently on a site, yet one would still find workers who are ignorant of the HSW regulations because of their actions and decisions when working on the site. Therefore, it can be concluded that people in construction must understand that safety work is institutional work that serves a purpose beyond achieving operational safety (Rae and Provan 2019).

5 Conclusions

As highlighted in the introduction, the research addressed poor working conditions and the effect of the lack of proper housekeeping on construction sites. The face-to-face interviews used to elicit the perceptions of workers based on lived experiences suggest that most of the construction workers are exposed to work in a competitive working environment, which might cause harm to their HSW. For example, some of the interviewees argued that the general workers are the one who is exposed to high level of noise created by machines or plants and the dust generated by moving vehicles and the wind. This negatively affects the HSW of the workers, and they might be infected with diseases such as tuberculosis (TB) due to the dust they are breathing while working. It was also discovered that a lack of housekeeping is a problem that is causing an unfriendly working environment. Most of the workers in the construction industry ignore the importance of housekeeping practice. Effective housekeeping is essential since it helps to prevent or reduces workplace hazards. The 5S tool is recognized as effective in tackling the challenge. It is recommended that site management begin to implement the tool, which means Sort, Set, Shine, Standardize and Sustain. Therefore, it can be concluded that it is the responsibility of both management and the workers to improve the working conditions. This can be achieved by complying with the safety regulations designed to govern the construction sites.

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Construction and Demolition Waste Management on Construction Sites in Kazakhstan

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Abstract

The rapid development of the construction industry in Kazakhstan has led to the formation of construction and demolition (C&D) waste which significantly affects the environment. C&D waste contains hazardous materials in significant quantities which have an adverse effect on public health and the environment. It is essential to reduce C&D waste. This paper focuses on the determination of appropriate C&D waste management strategies. C&D waste minimization techniques such as reducing, reusing, recycling, bioremediation, composting, and incineration were identified and explored through the literature review. A questionnaire survey was conducted to investigate current C&D waste management practices on construction sites in Kazakhstan. The questionnaire survey was sent to 270 respondents in 11 companies in different cities of Kazakhstan. The response rate of the questionnaire was about 93%. It was found that recycling was the most appropriate method for waste minimization on construction sites in Kazakhstan. The information which came from the questionnaire survey helped to understand how to apply the recycling methodology on construction sites with benefits and drawbacks. Consequently, after identifying a proper waste minimization method, it is necessary to prepare an adequate site waste management plan.

Keywords

Waste management • Construction and demolition waste • Kazakhstan

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1 Introduction

Construction and Demolition (C&D) waste is represented as a "wide" term which includes waste coming from construction, demolition, excavation, road planning, and maintenance activities (Fatta et al. 2003). C&D waste is divided into inert and non-inert materials. The inert materials like concrete and subsoil have substances which hardly react under the chemical conditions, while non-inert materials can react with other substances when used or disposed. Some of the C&D waste are illegally disposed in natural drainages with water, which is detrimental for the environment and public health (Bolden et al. 2013). It is essential to determine a sustainable method for the management of C&D waste.

Waste optimization is the objective of waste management to minimize waste disposal from a construction site. This approach gives an opportunity to significantly reduce the cost of the project related to material and landfill resources (Steuteville 1994).

This study examines construction waste management methods to achieve waste optimization. The main approaches to dispose of construction waste are reducing, reusing, and recycling. Additional methodologies like composting, bioremediation, and incineration are also discussed. The key objectives of this paper are (1) to evaluate construction waste management methods and identify their benefits and drawbacks; and (2) to determine the most advantageous construction waste management method.

2 Literature Review

Construction and Demolition (C&D) waste arises from construction, renovation, and demolition activities (Kofoworola and Gheewala 2009). Generation of C&D waste is attributed throughout the lifecycle of the construction project and can be divided into several source categories like design, contracting, transportation, procurement, on-site management and planning,

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material handling, site operations, residual, and others (Osmani et al. 2008; Kulatunga et al. 2006; Gavilan and Bernold 1994). These categories and the reasons for waste generation are given in Table 1.

The strategies for C&D waste management are eliminating waste, reducing, reusing, recycling, bioremediation, composting, and incineration (Peng et al. 1997). Reducing construction waste is performed by continuously using materials. This methodology helps to significantly reduce any waste disposal in construction (Faniran and Caban 1998). Waste can be reduced by transporting resources in small capacities as this will reduce packaging wastes (Saez et al. 2013). Minimizing the waste is also applicable to minimizing wastes in the processes and the minimization of toxic wastes on-site.

Reusing the construction-based waste is to recover material to its initial form by using it again. The main purpose of the reusing methodology is the transportation of materials from one to another application in an eco-friendly way. It is a preferable method to achieve optimization of waste products on the site after the reduction. This methodology significantly reduces expenses for construction materials.

Table 1 C&D waste source and reasons for generating

Sources of the waste	Reasons for waste generation
Design	Alteration in design
	Complicated design details
	Design errors
	Improper specifications
	Specifying low-quality materials
	Lack of coordination and communication
	Lack of information about alternative products
Contractual	Mistakes in the contract documents
	Incomplete contract documents
Transportation	Losses during transportation
	Problems with access to transport to the construction site
	Inadequate protective tools during unloading
	Unsuitable methods of unloading
Procurement	Purchasing materials not meeting specifications
	Over-ordering materials
	Errors from the supplier
On-site management and planning	Absence of on-site waste management plan
	Inadequate planning of materials for needed quantity
	Lack of on-site monitoring and control
	Missing the deadlines of giving a report regarding product data
	Lack of supervision
Material handling	Transportation of materials from storage to the final destination
	Improper material handling
Material storage	Inadequate material storage place which causes the damage
	Unsuitable storage procedures
	Storage place is far away from the point of application
Site operation	Collection of materials which are not used
	Hardware malfunction
	Application of wrong materials
	Lack of time
	Poor quality of work
Residual	Remaining waste from the preparation of material
	Waste from cutting materials in an uneconomic way
	Packaging waste

Recycling is a prominent strategy in solid waste management that is more environmentally friendly and beneficial. It is known that the construction industry meets major difficulties while searching for a place to secure waste disposals. In fact, annual construction-related waste reaches approximately 20–30 kg/m^3 in the USA. These figures are more clearly presented when converting them to 500 kg/person per year (Peng et al. 1997). The disposal of C&D waste requires large landfill sites, which are increasingly becoming limited in supply nowadays. For recycling, it is necessary to determine materials which are recyclable and then to prepare a cost analysis for recycling procedure. After that, it is essential to develop a waste utilization plan for a construction site and add it in the contractual agreement (Bolden et al. 2013).

Composting is the decomposition of organic materials into small particles with the help of microorganisms like bacteria and fungi. In composting process, the debris is disposed in a landfill, the organic matter is reused and then, recycled for soil amendment. This kind of product enriches the soil structure (Lu 2013). The composting process accelerates the natural waste disintegration process.

Bioremediation has a similar approach like composting techniques. It also naturally degrades construction pollution with the help of small living organisms. This process helps to disintegrate wood-based construction debris in different ways. To prepare an appropriate substance for bioremediation, mixed shredded chipboard, medium density fiber, hardboard, and melamine serve as nutrient components of the process. The outcome of the process generally reveals good results by enhancing the quality of the ground (McMahon et al. 2009).

In the incineration process, the organic matter after achieving the required ignition temperature and reacting with oxygen starts to compost (Sabbas et al. 2003). The main purpose of the incineration is to treat C&D waste by diminishing its quantity and toxicity. In other words, incineration helps to eliminate hazardous materials in construction-related waste. Furthermore, this technology of waste optimization produces energy and recovers minerals that are secured in debris.

In view of this brief literature review, this paper helps to understand each waste management methodology and their specifications to assess the applicability of all these activities on the construction site.

3 Methodology

To achieve the target of the research objectives, a questionnaire survey was conducted among native companies in different parts of Kazakhstan. The majority of the companies were located in Astana. The questionnaire survey helped to identify the most applicable C&D waste management strategy on the construction sites in Kazakhstan. Eleven companies participated in the questionnaire survey. A five-degree Likert scale to questions in the survey was adopted. Five-degree Likert scale was aggregated by using the relative importance index (RII). It is calculated for each of the indicators and ranked accordingly. The RII is given by Eq. (1).

$$RII = \sum_{i=1}^{N} \frac{W_i \times X_i}{5 \times N} \tag{1}$$

where W_i = weighting as assigned on Likert's scale by each respondent in a range from 1 to 5, where 1 = very low to 5 = very high, i = index of response category i = 5, 4, 3, 2, and 1, X_i = frequency of the ith response, N = total number in the sample.

The relative importance index gives an opportunity to analyze information from the questionnaire survey. In addition, this questionnaire survey includes data about company profile and its waste management strategies.

4 Results and Analysis

The questionnaire survey was implemented among 270 respondents in which 251 provided the answer. The respondents of the questionnaire survey identified themselves as project managers (12%), civil engineers (18.7%), architects (10%), environmental engineers (16.7%), site engineers (20.3%), quantity surveyors (11.6%), and others (10%).

By the perspective of the respondents, the problems which affect waste management are given in Table 2 along with their RII score and RII rank. These problems are important factors of waste generation on site which gives an idea about how to reduce overproduction of the C&D waste.

According to these calculations, the highest possible value of RII is 5, whereas the lowest possible value is 1. In accordance with the ranks, it is found that the most important factors which lead to the formation of the debris on construction site are the over-ordering of material due to lack of coordination and management and the lack of coordination between design and construction teams. Both factors should be mitigated at the initial stage of the design. This can be implemented by the application of an appropriate waste management plan.

The waste management plan significantly reduces the quantity of the C&D waste stream. Referring to the questionnaire survey, the majority of the respondents choose that, a waste management plan is a helpful tool which reduces the

Table 2 Factors affecting the generation of waste

No.	Factors	RII	Rank
1	Lack of detailed information on design and specifications	3.41	6
2	Design changes and revisions	3.41	6
3	Lack of coordination between the design and construction team	3.96	1
4	Over-ordering of material due to lack of coordination and management	3.96	1
5	Lack of coordination of supply chain with design and construction team	2.81	13
6	Lack of awareness of on-site personnel on waste prevention	3.63	4
7	Poor workmanship	3.00	11
8	Lack of/poor quality control system	2.23	14
9	Lack of coordination among sub-contractors on site	3.06	10
10	Unskilled labor	1.82	15
11	Poor communication between contractor and sub-contractors	3.56	5
12	Lack of adequate storage	3.28	9
13	Poor skills and knowledge in the handling of the material	3.39	8
14	Lack of material inspection and quality control system for incoming material	2.97	12
15	Damages caused by improper transportation, handling, and storage	3.74	3

C&D waste. The next question in the survey was to evaluate the importance of the site waste management plan on construction waste minimization. The data obtained has shown that nearly 39% of the respondents believe that the Site Waste Management Plan is a moderately helpful tool for the minimization of the C&D waste stream at the initial stage, whereas 20% and 30% of the respondents highly and very highly agreed with this statement, respectively.

Questionnaire survey gives an opportunity to determine proper C&D waste management strategy which leads to the application of the relevant waste management plan. The waste management plan initially can be prepared after finding the cause of the problems. The respondents were also asked about the processes which cause most the C&D waste. Nearly 39% of the respondents believe that material handling and storage process of the project contribute most toward waste generation on a construction site followed by on-site construction (32%), planning and design (18%), and procurement (11%). This can be mitigated by preparation of the successful site waste management plan applicable to Kazakhstan.

Respondents were also asked about the preferred methods of waste management. According to the survey results, nearly 60% of the participants believe that recycling is the desirable waste management methods compared with the other three methods (disposal 28%, incineration 6%, reducing 4%, and bioremediation/composting 2%). In addition, the respondents suggest that that recycling can also save the cost. A histogram was prepared which distinguished selected C&D waste management methodologies according to the key factors like cost, environmental impact (sustainability), and performance (efficiency). The histogram is shown in Fig. 1. It shows that approximately 98% of the respondents believe that recycling is the more cost-desirable C&D waste optimization way compared to others. Sixty percent responded that the incineration process is the most expensive and less sustainable than other methodologies. The next desirable waste minimization methodology after the recycling is composting technique. This technique has also similar results with recycling, according to sustainability and efficiency. Nevertheless, nearly 81% of the respondents answered that composting is a cost-attractive method. This figure is significantly lower than recycling methodology. Considering, all these features, it can be concluded that the recycling approach of waste management is the most appropriate and applicable to construction companies in Kazakhstan.

5 Discussion of the Results

The application of the waste management plan helps to reduce the capacity of C&D waste on-site. The results of this study show that traditional waste management methods

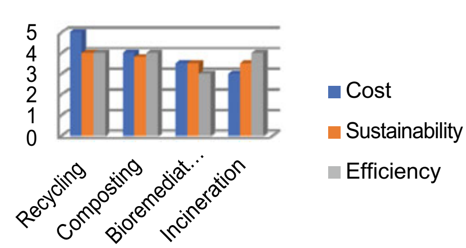

Fig. 1 Waste optimization methodologies

like reusing and reducing are not very suitable in Kazakhstan. The majority of the companies apply general waste management approaches like the collection of construction waste and transportation to the landfills. The disposal of construction waste, through recycling methods, allows construction companies to save money and avoid collection, transfer and other procedures because construction waste such as concrete and brick does not need to be moved. When a building is demolished, a new structure is almost always replaced in its place, and this requires a large amount of rubble for the foundation. Recycling of construction waste, instead of crushed stone, gives crushed brick and concrete obtained during the dismantling of the old structure. A construction company can significantly economize handling and transportation of the C&D waste and there is no need to pay for the placing of the waste stream in landfills since it is treated on a construction site in the waste management area. Recycling of C&D waste gives an opportunity to mitigate an annual rise of the solid debris in the country. This leads to the minimization of harmful impacts on the environment and public health. It is known that the place where construction waste is stored like landfill is not applicable for further land utilization. The results also help to monitor and analyze waste generation history on construction sites.

The main challenges during the waste management procedures for contractors are lack of detailed information in design and specification, design changes and revisions, lack of coordination between design and construction team, over-ordering of material due to lack of coordination and management, lack of coordination of supply chain with design and construction team, lack of awareness of on-site personnel on waste prevention, poor workmanship, lack of poor quality control system, lack of coordination among sub-contractors on site, unskilled labor, poor communication among contractor and sub-contractors, lack of adequate storage, poor skills and knowledge for handling of material, lack of material inspection and quality control system for incoming material, damages caused by improper transportation, handling and storage. However, the preparation of the appropriate waste management plan significantly reduces the quantity of the C&D waste stream. The majority of the respondents choose that; a waste management plan is a helpful tool which reduces the C&D waste.

6 Conclusions

According to the research study, it is found that the most convenient and traditional way to reduce C&D waste is recycling approach. Consequently, this paper considered recycling method as a good solution for the given issue. In recent times, recycling is one of the prominent disposal methods of C&D waste in the world.

However, this traditional approach is not widely used on the construction site of Kazakhstan. Some limitations have been found during the research study like the lack of information about the C&D waste management status in construction companies in Kazakhstan. Thus, the capacity of the questionnaire survey is limited. On the other hand, approximately 93% of the respondents provided answers. This information was enough to analyze and identify the most applicable waste management strategy.

In addition, this study suggests applying a waste management plan which will be efficient to implement recycling operation at the job site and defines its benefits with economic and resource perspectives. The waste management plan will be helpful to avoid overproduction of the C&D waste at the preliminary stage of the project.

In Kazakhstan, bioremediation and composting methodologies are not prominent as in the USA and the UK. In addition, this kind of technology requires an appropriate facility to conduct the process of minimization of waste. On the other hand, traditional approaches such as reducing, reusing, and recycling have also started to develop in recent times. In this case, the most desirable strategy is recycling, which becomes widespread in Kazakhstan now. However, there is a possibility to apply the incineration process which includes a traditional way of debris optimization.

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General Contractor Knowledge of Infection Control Requirements on Hospital Renovation Construction Projects

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Abstract

Healthcare-associated infections (HAI) are common afflictions for hospital patients. Construction-related renovation projects are abundant at hospitals in the United States, the results of which have the potential to cause HAI. Hospital-accrediting firms such as the Joint Commission have a strict focus on ensuring that infection control risk management assessments are completed by hospital owners prior to the start of renovation projects. Fifty-six hospital renovation subject matter experts from general contracting firms in the southeastern United States completed a survey to discern their knowledge of and experience with infection control on hospital renovation projects. The survey results showed that (1) general contracting firms place a focus on training their personnel in infection control, as general contractors are most often responsible for ensuring that infection control measures are adhered to, (2) there are an adequate amount of products on the market for infection control, which are utilized on almost every renovation project, and (3) field operatives (i.e., the individuals that actually complete the work) should receive more training on infection control. Future research should seek to expand this study into geographic regions outside of the southeastern United States and to discern how more training of field operatives can be implemented.

Keywords

Healthcare construction • Infection control

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1 Introduction

Healthcare-associated infections (HAI) are infections patients contract while receiving medical treatment in a healthcare facility that they did not have prior to arriving at the facility (Centers for Disease Control website 2019). HAIs are a pervasive issue in hospital settings across the United States, as approximately one in 31 hospital patients will acquire an HAI during their stay (Centers for Disease Control website 2019) which equates to over 1 million people annually (The American Society for Healthcare Engineering (ASHE) 2011).

Hospitals operate 24 h per day, 7 days per week, and are some of the most complex facilities to plan, design, construct, and operate (Enache-Pommer et al. 2010). Hospitals are constantly being renovated and expanded to comply with new standards and technologies, increase operating efficiencies, increase patient market share, and adhere to regulatory compliance, all which must be completed while the facility stays in operation (Nelson et al. 2005; Lucas et al. 2013). Moreover, the increasing age of hospital building stock in the United States generates a constant need for repairs and replacements of key pieces of plant and equipment within these facilities. The processes are necessary to remediate these depleted items increase the risk of environmental contamination, potentially leading to HAI risks for patients within the facilities (Bartley et al. 2010). Specifically, contaminants include high concentrations of spores, fungi, and organic matter released from insulation and other finish materials disturbed during the renovation process (Fournel et al. 2010; Grosskopf and Mousavi-Rizi 2016).

Healthcare facilities must be inspected and certified to ensure they meet certain requirements of the Centers for Medicare and Medicaid (CMS), the largest funder of healthcare in the United States. National accrediting organizations, such as the Joint Commission, which accredits and certifies nearly 21,000 healthcare organizations and

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programs, have standards and a survey process that meets or exceed the CMS requirement (The Joint Commission website 2019). It is imperative that these healthcare organizations receive this accreditation. The Joint Commission has a standard purposefully related to HAIs, which states:

> Standard EC.02.06.05 requires the organization to have a pre-construction risk assessment process in place, ready to be applied at any time if planned or unplanned demolition, construction or renovation occurs. Additionally, organizations must have a process that allows for minor work tasks to be performed in established locations or under particular low-risk circumstances using predetermined levels of protective practices. The assessment covers potential risks to patients, staff, visitors or assets for air quality, infection control, utility requirements, noise, vibration and any other hazards applicable to the work.

The Joint Commission does not dictate how healthcare organizations assess risk but instead defers to instructions set forth by the Facilities Guidelines Institute (FGI), which issues guidelines expressly related to healthcare planning, design, and construction. The current version of the FGI Guidelines for Design and Construction of Hospitals requires that owners complete what is called an Infection Control Risk Assessment, or ICRA, as part of their overall safety risk assessment. The ICRA requirement was first published in the 2001-version of the guidelines, which were previously developed by the American Institute of Architects (AIA). A standard template for ICRA assessments has also been developed by the American Society for Healthcare Engineering (ASHE). The ICRA is to be completed by the entire project planning team, including staff from the hospital's infection control department (Mohammadpour et al. 2016). The results of the ICRA provide designers and contractors with "a written plan that describes specific methods by which transmission of airborne and waterborne biological contaminants will be avoided during construction and commissioning" (The Facility Guidelines Institute 2018).

2 Research Purpose and Methodology

The purpose of the research described herein was to discern how informed construction professionals are related to infection control in healthcare construction projects, specifically hospital renovation projects completed by general contractors in the southeastern United States. The research methodology included developing and distributing an online survey instrument of 18 open-ended and closed-ended questions to two large general contractors in the southeastern United States. The survey was targeted toward superintendents, project managers, and corporate executives with substantial experience in healthcare construction (i.e., subject matter experts), especially those with experience in renovation/retrofit projects. Survey questions inquired about the subject matter expert's (SME) experience with hospital renovation and detailed questions about their knowledge and opinions of infection control. The survey itself was developed using the Qualtrics web-based software platform and was distributed during July of 2018. Snowball sampling, or requesting that targeted individuals suggest other individuals with similar expertise (Babbie 2011) was used to increase the survey response rate.

3 Survey Results

Fifty-six SMEs completed the survey during July of 2018. Twenty-nine of the SMEs (at the time of the survey) had a superintendent role in their firms, 22 had a project management (PM) role, and 5 had an executive role. (Note: all of the data presented herein has been sorted based on SME roles.) All of the SMEs had completed at least one hospital renovation/retrofit project within the preceding 5 years.

3.1 Infection Control Familiarity and Training

The SMEs were asked three questions in the survey regarding (1) how did they first become familiar with infection control, (2) had they ever received formal training regarding infection control measures, and (3) what topics were included in the training, such as types of infections, risk analysis, strategies for infection control during construction, and infection control documentation methods. The results to the first question concerning how the SME's first became acquainted with infection control is shown below in Table 1. As shown, none of the SMEs stated that they were not familiar with infection control. Forty-five of the 56 SMEs, or 87.5%, first became acquainted through their company's training program.

Fifty-three of the 56 SMEs, or nearly 95%, stated that they had previously received some kind of formal training concerning infection control. The topics covered in the infection control training are summarized in Table 2. As shown, strategies for infection control during construction was the most prevalent topic covered in the training sessions, followed closely by documentation and checklists, risk analysis as per the work area and construction activity, and types of infections. Additionally, 55 of the 56 SMEs, or 98%, were familiar specifically with ICRA.

3.2 Infection Control Importance, Responsibility, Strategies, and Cost

The SMEs were asked six questions related to their firm's perceived importance of infection control, who carries the

Table 1 Survey responses to the question "How did you hear about infection control during construction for the first time?"

	Super	PM	Exec	All
Work contract term/project specifications	4	2	0	6
Hospital facility manager/staff	1	1	0	2
Your company's training program	23	18	4	45
Healthcare facility's training program	1	1	1	3
I have not heard about it	0	0	0	0

Table 2 Topics covered in infection control training sessions completed by SMEs

	Super	PM	Exec	All
Type of infections	20	16	3	39
Risk analysis as per the work area and construction activity	24	17	4	45
Strategies for infection control during construction	28	19	4	51
Documentation and checklists	26	19	4	49

responsibility of infection control on hospital renovation projects, and infection control and prevention strategies. Fifty-four of the 56 SMEs, or 96%, stated that infection control (on their last major renovation project) was deemed to be "extremely important" by their firm.

The two other SMEs stated that infection control was very important. The SMEs also stated that, by and large, the general contractor carried the responsibility of ensuring that infection control measures were implemented correctly, as shown in Table 3. The healthcare facility manager, individual subcontractors, and special consultants simultaneously carried this responsibility on some projects, but at a lower overall scale.

The SMEs were asked if specifications for infection control measures were included in the contract documents on their last major hospital retrofit project. Forty of the 56 SMEs, or 71.4%, stated that yes, specifications were provided. Furthermore, the SMEs were asked what infection prevention strategies were put into place on their last major hospital retrofit project (based on a provided list), the results of which are shown below in Table 4. Maintaining negative air pressure in the area under renovation was overall shown to be the most prevalent strategy implemented, with 100% of SMEs stating that this strategy was implemented. Sealing the work area with plastic sheets and tape, using portable air purifiers, and isolating the HVAC system were also very highly implemented strategies, with 54 of the 56 SMEs, or 96%, stating that these measures were utilized.

The SMEs were asked to rank (using a Likert scale) a list of four potential problems related to the implementation of infection control measures on hospital renovations: lack of training for construction professionals, lack of effective management systems of protocol, communication and coordination between different entities (e.g., subcontractors, facility management), and the unavailability of ready-to-use products/systems for infection control. The average rankings are provided in Table 5, where a ranking of "1" equated to the "biggest problem", and the ranking of "4" equated to the "smallest problem." The SMEs overall felt that a lack of training for construction professionals was the biggest problem related to the implementation of infection control measures, while the availability of products and systems for infection control was the smallest problem.

Lastly, the SMEs were asked about the percentage of overall project cost spent on infection control measures on their last major hospital retrofit project. The results provided in Table 6 show that 1–2% of overall project cost was the most prevalent response.

Table 3 Survey responses to the question "On your most recent major healthcare renovation in the last five years, who was most often responsible to ensure infection control measures were implemented correctly?"

	Super	PM	Exec	All
General contractor	28	21	5	54
Healthcare Facility manager	7	9	0	16
Individual subcontractor	2	3	0	5
Dedicated individual or Special consultant	5	3	0	8

Table 4 Infection control measures implemented by SMEs on their last major hospital retrofit project

	Super	PM	Exec	All
Maintaining negative pressure in the area under renovation	29	22	5	56
Sealing the work area with plastic sheets and tape	29	21	4	54
Portable air purifiers	28	21	5	54
Isolating HVAC system	28	21	5	54
HEPA filter cart	25	19	5	49
ICRA sealing products	23	19	5	47
STARC partitions	11	7	2	20
None of the above	0	0	0	0

Table 5 SME ranking of potential problems related to the implementation of infection control measures

	Super	PM	Exec	All
Lack of training for construction professionals	1.59	1.86	1.6	1.68
Lack of effective management systems or protocol	2.48	2.68	2.2	2.45
Communication and coordination between different stakeholders	2.41	1.95	2.4	2.26
Unavailability of ready to use products/systems for IC	3.52	3.5	3.8	3.61

Table 6 Percentage of overall project cost spent on infection control measures on last major hospital retrofit project completed by SMEs

	Super	PM	Exec	All
<1%	5	8	2	15
1–2%	11	10	2	23
2–3%	7	1	1	9
>3%	6	3	0	9

4 Discussion of Results

The survey results show that infection prevention is paramount in hospital renovation projects, no matter what the size, and that the general contractors who undertake these projects are most frequently responsible for ensuring that infection control measures are implemented. Construction firms that work in this arena focus on training their senior personnel about infection control, with HAI-causing risk identification and mitigation strategies being emphasized. Hospital renovation SMEs feel that there are sufficient products and systems available for infection prevention, and tactics such as negative air containments (including associated temporary barriers and air filtration systems) are almost always utilized.

One surprising survey result was that SMEs feel that a lack of training for construction personnel is (relatively speaking) the biggest problem related to the implementation of infection control measures. The authors feel this relates to the actual field operatives that complete the work on these projects, as opposed to the management staff that oversees the work. Field operatives may receive only limited training on infection control, and may not fully understand the consequences of their actions related to how their specific work actions may cause HAI issues. Furthermore, field operatives working for subcontractors may only spend a short time on a project, as little as a day, and may not receive any project-specific training. This may occur even though the contract documents between the subcontracting firm and the general contractor may stipulate a requirement for such training, and include heavy damages if infection control practices are not adhered to.

Finally, the sheer cost of infection control on hospital renovation projects is substantial, with most SMEs stating that costs were in the 1–2% range. On a 50,000 ft^2

renovation project, assuming a cost of \$200 per ft^2, the cost for infection control alone could be \$200,000. This pure overhead cost is entirely substantiated, though, considering the negative effects that not instituting sufficient infection control may have on the population of patients in a facility being renovated. This sentiment is what drives accrediting agencies such as the Joint Commission to place such a large focus on ICRA-type risk assessments by owners ahead of the start of any renovation project.

5 Conclusions, Limitations, and Future Research

HAIs are an unfortunate side effect that many Americans experience associated with a hospital stay. Renovation work within hospitals can lead to HAIs, but general contractors that complete these projects and the firms that supply this industry have focused on mitigating HAI-causing contaminants through training of key personnel, risk assessment, and implementation strategies. Hospital renovation SMEs do feel, though, that more training of construction operatives is needed moving forward. The results presented were limited to superintendents, project managers, and executives of southeastern United States general contractors, hence, these results may not be generalizable to construction professionals or projects outside of this scope. Furthermore, the exact number of individual firms represented in this sample is not exactly known, as snowball sampling was utilized. Future research should seek to expand the sample to construction professionals in other regions of the United States, and the world. Moreover, further research should be performed to discern how construction operatives can better be trained and prepared for the infection-related demands of completing hospital renovation projects.

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Building Information Modelling in Transport Infrastructure Sector

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Abstract

The Building Information Model concepts include a range of IT tools supporting the collaborative processes in an organisation. This approach allows all stakeholders to have an integrated system in which editing and retrieving up to date information on shared models will become easier changing the businesses processes. This paper will be presenting a review of research on the Building Information Model in practice. The Building Information Model has been around for some time and is becoming more popular as of its mandate in the UK back in April 2016. This research is based on case studies on BIM in practice in the transport infrastructure sector. The methodology for this research is a case study on a Tier 1 contractor in the UK who are using BIM as one of their processes. A brief overview of BIM will be explained and the key findings in the research will be highlighted identifying the business value of BIM, the results will demonstrate how BIM is being practised within the organisation and to improve design management, the challenges with the implementation of the new processes will be outlined, this paper will also show how the construction company have utilised the adoption of BIM to mitigate and manage communication issues within their projects. Research has shown that the key communication and management problems such as loss of documentation, poor communication and quality can be mitigated with the use of BIM. Finding out these challenges will allow the issues found along with the potential of BIM to be outlined and allows the conclusion that BIM is the future of construction.

Keywords

Building information model • Communication • Engineering and construction • Collaboration • Infrastructure

1 Introduction

The UK economy has been growing over the years averaging at 0.6% growth in 3 months back in September 2018, which has been the strongest increase since the last quarter of 2016 (Ferreira 2018). The construction industry has played a major part in the economic growth as the UK government has invested over £600 billion over the next decade on infrastructure and at least £44 billion on housing (UK Government 2018). On a global scale, construction projects are becoming more complex, construction project now includes several stakeholders and with the rapid growth within the industry communication challenges arise. Communication can affect the quality of the design which can have an impact on project costs.

Construction projects also go through frequent design changes and these changes need to be fed back to the construction team as soon as possible to ensure projects are built to the updated and latest designs. The Building Information Model has a major topic in the construction industry globally as benefits of its use within construction have come to light. It has been noted that BIM can provide various benefits to the construction process, from the design stage to asset management. To better understand BIM this paper presents a case study to demonstrate the key challenges faced within the project. Key communication challenges are analysed and the key lessons learned are documented. The project currently uses the Building Information Model as one of its processes, this will be investigated, and this paper will highlight how the Building Information Model is being used within the project and if there have been any

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challenges with the use of BIM. The paper will be split into four sections which answer the research questions:

Research question 1: How important is design management within construction projects?

Research question 2: How does BIM benefit the construction industry and what technologies are being used in the construction industry?

Research question 3: What is the current state of BIM within the case study project and what challenges and benefits are being faced?

Research question 4: What are the future recommendation for the use of BIM within this project?

2 Literature Review

2.1 Building Information Modelling (BIM)

The Building Information Model is a maturing technology that has the potential to efficiently manipulate and visualise the whole projects life cycle data (Rodriguez 2018). The Building Information Model can be utilised during all stages of the project and functions during these stages include:

Design Stage (Pre-Construction): During this stage, the design can be visualised, and alternative designs can be rapidly generated, this allows the designers to choose the best solution for the project.

Construction Stage: BIM can create a communication platform between the designers and construction teams. With there being a 3D model, the design can be visualised by the construction team and the designs can be understood.

Asset Management (Post-construction): Project data and asset data are all stored as as-built information during construction, this allows for better asset management once the construction is complete as all data is stored efficiently (Hall 2018).

Many benefits of BIM have been documented such as a reduction in project costs, saving time, improving projects communication and collaboration and project quality (Diaz 2016). This Building Information Model also provides the means to increase design quality through detecting clashed between the different disciplines on the design prior to construction, BIM also improves the sharing of information within the different stakeholders via a Common Data Environment (CDE), this allows the construction teams to always have access to up to date information for construction.

BIM is a process and includes a wide range of other technologies which work together to provide more benefit to a project, this use of technologies is known as Industry 4.0 as the construction industry is going through a digitisation era.

2.2 Industry 4.0; IoT Technologies

The UK has now entered a new industrial era known as Industry 4.0, this is known as the trend towards the digitalisation and automation of the manufacturing and construction industry. Industry 4.0 comprises of various technologies including BIM to enable a digitalised environment for the construction and manufacturing industry (BCG 2019).

The results of the use of Industry 4.0 have proved to improve quality and decrease time while improving performance within a project, despite all these benefits, the construction industry have yet to integrate these technologies, as well as the automotive and manufacturing engineering sectors, have (BCG 2019).

Some of the technologies linked with Industry 4.0 are mentioned below:

Cloud: The construction industry contains a lot of data which is to be stored at all stages of construction to enable better asset management. Loss of data during the construction stage is a big issue, having a cloud to access data and store data can increase productivity and prove profitable for an organisation (IBM 2019).

Artificial Intelligence/Virtual Reality: Virtual reality is becoming more popular in the construction industry compared to Artificial Intelligence. With Virtual reality, the project can be view prior to its construction and its purpose can be viewed with the client and stakeholders making them confident in the project, the like of High Speed 2 railway in the UK have used this technology to show the public (IBM 2019).

Drones: Drones can be used for a variety of things in the construction industry, site data can be collected cutting surveying time to hours instead of days. Up-to-date and accurate site information can also be collected which can be used to check for the sites progress and productivity (Propeller 2010).

Simulation: Simulations are becoming more popular in the construction industry, they are extensively used for plant training which allows operators to use machines at its trial period in the virtual world before using it on-site (BCG 2019).

Additive Manufacturing: The construction industry has been using Additive manufacturing, it is where products are pre-constructed off-site such as modular blocks, and then transported to the site to allow for construction. This allows for complex designs to be constructed in an environment where the detail can be constructed accordingly and then placed the site with no delays (BCG 2019).

These are just a few of the technologies that are related to Industry 4.0, the Building Information Model is also one of the technologies linked with Industry 4.0; however, BIM in cooperates some of these technologies to provide more benefits. Drones can be used with BIM to compare site data with the 3D model of the design to check progress.

3 Research Methodology

For this research, a combined methodology was used, for the purpose of answering research questions 1 and 2, a systematic literature review was conducted to explore construction processes and identify the technologies linked with Industry 4.0 and BIM. For the purpose of answering research question 3, a case study research approach was adopted to investigate the Building Information Model in practice, identifying and analysing its use.

Systematic Literature Review

First, a literature review was conducted to gain a solid base of data for the context analysis, the scholarly context was analysed which enabled the findings of the basics of technologies used in the construction industry and BIM, it was clear that the research had to be broadened which was conducted by using Google search with the key phrases of this research.

Qualitative and Quantitative Context Analysis

It was clear that one form of analysis would not provide as much data as a combined methodology, within the qualitative analysis, recommendations from (Mayring 2000) was followed:

Preparation of the research questions, Introduce categories of definitions, Check categories are relatable to topic, and Interpretation of the results collected.

Case Study Research

The aim of this case study research is to examine BIM in its natural settings and by employing multiple methods of data collection and obtaining data from professionals in the business, during this investigation, we follow a framework strategy recommended by Yin (2014). Two factors are to be considered when interpreting the results. First, due to the limitation of an investigated research paper from the year 2010, it cannot be guaranteed that all relevant publications have not been covered, hence, the research should be validated with further studies, e.g. expert interviews or empirical study. Secondly, a few of the research publications are non-peer-reviewed, for example, blog posts which may contain information that cannot be verified. Data collection was obtained through 15 interviews and questionnaires were handed out to 20 employees. 8 observations were held with different disciplines within the project.

Through observing the employees, key interactions between the different disciplines were recorded, important points within meetings and communication methods were recorded. During the interviews, the responses were recorded and the main analysis method for the interviews was classifying the patterns and arguments. Notes were also taken during the interviews which were studied and the document analysis method was adopted to support the findings from the data collecting methods.

4 Results

The following section will start by providing related work to demonstrate the uniqueness of this contribution. The results are the presented as well as the findings from the case study research and, finally, future work and recommendations will be demonstrated.

4.1 Project Description

The UK government has invested in smart motorways all over the country in the hopes of converting normal motorways with three lanes and a hard shoulder into All Lanes Running motorways. The M23 Junction 8–10 is one of the current projects which commenced construction in 2018 and is expected to last a duration of three years. The proposed All Lane Running scheme would provide four permanent running lanes through converting the hard shoulder into a running lane and various technologies will be in cooperated to assist with safety and keep traffic moving. These technologies include installation of 26 new gantries (the existing gantries are to be demolished/retained and upgraded where possible), which will be fitted with message signs and AMI's (Advanced Motorway Indicators, strategic signs and variable message signs. Speed limits will be displayed based on traffic conditions to allow traffic to keep flowing and CCTV cameras and loop detectors will be fitted to provide information support to a control centre. The central reserve will also be hardened, and a rigid concrete barrier will be fitted. The projects overall view can be seen in Fig. 1.

The project has adopted as required by the UK government and a design 3D model was created as demonstrated in Fig. 1. The project comprises of three different organisations, the designers, the contractor and the client and sub-contractors. The project has a BIM coordinator, BIM manager and BIM Coordinator of the designer's company.

4.2 Project Analysis

The following section details some of the issues being faced within the project which have been identified after the data analysis regarding the use of the Building Information

Fig. 1 3D model of project; Junction 8

Model. The discussed issues include communication tools, implementing BIM, collaboration with sub-contractors and up-skilling (Table 1).

Even though there a number of issues with the use of BIM on this project, there are various benefits which BIM is providing to the project which are demonstrated in Table 2.

5 Conclusion

This research presents a detailed study which was executed between April 2018 and January 2019 on the Building Information Model in practice on a Smart Motorway Project. The case confirms several points identified: (i) The Building Information implementation process is a tough one, it involves a lot of awareness and training to staff for level 2 to be adopted in the right manner; (ii) communication can be improved with the use of BIM, the likes of subcontractors and different disciplines in the organisation can communicate easier with the use of a CDE while all data is also stored, this, however, is a process that team members must undertake and adopt; (iii) BIM can contribute to communication between team members, as the results suggested the 4D sequence was a collaboration between different teams showing the planned programme of works which helped the client understand how the works are going to be undertaken. The two most important findings in the research were that the

Table 1 Challenges of BIM within the case study project

Implication challenge
• **Acceptance**: The project has adopted BIM from the start and training session is held in order to be Level 2 BIM compliant and utilise the Common Data Environment. All project information is uploaded on the contractors CDE and distributed to the relevant disciplines, however, when distributed, there is a lack of responses as the disciplines do not download the updated documents form the CDE as they would grab a paper copy from team members. This is an issue because the printed copies may be previous revisions
• **Process changes**: The implementation of BIM must take place at all levels of the organisation which requires re-engineering the business practices, as most employees in the organisation have been in the industry for over 15 years, the reluctant to change the way of working is quite difficult. Training sessions are held every week to allow employees to understand the BIM Level 2 processes, however, once training is completed most employees tend to revert to their old ways of working
• **Communications**: Within this project, there are three CDE's. The client has their own CDE which a number of people have access to and is used for Technical Queries and raising PMI's (Project Managers Instruction), the designers also have their own CDE which the client, Document Controller of contractors and themselves have access to where documents are issued, and the contractors have their own CDE which everyone has access to, as there are three CDE's with limited access for employees to two of them this can be difficult as not everyone has access to view all project information
• **Use of 3D model**: **T**he 3D model is available for use and everyone on the project has access to it, however, not everyone uses it to gain the benefits it provides even though they have been trained
• **Communication tool**: The contractors CDE contains a communication tool which can be used to communicate with sub-contractors, etc., however, this has not used, and emails are mainly sent which can cause loss of data

Table 2 Benefits of BIM to case study project

Implication benefits
• **4D planning**: The project has produced a 4D sequence which was requested by the client, this allowed the Planners, Operational team, CAD technician, BIM team and designers to collaborate as the design model was needed along with the programme and works sequence to produce the 4D model. The 4D sequence was produced at a section where major works were to be conducted and there were a lot of risks involved with the works. the sequence allowed the operational team to view the programme and justify that there will be enough space for the machinery and plant
• **CDE**: There are pitfalls with the CDE as there are three of them, however, the CDE being used by the contractors takes a major role in the works, the contractors CDE is where all construction information in obtained by the operational team, however, there is still to be a push for employees to adapt to obtaining the current revision of drawings uploaded
• **Asset management (life cycle benefits)**: At this project, as the construction process is happening, asset data is being collected and this will be inputted into the model, the will allow the asset to be maintained in an easier way as all asset data is stored in one place and is attached to the model itself
• **Clash detection**: At the early stages of the project the model was used for clash detection between the sub-contractors and the contractors, the model was used to visualise where the proposed temporary CCTV cameras were to be placed and to check if it clashes with the proposed works, a number of clashes were found which enabled the team to move the CCTV cameras to locations where there were no clashes. this saved time of re-installing the CCTV bases if the clash detection was not conducted
• **Walk-through of job**: A fly-through of the job has been recorded by the BIM Team, which is regularly used to show stakeholders and visitors to the site and the works. Most visitors visit the site office and do not get to see the job, however, with the fly through in place that is possible and reduces the safety risk as visitors do not physically go on site

contractor should enforce a communication framework within the organisation to ensure the use of the right BIM processes to communicate between disciplines. Secondly. BIM competencies between the different disciplines should be similar and although training is being provided, more awareness on BIM would enable the organisation to raise interest on the BIM level 2 standards and processes.

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A Factor Analysis of Transportation Infrastructure Feasibility Study Factors: A Study Among Built Environment Professionals in South Africa

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Abstract

Feasibility studies conducted at the initiation stage of transportation infrastructure projects inform decision-making regarding the proposed project's development. However, non-comprehensive feasibility studies lead to project failure at the operational stage. This study, therefore, investigated the critical factors that should be incorporated in a comprehensive feasibility study in order to make reliable investment decisions, which will, in turn, affect the performance at a later stage. Empirical data collected from 132 built environment professionals in South Africa, were analysed to output descriptive and inferential statistics. The inferential statistics entailed factor analysis. Outputs were common factors and the minimum number of variables that contributed the most variance in the data set. Findings revealed that a six-factor structure including methods of appraisal, finance availability and source, user needs, local environment, available data and strategic support. By establishing critical factors to consider during the planning of infrastructure to ensure that a comprehensive feasibility study is achieved, the current study provides valuable evidence for transportation infrastructure stakeholders to make informed and reliable decisions about the worthwhileness of the projects they intend to invest in.

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Keywords

Feasibility studies • Infrastructure • South Africa • Sustainability • Transportation

1 Introduction

Transportation infrastructure plays important roles in economic growth and development by employment and wealth creation, trade costs reduction and facilitation of economies of scale and knowledge accumulation (Carlsson and Otto 2013). Therefore, achieving successful and sustainable projects should be the focus in transport project planning and development (Allport et al. 2010). However, the sustainability of projects is partly marred by the inadequate extent to which factors that affect the development in its life cycle are considered at the planning stage. The success of a project is determined by the assumptions that are set during the feasibility process (Tsimplokoukout et al. 2012). About 25% of projects fail; a further 20% perform better than expected; and the remaining 55% perform more or less as expected (AMC Consultants 2017). One of the main weaknesses in transport infrastructure sector is the lack of planning at the onset of projects, which has a ripple effect on the projects at the operational stage (Mabugu 2016). Often, the main cause of project failure is an inadequate understanding of the project viz-a-viz risks (deviation from expected or wanted results), rewards and a plethora of uncertainties which infrastructure developments are fraught with, with regard to costs, benefits, schedule, demand and risk estimation and control (Hampton 2009; Bertolini and Giezen 2013). Therefore, one of the ways to achieve sustainability of transportation projects is through attention to the factors considered during the feasibility stage (front-end considerations). This implies starting transportation infrastructure developments with the end in mind (Gausden and Miskimmin 2018). Previous studies have been conducted on the factors to consider during the planning of

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transportation infrastructure. For instance, (Bueno et al. 2015) investigated sustainability element including social, economic and environmental factors, which should be considered during feasibility studies. Okoro et al. (2016) reviewed travel demand forecasting considerations. Similarly, (Okoro et al. 2017) identified feasibility study considerations for transport infrastructure performance in an integrative review. Other studies identified that appraisal methods (Jeerangsuwan et al. 2014), criteria factors considered (Parthasarathi and Levinson 2010; Salling and Leleur 2012), and data used in evaluation of projects (Etemadnia and Abdelghany 2011; Hassan et al. 2013) are critical considerations in transportation infrastructure feasibility studies (TIFS). However, there is no consensus on the critical factors that should be considered in a comprehensive feasibility study. The objective of the current study is therefore to establish the factors which are critical to a comprehensive feasibility study using factorial analytic techniques. The succeeding sections present brief overview of TIFS, the methods employed in conducting the study, the results and, subsequently, conclusions drawn from the findings.

2 Transportation Infrastructure Feasibility Studies

2.1 Significance of Feasibility Studies

Proposed projects are analysed and evaluated to discover positions or situations, which may jeopardise the projects in the long run (Khatleli 2016). Feasibility studies identify risks to a project at the concept stage, which may affect the project during the operational stage. The feasibility study follows a process of conceptual ideation of a project and entails a detailed assessment of the viability of a project from different points of view including technical, financial, social and environment aspects as well as legal structuring to ensure value for money (Hyari and Kandil 2009). Feasibility studies entail testing the sustainability of structures and strategies (through indicators) and making statements about the future based on identified uncertainties.

Feasibility studies are useful in reducing uncertainties in order to make better decisions, which otherwise, can lead to disastrous consequences (Hassan et al. 2013). Moreover, the usefulness of the FS is linked to the significant decrease of the risks taken by the one who undertakes them, when attempting to capitalise on identified economic opportunities (Ehlers 2014). A poorly defined project, at the feasibility stage, will not deliver the same outcome as a well-defined project no matter how well it is executed and operated (Mackenzie and Cusworth 2007). Inadequate feasibility studies result in scarce financial and natural resources being wasted since investment decisions and projects, which are usually capital-intensive (huge amounts of funds injected), are made and built with misleading information regarding their potential capacity to succeed (financially and otherwise) while in operation and to serve generations of users (Roxas et al. 2015). Consequently, very intricate and influential problems, which could be averted to a great extent in the planning of such risky endeavours, arise, if they are not given adequate consideration. Proficient planning and proper evaluation are needed to identify potential impacts, costs and benefits accruable to a project and thus resulting in improved decision-making. Infrastructure project owners, decision-makers and investors decide to proceed with a given project (new and/or otherwise) based on the results of the feasibility studies carried out at the planning stage to identify different elements/aspects of the project that pose risks and may affect the expected revenue/returns from the project. Therefore, based on the outcome of feasibility studies, projects that deserve to be built are undertaken and those that do not are abandoned (Roxas et al. 2015).

2.2 Factors Incorporated in Comprehensive Feasibility Studies

Comprehensive feasibility studies include all elements that may impact on a project's performance (ADB 2005). Such factors include finance availability and procurement strategies (Allport et al. 2010), local environment (Rudžianskaitė-Kvaraciejienė et al. 2015), institutional support (Quium 2014) and users' needs (Friedl and Reichl 2016; Erlich 2015; Mišic and Radujković 2015).

Therefore, a comprehensive feasibility study should consider a wide variety of project performance influencers.

Extant literature revealed that a number of factors are considered in feasibility study and they may affect the quality of feasibility studies. For instance, the methods used in the appraisal of the investment, could result in different margins of error (Jeerangsuwan et al. 2014).

Some methods used singly, for instance, environmental impact assessment, could result in inadequate consideration of the interactions between various complex systems and influencers which could affect the project during the operational stage (Etemadnia and Abdelghany 2011). Other studies argued that irrespective of the methods used, the data may be manipulated by the people involved (Nicolaisen et al. 2012). This suggested that the nature and availability of data used could influence the quality of feasibility studies (Etemadnia and Abdelghany 2011; Hassan et al. 2013).

Literature further identified that considerable attention should be accorded to a plethora of factors that influence the comprehensiveness of feasibility studies in order to reduce errors and develop appropriate strategies to ensure sustainability (Rudžianskaitė-Kvaraciejienė et al. 2015; Mišic and Radujković 2015).

3 Methods

A quantitative approach was adopted to conduct the study. A pilot-tested field questionnaire survey was used to collect data regarding transportation infrastructure feasibility studies, quality of feasibility studies and project sustainability on a 5-point Likert scale, with responses ranging from 1 = strongly disagree to 5 = strongly agree. The questionnaire was developed from an integration of findings from a literature review and qualitative enquiry (using interviews and document analysis).

3.1 Data Collection

Ethical clearance was granted by the university authorities prior to the questionnaire distribution. The respondents, comprising built environment professionals in the nine provinces of South Africa, were selected using purposive and snowball sampling techniques. Consent was obtained from some of the participants' superiors as and where required. The questionnaire was distributed by hand, as well as online via email and google forms. These techniques were used in order to improve the response rate. A total of 132 questionnaires were returned and used for analysis.

3.2 Data Analysis

The data were analysed using SPSS Statistics version 25 and SPSS AMOS version 25. Common factor analysis was conducted on the conceptual constructs and variables using maximum likelihood factoring to examine their underlying structures. Prior to the factor analysis, preliminary tests entailed assessing the suitability of the data for factor analysis using the Kaiser–Meyer–Olkin (KMO) and the Bartlett's sphericity tests. The KMO values should be greater than 0.6 and the Bartlett's sphericity must be significant (≤ 0.05) for a good factor analysis (Pallant 2013).

Maximum likelihood factoring was used to extract the common factors. The maximum likelihood factoring technique considers the shared variance (unlike principal components analysis), avoids the inflation of estimates of variance accounted for and assumes that individual variables are normally distributed (unlike the principal axis factoring) and was observed to be suitable for the non-normal data which was obtained (Costello and Osbourne 2005). The outputs from the factor analysis were "common factors", which were believed to account for most of the variance in the observed variables. These were rotated and interpreted using oblique rotation to determine the items which defined the common factors. Items cross-loading or loading below 0.4 were deleted and the test was rerun. In addition, the decision on which factors to retain was made based on the Kaiser's criterion (to retain only the factors with an eigenvalue larger than 1 was primarily used), the scree plot (the number of factors above the break or elbow of the scree plot) and variance explained (as displayed on the pattern matrix, which showed the number of factors that cumulatively accounted for more than 70% of the variance and thus gives the most interpretable solution). The results of the analysis are presented in the succeeding section.

3.3 Validity and Reliability

The qualitative information was obtained from the actual feasibility reports conducted on the projects as well as the custodians of the reports. This enhanced convincingness (validity of case research) (Stewart 2012). The piloting and reviews of the questionnaire by the researcher's supervisors and statistician refined the tool and increased face or content validity. Internal reliability consistency tests for the TIFS measures was assessed before and after the EFA using the Cronbach's alpha test. The results of the constructs measuring TIFS before the EFA are presented in Table 1. The table indicates that the sub-scales had good internal validity, with values exceeding the recommended 0.7 (Pallant 2013). Likewise, the collective results of the TIFS factors revealed that the measures before and after EFA were 0.94 (N = 38) and 0.92 (N = 23), respectively, and thus indicating good internal consistency (Pallant 2013).

4 Data Analysis

4.1 Demographic Characteristics of Respondents

The respondents were made up of 69% public and 31% private entity professionals, with directors, deputy director and heads of departments forming the majority (25%) of the responses. Project managers made up 15%, and engineers and safety officers made up 12% and 10% of the population, respectively. Other positions indicated were executive/ deputy managers (8%), development managers/ agents (6%), feasibility study consultants (4%), planners (4%), quantity surveyors (4%), academics (3%) and technical assistants on project (2%). The projects were new and expansion projects, comprising road (74%); rail (12%); bridge (8%); airport (3%); and tunnel (2%) projects. These

Table 1 Cronbach's alpha test results before factor analysis

Construct		Cronbach's Alpha	Mean inter-item correlations	Number of items
Transportation infrastructure feasibility study (TIFS)	Data used	0.72	0.25	8
	Criteria factors considered	0.93	0.39	21
	Methods used	0.89	0.51	9

statistics indicated that a varied and representative population was obtained, with the respondents having been involved in the different projects.

4.2 Factor Analysis Results

Sampling adequacy was assessed using the Kaiser-Meyer-Olkin (KMO) value for the measure of sampling adequacy, the Bartlett's Spericity tests as well as the communalities and anti-image matrix. The KMO value was 0.824, exceeding the recommended value of 0.6, and the Bartlett's test of sphericity reached statistical significance at $p = 0.000$ (χ^2 (703) = 3520.135), indicating factorability. Inspection of the correlation matrix revealed the presence of many coefficients greater than 0.03, and all the variables correlated with at least one other variable, indicating suitability of data for factor analysis. The anti-image correlation matrix, with diagonals all above 0.5 (ranging from 0.604 to 0.931) also supported the factorability of the data set. The initial communality estimates all had values greater than 0.4 and thus further indicating that the data was suitable for factor analysis. The exploratory factor analysis revealed that nine factors, accounting for 73.27% of the total variance in the model, could be retained. This was also supported by the scree plot, which showed eigen values greater than 1, above the breaking point. However, since the purpose of the EFA was to determine the minimum number of factors underlying the structure, correlations among items, as well as items that did not load or had low loadings (below 0.4) on any of the extracted factors, the pattern matrix was examined for such items. Items loading below 0.4 and cross-loading on two or more items with >0.32 were therefore deleted, respectively, and the test rerun. A six-factor structure emerged with item loadings well above 0.4 on the common factors (Table 2). It is notable that the fifth factor had only two items loading on it. However, it was still considered acceptable because the items were related to data and since data is indispensable in feasibility studies, these were considered important and therefore retained. The emerging common factors were named methods of appraisal, finance availability and source, user needs, local environment, available data and strategic support.

5 Discussion

The measures emerged as a six-factor solution, as opposed to the three-factor structure. The resultant factors were named as discussed hereunder, in relation to extant literature.

5.1 Methods of Appraisal

This common factor contained elements which were initially theorised as methods used in feasibility studies (Etemadnia and Abdelghany 2011; Al-Masaeid and Al-Omoush 2014). The first common factor had items loading strongly on them, including *best scenario outcome, site/location characteristics, design and scope requirements, traffic growth analysis*, *costs and benefits analysis* and *multi-criteria analysis*.

5.2 Finance Availability and Source

The second factor comprised items related to financial connotations, which are critical in feasibility studies. These included *financial input from private investors, financial self-sustenance of the system, financing alternatives relative to costs (financial), existing financial and tender records* and *sources of project finance*. These were therefore named "finance availability and source" (Griskeicius and Griskeviciute-Geciene 2008).

5.3 User Needs

Elements that related to users and their travel needs of transportation infrastructure congregated on the third common factor. These included *user comfort during travel, convenience to users, user safety* and *speed and travel time*. These items suggested reference to the experience or perceptions of end users or consumers of transportation infrastructure while in operation. Users of transportation infrastructure are external factors which could act on the level of investment, value-add or costs, with their input, perception or opposition and should be

Table 2 Factor loading of transportation infrastructure feasibility study measures

S/No.	Label	Measures			Factor			
			1	2	3	4	5	6
1	ME2	Best scenario outcome	.982					
2	ME5	Site/locational characteristics	.888					
3	ME6	Design and scope requirements	.780					
4	ME1	Traffic growth analysis	.771					
5	ME4	Costs and benefits analysis	.731					
6	ME3	Multi-criteria analysis	.707					
7	CF15	Financial input from private investors		.981				
8	CF16	Financial self-sustenance of the system		.847				
9	ME7	Financing alternatives relative to costs (financial)		.546				
10	DA6	Existing financial and tender records		.540				
11	CF14	Sources of project finance		.516				
12	CF1	User comfort during travel			1.056			
13	CF2	Convenience to users			.920			
14	CF6	User safety			.601			
15	CF4	Speed and travel time			.571			
16	CF11	Condition of existing infrastructure, for upgrade projects				.935		
17	CF10	Structural capacity of existing infrastructure, for upgrade projects				.829		
18	CF12	Existing businesses/vendors				.493		
19	DA3	Audit observations and performance reports, for upgrade projects					.924	
20	DA2	Existing design and structural reports, for upgrade projects					.702	
21	CF20	Stakeholders' interests and needs						.832
22	CF21	Competing transportation modes within the locality						.569
23	CF18	Management capacity at operational stage						.482

Extraction Method: Maximum Likelihood
Rotation Method: Promax with Kaiser Normalisation
Rotation converged in 6 iterations

taken into account during feasibility studies (Griskeicius and Griskeviciute-Geciene 2008). Users are instrumental in directly influencing decision-making regarding transportation infrastructure and should be considered in feasibility studies (Cornet 2016). Based on this notion, the user-related items, which loaded on the third factor, were collectively encoded as *user needs.*

5.4 Local Environment

The fourth common factor consisted of factors connoting status quo with regard to infrastructure condition, structural capacity and businesses or vendors to be considered in the vicinity. Transportation infrastructure planning considers previous developments and current status in a catchment area (including the beneficiaries' and physical infrastructure conditions) in order to compare and develop and compare scenarios while predicting future impact, opportunities and benefits accruable from the project (Hyari and Kandil 2009; Asian Development Bank (ADB) 2013). Information on current trends and activities or patterns of behavioural and professional activities around the area, as well as services and facilities that could modify traffic flows (origin and destination) are vital considerations in transportation infrastructure feasibility studies. On this premise, *the condition of existing infrastructure and structural capacity for upgrade projects* as well as *existing businesses/vendors* were denoted as *local environment*.

5.5 Available Data

The fifth common factor had two items loading on it. These included statements related to sources of data referred to during feasibility studies. These included *audit observations and performance reports, for upgrade projects* and *existing design and structural reports, for upgrade project.* This factor, although having only two item loadings, was retained because data is an essential component of feasibility studies. Data availability is an essential feature in the development of criteria to assess the level of sustainability of planned infrastructure during feasibility studies (Cornet 2016). The term *available data* was therefore used for the fifth common factor.

5.6 Strategic Support

The emerging structure on the sixth common factor showed variables that influence people's preferences among different modes and fulfil strategic intents and needs of various stakeholders in a bid to achieve failure-free infrastructure (Matti et al. 2017). To avoid failures, operators make decisions regarding the performance of the project by involving different levels of executives and expertise in making strategic decisions based on stakeholder and professional input (Dey 2001). Based on these conceptions, the sixth common factor, with items including *competing transportation modes within the locality, stakeholders' interests and needs, management capacity during operations* and *was conducted by professionals with relevant experience on feasibility studies,* was denoted as "strategic support".

6 Conclusion

The study set out to establish critical factors which should be incorporated in a comprehensive transportation infrastructure feasibility study (TIFS). The objective of the current study was achieved through a factorial analysis of the TIFS measures. Findings revealed that methods of appraisal, finance availability and source, user needs, local environment, available data and strategic support are critical factors which should be considered during feasibility studies to ensure that comprehensive outcomes are obtained. This would in turn result in better and more reliable decision-making regarding the potentialities of proposed projects with regard to delivering intended objectives in the long run.

The validity and reliability of the research tool was demonstrated. A confirmatory factor analysis in further studies is recommended to validate the study.

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Identification of Critical Factors for Construction Megaprojects Success (CMS)

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Abstract

The worldwide growth of construction megaprojects has triggered an increasing number of academic publications in the past few decades. Therefore, this paper aims to systematically review studies on the critical success factors (CSFs) to identify the CSFs for construction megaprojects from academic journals between 2000 and 2018. The research results indicated an increasing research interest in the investigation of critical factors for CMS since 2000. Meanwhile, based on the number of 27 journal articles, a total of 33 CSFs were identified eventually and the top five were adequate resource availability, partnering/relationships with key stakeholders, adequate communication and coordination among related parties, public support or acceptance, and clear strategic vision. A checklist of CSFs for CMS was developed and could render new insight for researchers and practitioners to conduct further studies and enhance megaproject management in practice. Moreover, the results would also enrich the theory of megaproject management.

Keywords

Critical success factors • Construction megaprojects • Megaproject management • Project success

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1 Introduction

Generally, megaprojects are defined as large-scale and complex ventures that cost more than \$1 billion and take many years to build [1]. Megaprojects are intrinsic complexities, risky, and uncertainties. It is worth noting that they are not magnified versions of normal projects but are comprised of interdependent subsystems usually aiming to provide public service and welfare [2]. Typical examples of megaprojects include airports, seaports, dams, high-speed railways, offshore oil and gas extraction, defense projects, the Olympic, ICT systems, and the development of new aircraft [2]. Over the past few decades, an increasing number of megaprojects are being built worldwide. As pointed out by Merrill Lynch, US\$2.25 trillion annually between 2009 and 2012 have been spent on infrastructures in emerging markets [3]. According to the estimation by McKinsey, the world needs no less than US\$57 trillion to the investment of infrastructure construction by 2030 in order to keep the expected growth of global GDP [4].

Given the increasing interest in megaprojects [5], different areas of megaprojects have been researched by researchers worldwide, including megaproject performance [6]; complexity management [7]; relationship management [8]; and so on forth. For the past years, an area of megaproject studies that has received much attention from researchers is on megaproject success. For example, Shenhar and Holzmann [9] pointed out that megaproject success, especially on the CSFs, as a research area should be highlighted for future explorations. The above researches exhibit how researchers are interested in exploring the successful ways of delivering megaprojects. However, despite the increasing interest in success factors for megaprojects, the effort given to the need for review and analysis of what has already been done in literature is still lacking. Therefore, it is of great value to carry out a study on identification of CSFs for megaprojects so as to make an insightful understanding of effective and successful ways of delivering megaprojects.

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2 Research Methodology

In this research, there are major two phases to reveal critical factors for CMS, and this research process was adopted by other existing review work of Zhang et al.[10]. In the first phase, the authors conducted the literature exploration to identify target papers. In the second phase, a descriptive analysis to research the characteristics of the target papers, including the year of publication and distributions of journals. Then, a content analysis was followed by identifying the sub-themes of CSFs. Firstly, Authors conducted a comprehensive literature review on CMS via two academic databases, namely Web of Science and Scopus in October 2018. The first round of electronic search identified a total of 331 journal articles. Afterward, two main criteria were considered in the second round of paper selection. One is that articles should focus on construction megaprojects, and papers not related to the construction projects, such as IT project management, were excluded. The other one is that articles should concentrate on the CSFs. Based on the above-mentioned two selection criteria, after briefly reviewing titles and abstracts, a total of 62 relevant journal articles were left. Next step involved a brief review of the contents to identify irrelevant papers, and the identified journal articles were narrowed to 27 eventually. After identifying the relevant papers, the descriptive analysis was adapted to reveal the characteristics of the identified papers. It is a common method and usually employed in previous review work [10]. Using methods such as frequency count and percentage, the results via descriptive analysis can provide an overview of the annual number of publications and distribution of selected journals.

The content analysis was employed to inductively identify and classify CSFs for construction megaprojects. This method is a structured and systematic approach to compress many words or textural materials into fewer content classifications based on a series of rules of coding [11]. This method has been adopted many times to facilitate the researches in the area of construction and engineering management, such as Zhou and Mi [12]. Preparation, organization, and reporting are regarded as three main processes in content analysis, but there are no standardized rules for conducting the content analysis [13]. In this study, the authors selected a four-step process, including de-contextualization, re-contextualization, categorization and compilation, and assessment of consistency. As stated by Elo and Kyngas [13], these processes not only combine typical content analysis procedures but can provide the most recent strategy for scholars to conduct a qualitative study.

3 Results and Discussions

3.1 Analysis of Annual Publications and the Distribution of Selected Journals

Figure 1 shows the annual number of relevant publications during the selected period. It is worth noting that the figure only illustrates years with publications in this study. As illustrated in the figure, during the selected period of 2000–2018, the number of publications shows an increasing trend from 2004 to 2018. In fact, the rapid increase began in 2012, which then stepped to a peak of five publications in 2017. The above-mentioned result indicates the gradual rising of interest in exploring the ways of delivering construction megaprojects successfully.

It is also not surprising with the above-mentioned data as, after the 2008 global economic crisis, many countries implemented a series of economic stimulus policies, especially on the investment and construction of mega infrastructures. Hence, more attention was paid to research on how these construction megaprojects could be effectively and successfully delivered. According to the research results between 2000 and 2010, only three journal articles were published on CSFs for CMS, which reveals that during these years, research on construction megaprojects could at the infancy stage. However, after 2010, 24 journal articles were published on CSFs of construction megaprojects, this also an indication of the continuously growing of the development of construction megaprojects between these years. It is worth mentioning that the increasing trend of researching on critical factors for CMS would continue since the number of construction megaprojects worldwide is growing, which would spur more studies on CMS for implementing future projects.

What's more, the number of selected articles published in the 22 journals between 2000 and 2018. According to the results, the top six journals, namely International Journal of

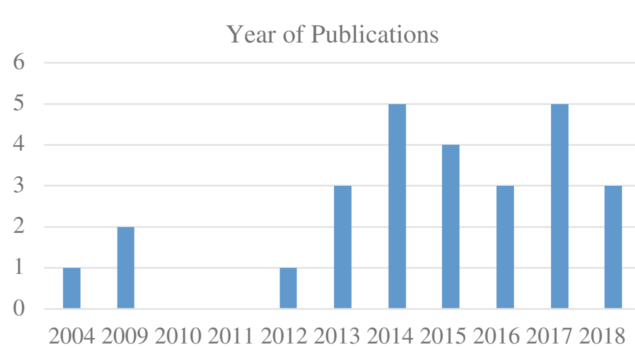

Fig. 1 The annual number of relevant publications from 2000 to 2018

Project Management, Journal of Management in Engineering, Journal of Construction Engineering and Management, Project Management Journal, Construction Innovation, and Engineering, Construction and Architectural Management published the most relevant articles within the selected period (5, 3, 2, 2, 2, 1 articles, respectively). Obviously, among 27 journals, the International Journal of Project Management published 5 target articles, accounting for nearly 18.5% of all 27 papers and contributed the most to relevant research from 2000 to 2018, followed by the Journal of Management in Engineering with three publications ranked the second place.

3.2 Analysis of Findings from Previous Studies on CSFs for CMS

Table 1 shows the findings from previous studies on CSFs for CMS. It is observed from the table that a total of 33 factors account for successful construction megaprojects, however, the topmost 5 factors were adequate resource availability, partnering/relationships with key stakeholders, adequate communication and coordination among related parties, public support or acceptance, and clear strategic vision, with the number of 9, 8, 7, 7, 6 accumulation times, respectively. The adequate resource availability was identified as the significant factors for CMS, with nine times mentioned, accounting for one-third of all selected articles. The resource in the megaprojects generally refers to adequate workers, construction materials, machines, and funding as well. Adequate resource, especially the adequate funds available in projects, is vital to the progress of construction megaprojects. Project funds can be used to purchasing construction materials, machines, and hiring workers, which are the basis for the smooth construction of megaprojects. In practice, interruptions in the supply of project funding could happen for some reasons, such as untimely issued bank loans, and private or governmental funding not in place, which finally affecting the smooth progress of construction or even resulting in a failure. Partnering or maintain good relationships with key stakeholders was in second place with a total number of eight accumulation times. Generally, formal contracts stipulate clear rights and responsibilities of participants in construction projects to ensure the progress of construction activities. Nevertheless, existing studies partnering and good relationships which may beyond contracts, still could play important roles in improving project governance and project efficiency, and contribute to project success finally [14]. What's more, for the consideration of long-term cooperation, partnering or good relationships is encouraged to be implemented. In the Hong Kong–Zhuhai–Macau Bridge, a kind of partnering that called a partnership based on the strict implementation of contractual agreements was encouraged to implement. Different from the traditional relationships among project participants in megaprojects, under this kind of partnership, organizations involved in the megaproject were expected to be viewed as a union and made their best efforts to complete this super bridge [15] publications. Lacking cross-functional communication is identified as one of the main obstacles to maintaining the effectiveness of the organization. On the contrary, timely and effective communication between project teams can greatly improve project success. Considering the construction megaprojects involve numerous participants in the progress of megaproject construction, it is not surprising that communication and coordination are of great importance to the successful outcomes. Moreover, as pointed out by Hu et al. [5], regular and informal meetings, newsletters, training programs, joint working activities, and emergency drills with government agencies and contractors were highlighted to improve communication and coordination among key stakeholders in megaprojects.

Public support or acceptance was also one of the most important factors for CMS, with the number of 7 the same as that of adequate communication and coordination among related parties, ranked as the third place. The acceptance and understanding by the public are rather important in ensuring the progress of megaprojects since the public is a necessity to establish a harmonious and stable environment for the construction of megaprojects, especially when some construction work that may have a seriously negative impact on people's living surroundings. And meanwhile, the public support at initial stages could reduce delays, such as land acquisition and immigration work for project development [16]. For instance, the megaproject "Three Gorges Dam" in China involved a large amount of immigration work, and the support of immigrants became one of the critical factors determining the success of this project.

A clear strategic vision was mentioned six times in the literature review. A vision can be defined as a simple and exciting expression of project results. The strategic part refers to that the project sets a very desirable and important long-term goal which is expected to have a lasting impact beyond its immediate outcome [9]. A strategic vision of construction megaprojects is always presented in a visual and emotional way and can be acted as a strong link to exceptional leadership. Good leaders know how to use the strategic vision to effectively motivate the people involved in the construction projects, and meanwhile, they are able to combine the vision with the right strategy to implement.

Table 1 Findings from studies on critical success factors for CMS from 2000 to 2018

CSFs	Publications																											Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
Adequate resource availability		✓				✓	✓										✓		✓	✓		✓		✓			✓	9
Partnering/relationships with key stakeholders	✓	✓		✓											✓		✓		✓			✓		✓				8
Adequate communication and coordination among related parties	✓	✓				✓	✓									✓	✓										✓	7
Public support or acceptance		✓							✓					✓			✓		✓	✓					✓			7
Clear strategic vision	✓	✓				✓													✓					✓		✓		6
Project manager competency		✓				✓											✓		✓					✓				5
Governance	✓									✓		✓							✓	✓								5
Top management support from key stakeholders		✓				✓											✓				✓			✓				5
Aligned perceptions of project goals and success						✓	✓										✓		✓							✓		5
Clear goals		✓				✓											✓			✓				✓				5
Effective risk management		✓			✓						✓						✓	✓										5
Competitive and transparent procurement process						✓													✓			✓		✓			✓	5
Leadership	✓														✓		✓	✓										4
Learning from previous experiences						✓											✓		✓					✓				4
Effectively address complexities					✓						✓						✓					✓						4
Scope management	✓												✓						✓			✓						4
Well-formulated and detailed contracts						✓							✓						✓					✓				4
Effective strategic planning																			✓			✓		✓			✓	4
Government support																			✓	✓				✓			✓	4
Capabilities of the owner		✓	✓																		✓							3
Positive organizational culture for effective project management						✓			✓										✓									3
Project size		✓											✓									✓						3
Right project identification and project technical feasibility		✓				✓											✓											3
Innovation strategies and practices	✓							✓															✓					3
Full understanding of cultural, financial and legislative requirements	✓																✓								✓			3
Mutual trust among project stakeholders						✓						✓																2
Systematic control and integration mechanisms																	✓							✓				2
Using up to date technologies						✓																		✓				2

(continued)

Table 1 (continued)

CSFs	Publications																											Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
Capabilities of contractors		✓																										1
Project organization structure	✓																											1
Great organizational support																					✓							1
Awarding bids to the right designers/contractors						✓																						1
Economic and political stability																			✓									1

4 Conclusions

This paper reviewed 27 relevant journal articles published from 2000 to 2018 to investigate the status quo of studies on CSFs for CMS. The main results revealed an increasing interest in the research on CSFs for CMS during the selected period A total of 22 journals were identified as the publication sources for the target articles and top 6 were International Journal of Project Management, Journal of Management in Engineering, Journal of Construction Engineering and Management, Project Management Journal, Construction Innovation, and Engineering, Construction and Architectural Management. Meanwhile, a total of 33 CSFs were explored and the top 5 were discussed, namely adequate resource availability, partnering/relationships with key stakeholders, adequate communication and coordination among related parties, public support or acceptance, and clear strategic vision.

This study contributed to the body of knowledge in two ways. On the one hand, the findings revealed in this research have provided a solid foundation for future studies on relevant topics. For instance, a list of identified journals could be useful for researchers to acquire and publish studies on CSFs for CMS. On the other hand, the paper identified a list of 33 CSFs for CMS which was expected to be regarded as the checklist of CSFs for practitioners to check project activities in practice in order to improve the success of construction megaprojects. These research findings would help industry professionals and academic scholars to manage megaprojects in a more effective way and improve the possibility of CMS. Meanwhile, the results could also enrich the existing theory of megaproject management.

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Investigating the Criticalities of Corruption Forms in Infrastructure Procurement in the Developing Regions

Emmanuel Kingsford Owusu, Albert Chan, David Edwards, and Gabriel Nani

Abstract

This study examines the criticalities of the forms of corruption in infrastructure project procurement. Using non-probabilistic sampling techniques, 62 experts involved in infrastructure procurement processes participated in the study by evaluating the criticalities of the forms. The variables captured under the constructs of the forms of corruption were identified via the review of pertinent literature. They were empirically examined after being evaluated by the experts involved in the survey. A total of 27 variables were identified and examined. From the analysis, bribery, lobbying, and price-fixing were identified to be the most critical forms within the developing context. This study intends to contribute to a deepened understanding of corruption-related attributes in construction project management. It also offers valuable information to practitioners, particularly from the developing regions on the critical forms of corrupt practices within the different stages of the procurement process and the need to mitigate their incidence and widespread strategically based on informed decisions.

Keywords

Corruption • Infrastructure • Construction • Project Management • Developing Countries

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1 Introduction

Corruption in a project can be defined as the abuse of a project's resources for illegitimate personal gains (Lee et al. 2014; Owusu et al. 2019b), and it remains one of the most critical issues not only in governments or at the national level but also at the institutional and project levels. It distorts the eternal triangle or aim of every construction project (i.e., cost, time, and quality). Corruption results in excessive spending, as opposed to the estimated allowable budget for a project, cause project delays and substandard execution of projects (Tabish and Jha 2011; Owusu et al. 2017). In other critical cases, corruption has been linked to the collapse of either ongoing or completed projects due to non-compliance to contractual specifications and standardized modus operandi of project planning and construction. A typical example is the collapse of the Rana Plaza commercial building in Bangladesh that recorded a death toll of more than 1,100 people with several others injured (Aljazeera 2017).

The first case of corruption recorded existed in the form of bribery (Noonan 1984). Bribery has, therefore, been tagged as the form of corruption with long-standing recognition (Chan and Owusu 2017). However, due to the evolution of corruption over the years, different forms of corrupt practices have emerged across diverse contexts (Jain 2001). For instance, in the context of procurement, some notable forms of corruption include bid suppression and rigging, solicitation, and extortion, among others (Lee et al. 2014).

All these practices and effects do not just happen in a vacuum. They are instigated by three primary theoretical constructs of corruption, namely the causal factors of corruption (Lee et al. 2014; Locatelli et al. 2017), risk indicators, vulnerabilities, or irregularities associated with project procurement and construction (Owusu et al. 2019b; Tabish and Jha 2011) and the barriers that hamper the efficacy of anti-corruption measures (Bowen et al. 2012; Owusu and Chan 2018). All these three theoretical constructs are still receiving a great deal of devoted attention by scholars even

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though new studies are yet to be conducted on the criticality of these constructs. Particularly on the specific stages of the construction process as well as how these factors can be thwarted. Moreover, despite the attention devoted to the explorations of the various constructs of corruption such as the causal factors of corruption and their corresponding risk indicators, the empirical assessment of the criticalities of the various corruption forms remains unexplored. The exploration of the forms of corrupt practices in infrastructure projects is needful for future endeavors such as the development of focused anti-corruption measures, provide a deepened understanding of the various forms of corrupt practices and facilitates the performance of in-depth research on the subject matter. This study is, therefore, intended to deepen the understanding of the subject matter and provide valuable information to project participants, policymakers, anti-corruption activists, and other key stakeholders involved in infrastructure projects on the criticality of the various corruption forms in projects and the need and efforts to extirpate them.

2 Methodology

2.1 Research Design

A questionnaire survey was conducted to solicit views from the experts concerning the forms of corrupt practices captured in this study. The underlying measurement items used to develop the questionnaire was adapted from the study of (Chan and Owusu 2017). The items are identified to be the prevalent forms of corruption in the procurement of construction and other infrastructure-related works. While the study of (Chan and Owusu 2017) reported over 28 prevalent forms of corrupt practices, this study made use of 27 forms discarding one of the forms known as *'guanxi'*. This form is noted to be a context-specific form common within the Chinese context. Thus, not entirely applicable to the Ghanaian context. The survey respondents were asked to rate the levels of criticalities of each of the 27 forms based on a 5-point grading scale (1 = not critical and 5 = very critical). The use of questionnaires was adopted because they offer a valid and reliable source of information and is less costly (Owusu and Chan 2018). Moreover, a questionnaire survey, to a large extent, warrants anonymity and the protection of respondents' data, especially on a sensitive topic of this nature (Ameyaw et al. 2017).

2.2 Survey Participants

The respondents for this survey comprised of academics and practitioners involved n the procurement and delivery of construction projects in Ghana. The criteria of experts selection were limited to one's possession of a wealth of experience and knowledge on the processes involved in the procurement and management of construction works, and familiarity with the dynamics and stipulations or unethical practices binding contractual and procurement works. A non-probabilistic sampling technique known as purposive sampling approach was adopted for this study. The snowballing technique is believed to also commence at some point since the respondents were requested to invite their colleagues possessing similar skillset to respond to the questionnaire. Even though the topic of corruption may be considered as a general concern and therefore the questionnaire could be answered by any person from the general public, it often becomes difficult to explicate, especially when viewed under a specific context. For instance, the subject of corruption observed in this study is captured under the domain of construction procurement and management. Therefore, any potential respondent should be able to understand the complexities involved in the procurement process from the pre-contract stage to the post-contract stage and the construction process which includes project design and execution, contract closeout, and dispute resolution. This kind of knowledge is not common to the general masses even though the subject of corruption remains a social issue and some may understand the concept of corruption in the general setting but not in a defined context of expertise.

After the pilot study, expert survey, retrieval of the questionnaires, and the assessment of the initial data to address any discrepancy that may negatively affect the data; 62 responses were regarded to be valid and suitable for further analysis. While over 200 experts were invited, 91 responses were retrieved. And out of this number, 62 responses were regarded to be valid for further analysis. The survey was conducted using practicing construction professionals, including civil engineers, quantity surveyors, architects, contractors, and academics. Whereas the academics involved were identified through their publications on the subject matter, the industrial experts are senior managers of both private and public sector domains involved in the procurement, execution, and the management of construction and other infrastructure works. The overall biodata of the respondents is presented in Table 1.

3 Discussions

The categories developed in the study of (Chan and Owusu 2017) were maintained to ensure consistency. As a result, the five main constructs, in addition to the unclassified construct, were empirically assessed. They are bribery acts, collusive acts, fraudulent acts, discriminatory acts, and

Table 1 Respondents' data

Sector	Public	20	32.26	32.26
	Private	30	48.39	80.65
	Both	12	19.35	100.00
	Total	62	100	
Professional background	Civil Engineer	17	27.42	27.42
	Quantity Surveyor	31	50.00	77.42
	Contractor	4	6.45	83.87
	Architect	7	11.29	95.16
	Academics	3	4.84	100.00
	Total	62	100	
Years of experience	Up to 10 years	45	72.58	72.58
	11–20 years	12	19.35	91.94
	21–40 years	5	8.06	100.00
	Total	62	100	

Source Field data

extortionary acts. However, only the top three constructs are discussed due to word count or page limitation. Table 2 presents the descriptives of the athered data. It must be emphasized that the list was adapted from (Chan and Owusu 2017).

3.1 Bribery Acts

Albeit, bribery acts' construct was not anticipated to emerge as the most critical construct, especially when the entire construction and procurement activities and stages are identified and reported to be plagued with collusive and fraudulent acts (Shan et al. 2016). However, the bribery acts' construct was revealed to be the most critical construct among all the forms of corrupt practices. It also emerged as one of the two constructs with their entire variables identified or noted to be critical. However, unlike the results ascertained regarding the most discussed construct of corruption forms, the bribery acts construct was identified to be the third most discreet construct. Thus, while other constructs are widely discussed as compared to the bribery construct, the bribery construct was empirically identified to be the most critical in the context of the developing countries such as Ghana (Ameyaw et al. 2017). From the descending order of criticalities, the bribery variable was empirically assessed to be the most critical with a criticality index of 4.02 followed by lobbying, facilitation payments, kickbacks, solicitation, and influence peddling with their criticality indexes at 3.81, 3.79, 3.74, 3.66, and 3.65, respectively, as indicated in Table 2.

The realization of the bribery acts construct was not all surprising as the construct and its attributes are noted to be the most long-standing variants of all forms of corruption (Noonan 1984). Moreover, the form 'bribery' was assessed by the experts to be the most critical form of corruption, not only under its construct but also among the entire 27 forms of corrupt practices. The promising and offering of rewards (most typically, in monetary terms) to entice officials with delegated authority (e.g., the tender adjudication panel member(s) or committee to illegally award a contract to the supply-side (briber) of the corruption process is a common practice in the Ghanaian public project processes (Ameyaw et al. 2017). And as indicated, this is expressed in the other forms such as lobbying (distorting or negatively influencing, the policies of an institution to one's favor), facilitation or grease payments and kickbacks (Chan and Owusu 2017). However, inasmuch as these forms have been indicated or identified to be the most critical in the developing context, their generic criticalities may be argued out to be a common knowledge which does not contribute that much toward the mitigation of their influence and negative impacts in the modus operandi of the processes involved in a project. Thus, the needed attention or the next line of focus toward the exploration of this construct and its variables cannexamine their criticalities at the different stages of the project processes and the mechanisms needed to limit the irregularities and the opportunities that create room for any of these forms of corrupt practices. However, this recommendation does not only apply to this construct (i.e., the bribery acts' construct) but all the other forms of corrupt practices.

3.2 Collusive Acts

As indicated in (Chan and Owusu 2017), while the construct of collusive acts tends to be stand-alone, it is viewed by different scholars and reports as the most mentioned form of

Table 2 Descriptive of the variables (criticalities of the forms)

No.	Variables	Mean	N-V	SIG	SD	OR	CR
1	Bribery	4.02	1.00	0.000	1.12	1	1
2	Lobbying	3.81	0.76	0.000	1.07	2	2
3	Facilitation payments	3.79	0.74	0.000	1.18	4	3
4	Kickbacks	3.74	0.68	0.000	1.24	7	4
5	Solicitation	3.66	0.59	0.000	1.28	9	5
6	Influence peddling	3.65	0.57	0.000	1.22	10	6
7	Front/shell companies	3.63	0.55	0.000	1.24	11	1
8	Collusion	3.58	0.49	0.000	1.03	14	2
9	Fraud	3.53	0.44	0.003	1.38	15	3
10	Ghosting	3.52	0.43	0.001	1.20	17	4
11	Dishonesty	3.44	0.33	0.007	1.24	18	5
12	Deception	3.37	0.25	0.020	1.22	20	6
13	Money laundering	3.27	0.14	0.129	1.41	23	7
14	Price fixing	3.81	0.76	0.000	0.99	3	1
15	Bid rigging	3.76	0.70	0.000	1.11	5	2
16	Cartels	3.26	0.13	0.08	1.14	24	3
17	Coercion	3.34	0.22	0.05	1.31	21	1
18	Blackmail	3.29	0.16	0.09	1.31	22	2
19	Extortion	3.24	0.10	0.13	1.22	25	3
20	Client abuse/clientelism	3.19	0.05	0.22	1.24	26	4
21	Intimidations and threats	3.15	0.00	0.33	1.16	27	5
22	Favoritism	3.68	0.61	0.00	1.17	8	1
23	Nepotism	3.58	0.49	0.00	1.18	13	2
24	Patronage	3.44	0.33	0.01	1.22	19	3
25	Conflict of interest	3.74	0.68	0.00	1.13	6	1
26	Embezzlement	3.61	0.53	0.00	1.08	12	2
27	Professional negligence	3.52	0.43	0.00	1.35	16	3

fraudulent acts. Thus, these two are correlated with each other as collusive practices fall under the construct of fraudulent practices. With an overall criticality index of 3.61, three main forms are captured under this construct, namely price-fixing, bid-rigging, and the influence of cartels (Brown and Loosemore 2015; Chan and Owusu 2017). However, two out of the three forms were revealed to be critical, as assessed by the experts involved in the survey. They are (1) price-fixing, with a criticality index of 3.81 followed by bid-rigging with a criticality index of 3.76. Inasmuch as these variables or forms have been indicated by the experts to be critical, one will hardly find forms like price-fixing or cartels being reported in the news due to the subtle or clandestine nature as well as the ingrained endemic culture of corruption within the project-context of most developing countries such as Ghana (Ameyaw et al. 2017). Taking price-fixing as an example, unless one of the members of the cartel is willing to betray the rest of the team responsible for fixing prices, it is often difficult or challenging to discover such acts. It is, however, obvious that these forms of corrupt acts are often prevalent at the pre-contract stage of a project where tenders are advertised and solicited (Owusu et al. 2019a). Thus, measures taken toward the extirpation of collusive practices as mentioned above may consider not only the generic connotations and incidences but also needful to strategically target the specific stage (with the respective activities) within which these forms occur. For instance, given that bid-rigging occurs when consenting parties (from both the consulting and contracting teams) meet to settle on the bid results beforehand, how can this be stopped? Or what mechanism can be established to limit the opportunities that create room for corrupt practices of this nature to happen? Adopting transparency mechanisms have been suggested as one of the good approaches to limit such acts (Lee et al. 2017; Tabish and Jha 2011). However, the adoption and modes of applications remain challenging, again due to the clandestine nature of corrupt practices (Bowen et al. 2007; Zhang et al. 2016).

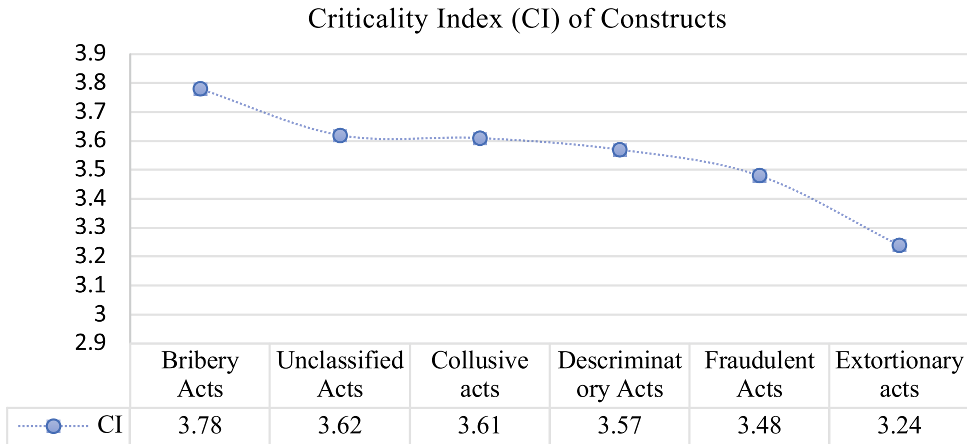

Fig. 1 Criticality Index (CI) of constructs *Source* Field data

3.3 Unclassified Acts (Professional Malfeasance Acts)

This construct contains stand-alone variables. Thus, as explicated at the literature review section, the construct was labeled unclassified because a common name was not developed. Three variables were captured under this construct, and they were all revealed to be critical in the developing context. According to the rating of the experts, the three variables captured under this construct together with their criticality indexes are (1 conflict of interest, noted as the most critical variable under this construct with a criticality index of 3.74) embezzlement with a criticality index of 3.61) professional negligence also with a criticality index of 3.52. Commencing from the most critical within this construct, the incidence of conflict of interest (defined as either any condition where a person or the organization within which they work is faced with choosing between the demands and duties associated with their work in contrast to their interests, within the public projects in the developing context is a common phenomenon (Owusu and Chan 2018; Owusu et al. 2019a).

The other forms captured under this construct, namely embezzlement and professional negligence share some common characteristics with conflict of interest in that all the three classes of corrupt parties are not supposed to be present for these forms of corruption to occur. In essence, one party (the corrupt party) is the key player in all the three forms of corruption captured under this construct. For instance, unlike bribery, collusive and discriminatory acts where there should be at least two consenting parties, the forms under this construct epitomizes the misappropriation of power by just in an individual with either absolute or delegated power. In the instance of embezzlement, a single person holding an either an authoritative or a delegated power (i.e., either project managers or employees) position illegally uses, misappropriates or traffics the resources entrusted in his care but intended to complete the project for his interest (Owusu et al. 2019a).

Again, similar to the conflict of interest, the acts of embezzlement also distort or compromises on the actual intended purpose of the projects' resources (Owusu et al. 2019). Same goes for professional negligence where a careless act of a professional creates a vulnerable room for the intended purpose of project resources to be misappropriated (Chan and Owusu 2017). However, unlike the first two variables where the actors or professionals involved are mostly intentional about engaging in such acts, professional negligence can either be intentional or unintentional. Thus, the development of effective measures to curb the incidence and proliferation of these forms may consider not only the intended negative acts from the professionals but also the proactive measures to curb or mitigate the unexpected shortcomings of professionals that carry the potency of distorting any of the processes involved in a project. The mean values of the constructs are presented in Fig. 1.

4 Conclusions

This study examined the criticality of the forms of corruption in the infrastructure procurement process. Following a comprehensive review conducted by (Chan and Owusu 2017), this study extended the previous knowledge by conducting an empirical examination of the forms which was not conducted in the previous study. The empirical examination was conducted using experts involved in the procurement and management of infrastructure works in Ghana. The experts were sampled purposively (a non-probabilistic sampling) because of the expertise needed to respond to the survey. A total of 62 responses were noted to be valid and appropriate for further analysis. Per their assessment, the top three critical constructs were bribery acts, professional malfeasance acts, and collusive act. This study is intended to extend the current study on the forms of corruption and offer valuable source of information to project parties and anti-corruption activists on the criticalities of the identified forms in the context of developing regions. Future studies can examine the criticality of each form at the various stages of the procurement process as informed by big data on actual cases. This study can, however, serve as a source of reference to instigate more specific and focused works in other contexts. It is also intended to deepen the understanding of the subject matter and provide valuable information to project participants, policymakers, anti-corruption activists, and other key stakeholders involved in infrastructure projects on the criticality of the various corruption forms of corruption in projects and the need and efforts to curb them.

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Benchmarking Project Manager's Compensation

Khalid Siddiqi and Enes Kol

Abstract

The US construction industry has faced fluctuating economical periods in the 21st century. In 2008, the industry decline was so extreme that it not only affected the construction industry but also the entire economy of the nation. Those fluctuations affected many aspects of the construction industry, compensation rates were one of the most impacted areas. With the construction industry's fragile and highly connected nature to economic trends, it became harder to determine remunerations of the workers in the industry. This study focuses specifically on construction project managers' (PM's) compensation. The objective of this study was to benchmark project manager's compensation in general contracting firms. The intended audience are GCs or human resource departments of general contracting firms. The data was collected from privately-held Georgia-based general contracting companies in a survey conducted in 2016. The study analyzed PM's compensation rates alongside industry and market statistics to identify correlating trends. The results of the study add to the field of business and management practices in construction. The results provided patterns of compensation for PMs in the construction industry. The study concludes that PM compensation is not determined only by the size of an organization, but it depends on a set of organization specific factors including gross revenue earnings, and experience (age).

Keywords

PM compensation • Benchmarking • Project manager • Construction industry • General contracting

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1 Introduction

The objective of this study was to benchmark project manager's compensation in general contracting firms. The study analyzed PM's compensation rates alongside industry and market rates to determine correlation ship or trends for GCs or human resource departments of general contracting firms. The aim of the study was to augment business and management practices in construction industry. The findings from this study provided patterns of compensation for PMs in the construction industry. One major finding was that PM's compensation is not determined only by the size of the organization, but it depends on a set of organization specific factors including gross revenue earnings, experience, and age of the organization.

After the recent recession, there were a lot of changes in many businesses in terms of employment, salary ranges, skilled labor, and more. This impact was more visible in construction and construction related businesses which led employers to rethink and reinvent their operations and organization behavior. This changed a lot of variables in construction and resulted in making operations more viable. All aspects of the construction industry became sensitive to survival of the fittest theory and therefore, very little data was available to benchmark PM Compensation in the post-recession period.

While peer-group benchmarking is still partially grounded in organization size and industry peers, the practice has greatly evolved over the years, with other factors such as performance, complexity, global operations, or credit ratings being increasingly used as criteria for benchmarking, irrespective of an organization's parent industry (Bizjak 2011). As stated above, it is common for companies to have benchmarking to improve viability of an organization. It can be related with a variety of factors and compensation should be considered as one of them. "The demand for benchmarking at a firm can come from a variety of factors such as regulatory issues, liability concerns, investor concerns,

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competitive pressures, and public perception (Tosi 1973)." As mentioned, it is not only restricted with certain topics which let us to broaden the factors and come up with more efficient solutions.

Furthermore, even in healthy economies it is a hard job to do comprehensive study about compensation benchmarking since there are a lot of variables that impact these studies. As, Michael Thom and Thom Reilly state in their study; "But by all accounts, making such comparisons is challenging. Job classifications differ, and even when attempting to match salaries for comparable positions, certain duties and required education levels can vary. Comprehensive assessments must also go beyond simple wage comparisons to include additional elements of compensation, including fringe benefits, employee tenure, performance, and retirement policies (Reilly 2015)."

The compensation benchmarking was necessary to improve organization gains. It also serves as an element to settle efficient pay rates in order to maximize company's performance. As stated by Shin, "Firms use benchmarking to maintain the competitiveness of pay packages and retain managerial talent (Shin 2013)." Compensation benchmarking benefits the organizations not only monetarily but also in a variety of ways such as productivity and retention of key employees. However, being micro-economic oriented (i.e., assessing only firm and industry specific influences), hegemony and agency perspectives do not offer a comprehensive explanation for the evolution of CEO compensation across firms and industries (Sujit Sur 2015). In fact, this conclusion was also valid for project managers and for other fields too. There were very few reliable sources available for executive compensation comparisons.

Additionally, there was another challenge, which was mentioned by Gomez-Mejia "…the empirical evidence to date regarding the sales versus profit maximization hypothesis as a determinant of executive pay level is mixed at best (Gomez-Mejia 2010)." However, they contend that there is a large link between firm size and CEO pay and a marginal one between firm performance and CEO pay (Tosi 2000), which lead us to use that example for determining project managers' compensation in construction (Tosi 2000). Yet, it is stated that "…challenge future compensation scholars to develop more complete theoretical and empirical support and validation capable of guiding researchers' choice of performance measures, timeframes, samples, methods, and variables (Devers 2007)."

One study by Bender (Bender 2013), examined the determinants of executive remuneration consultants' advice. The study found out that remuneration consultants take into account the size and ownership of the company, the company's business and strategy, the company's culture and organization, the impact of individuals on the process and scheme and the scope of the assignment to be able to advise the remuneration committee on executive pay structure and levels (Ndzi 2015). In this study, all the variables mentioned were kept constant except organization size in order to benchmark these compensations. By doing so, companies were analyzed as independent variable where the salaries of the project managers were considered as the dependent variable.

2 Research Methodology

2.1 Data Collection

In order to benchmark project managers' compensations, a wide range of data was collected with a survey conducted in 2016 (Bennett Thrasher and Kennesaw State University 2016). Over 2,300 companies were contacted across Georgia with 81 contracting companies participating in the survey. First, participants were asked to state their company type whether it is general or specialty contractors in order to prepare appropriate results. The data collected was from forty Georgia-based general contracting companies and 41 specialty contractors. The survey included a wide range of contractors' annual revenue that ranged from 5million dollars in gross revenue to more than 100 million dollars in gross revenue with responses ranging from 16 of the general contracting companies. Given the results, it became clear it was important to benchmark project manager's compensation in relation to company size.

2.2 Data Analysis

According to the results of the survey, the data collected was analyzed in terms of size of the organizations in relation to the project managers' compensations. In order to tabulate the results, company size was taken as an independent variable where the compensation of the project manager of that company was considered dependent variable. The change between these two variables was mapped to benchmark the PM Compensation. Company size was defined based on the yearly gross revenue of each organization.

In order to analyze the data, the annual gross revenues of the general contracting companies were divided into six groups. The group categories were named as: Under $5 million, $5–9.9 million, $10–24.9 million, $25–49.9 million, $50–99.9 million and more than $100 million.

The organizations that accrued less than 10 Million $ gross revenues were categorized as small-size organizations whereas those with 10–25 Million $ gross revenue were categorized as mid-size and the ones with gross revenue greater than 25 Million $ were categorized as large-size organization.

Additionally, considering end-user perspectives and to relate the results more appropriately with the prevailing trends for construction types, commercial and heavy civil contractors were analyzed separately for small and mid-size organizations.

3 Results & Inferences

First, the project managers of each contractor type were determined. According to the results, it has been understood that project managers working for heavy civil contractors are getting paid more than the others with an average payment of $112,800 annually. Project managers that are working for general contractors has the second highest payment rates where they got paid $76,264 average annual payment. Finally, project managers that are working for specialty contractors are getting paid an average payment $69,643 annually (Fig. 1).

After project manager's salaries matched with the contractor types, the study also examined the relationship between gross revenues and PM's salaries and then also compared the same with the organization expertise.

According to the results of the survey as shown at Table 1, the PMs compensation tends to increase between the companies which have less than $5 million gross revenue to $10–24.9 million and then decrease for the companies with $25–49.9 million. It again increases for the companies with more than $100 million gross revenue (Fig. 2).

Organizations with $10–24.9 million gross revenue tend to pay more to their project managers as compared to less than $10 million and $25–99.9 million. However, the organizations with the revenues more than $100 million are the ones who pays the most.

It has been shown that project managers compensation reflects an increasing trend for small-size construction organizations with gross revenue increase. The gross revenue of the organization and PMs compensation increases together with the company sizes until the organization become mid-size which is between $10–25 Million. After that point onwards, the gross revenue increase of the organization starts affecting PMs compensations negatively until the organization reaches large-size category. When an organization reaches large-size category, compensation for the project managers again begins to increase with the increase in gross revenue earnings. Additionally, it was observed that organization's years of experience and field focus can affect this trend too. Hence, the PM's compensations and company experience in different contracting types was also examined and compared (Fig. 3).

The results show, the company experience and the gross revenue increase has the same impact on the PM's compensations in commercial contractors while the same relationship was not found true for heavy civil contractors (see Fig. 4). For heavy civil contractors, the project manager's compensations showed an increasing compensation trend with the organization experience until it reached 30 years of experience, and then the organization tends to pay less for their project managers according to the findings from this study (Fig. 5).

The results for specialty contractors matched the trends shown in findings from commercial contractors to some extent. PM compensations belonging to specialty contractors showed increasing salaries with the experience of the organization until the companies achieve 15 years of experience. Thereafter, the curve shows a slight dip or stagnation of salaries for organizations from 15–30 years of experience. Another interesting finding is that an organization's experience and gross revenues has the same impact on project manager's compensation for commercial and specialty contractors, whereas the salaries decrease after an organization reaches closer to large- size gross revenue earning category.

4 Conclusions

The findings discussed above clearly show different trends in PM's compensation for those belonging to mid-size organizations versus high or low gross revenue earning entities.

Table 1 Company sizes and PMs compensations

Company size	PMs compensations	Avg.
Under $5 Million	$32000, $55000	$43500
$5–9.9 Million	$55000, $78000, $66000, $15000	$87250
$10–29.9 Million	$83000, $135000, $70000, $65000	$88250
$25–49.9 Million	$84000, $80000	$82000
$50–99.9 Million	No data	–
More than $100 Million	$100000, $95000, $150000, $100000	$111250

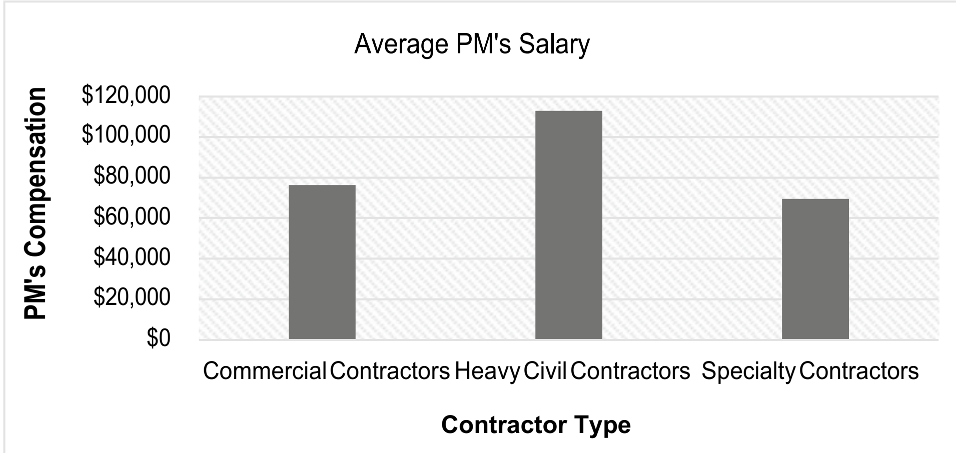

Fig. 1 Average project manager salary for different contracting company types

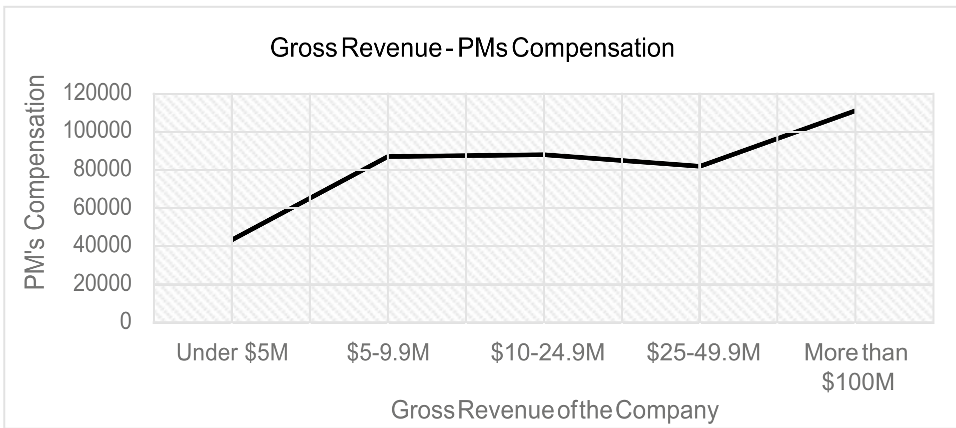

Fig. 2 Gross revenue - PMs compensation

Fig. 3 Commercial Contractors PM's Salary versus Company Experience

Fig. 4 Heavy Civil Contractors PM's Salary versus Company Experience

Fig. 5 Specialty Contractors PM's Salary versus Company age

Based on the above findings, PMs could expect to have increasing salaries while the organization continues to grow its earnings until it reaches the category of mid-size organization. For mid-size organizations, it was found that project managers' salaries have inverse relationship with company's gross revenue increase as the company's revenue gets closer to be Large-size organization earnings. It is important to note that gross revenue range of organizations influence the way project managers got compensated, however, these trends vary with the size and experience of the organization.

5 Future Recommendations

The salary-decrease phenomena taking place in mid-size contracting organizations even when revenues are increasing needs to be investigated in greater depth. The objective of such a study in future could be to determine the causes in salary decrease of project managers despite revenue growth in an organization. The salary drop between mid-size organizations versus others could also be related to its growth rate and investment in a future study. The anomaly of the middle-income trap theory from the principles of macroeconomics, needs to be investigated further for construction contracting organizations.

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Are the Ageing Workforce Satisfied with the Construction Work Environment?

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Abstract

The construction industry is experiencing a shortage of workforce and skill gap due to the significant reduction in the younger workers entering the construction industry compared to the exponential number of retiring workers. Providing ageing workforce with a satisfactory construction work environment (CWE) can be one of the ways to encourage them to remain in the construction industry. Therefore, this study aims to assess the level of satisfaction of the ageing workers with the CWE. The study adopted a quantitative approach and data was sourced from older construction workers in Edinburgh, Scotland using a questionnaire survey. Factor analysis and mean score analysis were employed to assess the older workers level of satisfaction with the CWE. The study identified five components of the CWE termed as organisational-psychological environment, physical environment, functional environment, policies and practices environment and auxiliary environment. The older workers were most satisfied with the functional environment, followed by the auxiliary environment, policies and practices environment, physical environment and lastly, organisational-psychological environment. The study recommended that the construction industry put in more effort in making the CWE very satisfying to all workers especially the ageing workforce. A very satisfying CWE should compensate and amend the losses accompanying ageing. The authors encourage future studies to explore the relationship between the level of satisfaction with the CWE and the quality of life of the ageing workforce.

Keywords

Ageing • Older workforce • Construction work environment • Construction industry

1 Introduction

Population ageing has been one of the most significant social transformers of the twenty-first century with implications on virtually all sectors of the society, including the labour and financial markets, demand for goods and services and family structures (United Nations 2015). The labour market will experience a shortage of workforce and skill gap in the next few years because the number of young people entering the workforce will significantly reduce compared to the number of people retiring (McNair and Flynn 2006). The proposed solution to this dilemma is to make better or more flexible use of older workers and encourage them to stay in work longer (McNair and Flynn 2006). Interestingly, the population of older workforce that forego retirement is increasing exponentially due to changes in retirement policies (Choi 2015). The trend of the aged remaining in the workforce has the potential to improve a nation's economy. Consequently, companies support the initiative of retaining their older employees due to the valuable knowledge and experience they possess Choi (2015), Leaviss et al. (2018). This implies that within the next few years the current workplaces need to be re-designed not just to accommodate the ageing workforce but also to improve their quality of life (QOL), so they can age healthy and remain in the workforce for as long as possible. Therefore, the present study aims to assess the level

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of satisfaction of ageing workforce with the construction work environment.

1.1 The Construction Work Environment (CWE)

The environment has been generally agreed as one of the important domains of QOL WHO (1996), Varghese and Jayan (2013). However, the CWE is one of the most hazardous in almost every country. The picture painted is always a poor work environment. The nature of work in the CWE is described as tough, heavy and physically demanding Schwatka et al. (2011), Eaves et al. (2016). The CWE is unfavourable for workers of all ages; however this environment can only catalyse the deteriorating ageing changes of ageing workforce (Eaves et al. 2016). The proposed solution to this dilemma is to properly evaluate and modify the CWE to complement the needs of the ageing workforce (Leaviss et al. 2018).

As increasing older construction workforce forgo retirement and spend most of their time on construction site, they will need to depend on the environment on construction sites to overcome or compensate for the multiple and increasing physical impairments such as vision, hearing, strength, balance, and response time (van Hoof et al. 2009). Environmental psychology researchers have devoted attention and resources on researching about the influences of the built and natural environments on the health, comfort, safety, behaviour and attitudes of occupants (Vischer and Wifi 2017). According to environmental psychologist, QOL largely depends on understanding the needs of the older workforce. The degree to which the older workforce needs are met determines their QOL (Vischer and Wifi 2017). This means that providing a healthy and comfortable CWE is fundamental to promoting and maintaining the QOL of not only the older workforce but also, the younger workforce. In relations to this study, the CWE facets are the approaches, support services, adjustments, practices, policies or procedures that organisations implement which can positively or negatively impact the health, safety, comfort, productivity and QOL of older workforce (adopted from Choi (2015), Vischer (1989)). The rationale is to improve person-environment fit by identifying facets in the CWE that affects fit between the older workforce and the CWE. Upon a critical literature review, 18 CWE facets were identified. These facets are listed in Table 1.

2 Methods

A total of eleven ongoing construction projects in Edinburgh, Scotland were invited to participate in the study. However, only five agreed to participate in the study. Purposive sampling technique was used to select older workers amongst all worker in the five construction projects. Older workers refer to participants who were aged 40 years and above (Leaviss et al. (2018), Buckle et al. (2018)). A total of 100 questionnaires were administered to older workforce, and 38 completed questionnaires were retrieved, representing a response rate of 38%. Albeit the sample size was relatively small, statistical analysis could still be performed because according to the generally accepted rule, with a sample size of 30 or above, the central limit theorem holds (Ott and Longnecker 2010). A five-point Likert scale ranging from 1 (very dissatisfied) to 5 (very satisfied) was used to determine how the older adults were satisfied with the facets shown in Table 1. Due to a large number of variables (18 facets), factor analysis was used to identify facets that measure the same underlying construct.

3 Results

The overall Cronbach alpha value of the 18 facets is 0.853 which is higher than 0.7. This implies that there is a good internal consistency and reliability with the dataset and the five-point Likert scale adopted for the study (Field 2005). The KMO value for the 18 facets is 0.616 which is higher than 0.5, confirming that factor analysis is appropriate for the study Field (2005), (Child 1990). The facets were further subject to principal component analysis with varimax rotation. The number of components to be extracted was determined using both Guttman-Kaiser rule and the Cattell scree test. Guttman-Kaiser rule suggests that factors with eigenvalue greater than one should be retained. Therefore, five components with eigenvalue greater than 1.00 were extracted with varimax rotation after six iterations, explaining 74.010% (Table 2) of the total variance. The level of satisfaction with each of the five components is derived using mean score analysis as shown in Table 3.

4 Discussion

The organisational-psychological environment has the potential to positively or negatively affect the mental well-being of older workforce. A dissatisfaction in these factors can lead to constant mental stress for older workforce (Boschman et al. 2013). The level of satisfaction falls in between 'neither satisfied nor dissatisfied' and 'satisfied' according to the level of satisfaction scale adopted. The older workers were not very satisfied with their payment structure, salary, job security/employment tenure and career opportunities/advancement plausible because the construction industry is very competitive, and most contracts are won based on price and time for completion. Consequently,

Table 1 CWE facets and reliability results

Code	CWE Facet	Source
CF1	Job security/Employment tenure	Leaviss et al. (2018), Buckle et al. (2018), Bel (2015)
CF2	Salary	Leaviss et al. (2018), Bel (2015), Lynch et al. (2000), Takim et al. (2016)
CF3	Payment structure	Leaviss et al. (2018)
CF4	Employment flexibility	Leaviss et al. (2018)
CF5	Shift-work patterns	Leaviss et al. (2018, Buckle et al. (2018)
CF6	Career opportunities/advancement	Buckle et al. (2018), Bell (2015), Vischer (2007)
CF7	Managerial attitude	Buckle et al. (2018), Vischer (2007), Eaves et al. (2016), Aulin et al. (2009)
CF8	Management plan and style	Vischer (2007), Eaves et al. (2016), Bell (2015), Aulin et al. (2009)
CF9	Personal protective equipment	Leaviss et al. (2018), Eaves et al. (2016)
CF10	Environmental exposures such as heat, dust, noise and weather	Leaviss et al. (2018), Buckle et al. (2018), Boschman et al. (2013)
CF11	Repetitive task	Leaviss et al. (2018)
CF12	Manually handling heavy materials	Leaviss et al. (2018), (Eaves et al. 2016)
CF13	Performing wet work	Leaviss et al. (2018)
CF14	Task allocation/schedule approach	Leaviss et al. (2018), Buckle et al. (2018), Eaves et al. (2016)
CF15	Engaged in more skilled, but less physically demanding task	Leaviss et al. (2018)
CF16	Tools and equipment	Leaviss et al. (2018), Buckle et al. (2018)
CF17	Social networks	Buckle et al. (2018), Boschman et al. (2013), Portero and Oliva (2007)
CF18	Environmental control	Vischer (2007)

Table 2 Total variance explained

Com	IE			ESSL			RSSL		
	Total	% Var	Cum %	Total	% Var	Cum %	Total	% Var	Cum %
1	5.858	32.543	32.543	5.858	32.543	32.543	4.414	24.521	24.521
2	2.680	14.891	47.434	2.680	14.891	47.434	3.265	18.138	42.659
3	1.972	10.955	58.389	1.972	10.955	58.389	1.945	10.808	53.467
4	1.513	8.403	66.792	1.513	8.403	66.792	1.871	10.394	63.860
5	1.299	7.218	74.010	1.299	7.218	74.010	1.827	10.150	74.010
6	0.984	5.466	79.476						
7	0.758	4.212	83.688						
8	0.651	3.616	87.304						
9	0.541	3.007	90.311						
10	0.437	2.429	92.740						
11	0.350	1.942	94.682						
12	0.268	1.490	96.172						
13	0.195	1.083	97.255						
14	0.180	0.999	98.254						
15	0.134	0.745	98.999						
16	0.073	0.407	99.406						
17	0.069	0.381	99.787						
18	0.038	0.213	100.000						

C = Component, IE = Initial Eigenvalues, ESSL = Extraction Sums of Squared Loadings, RSSL = Rotation Sums of Squared Loadings Cum = Cumulative, Var = Variance

Table 3 Ranking of CWE Facets

CWE Facet	Mean	Rank	SD	SEM
Component 1—Organisational-Psychological	**3.60**	**5th**	**0.835**	**0.135**
Payment structure	3.71	1st	0.654	0.106
Career opportunities/advancement	3.66	2nd	0.745	0.121
Salary	3.63	3rd	0.633	0.103
Management plan and style	3.63	4th	0.883	0.143
Attitudes of management	3.63	5th	0.913	0.148
Job security/employment tenure	3.63	6th	1.051	0.170
Environmental control	3.53	7th	0.951	0.154
Shift-work patterns	3.37	8th	0.852	0.138
Component 2—Physical	**3.72**	**4th**	**0.838**	**0.136**
Performing repetitive tasks	3.89	1st	0.863	0.140
Manual handling of heavy materials	3.84	2nd	0.886	0.144
Performing wet task	3.68	3rd	0.775	0.126
Task allocation/schedule approach	3.45	4th	0.828	0.134
Component 3—Functional	**4.08**	**1st**	**0.673**	**0.109**
Engagement in more skilled, but less physically demanding task	4.08	1st	0.673	**0.109**
Component 4—Policies and Practices	**3.78**	**3rd**	**0.778**	**0.126**
Personal protective equipment (PPE)	4.45	1st	0.686	0.111
Protection from environmental exposures	3.89	2nd	0.689	0.112
Employment flexibility	3.00	3rd	0.959	0.156
Component 5—Auxiliary	**3.84**	**2nd**	**0.648**	**0.105**
Tools and equipment	4.00	1st	0.520	0.084
Social networks (opportunity to socialise) in the workplace	3.68	2nd	0.775	0.126

SD = Standard deviation, SEM = Standard error of mean

determining the salary and payment structure which gives financial reward for speed. This environment that rewards speed is unfavourable for older workers who are experiencing increasing physical impairments which affects their speed. Obviously, the older worker would perceive this as discrimination and threat to their job security and career advancement in the construction industry. As argued by Leaviss et al. (2018) and Takim et al. (2016) salary inequality and discrimination treatment affect CWE. Furthermore, the older workers were somewhat not very satisfied with their management plan and style, attitudes of management, environmental control and shift-work pattern. The temporary nature of construction projects resulting in different management on a different project can inhibit management-worker relationship. Different projects come with a different management plan, style and attitude towards the older worker. A mismatch between the environment created by different management and the older workers preferences can cause psychological stress which affects job performance, health, well-being and QOL Buckle et al. (2018), Bell (2015). Furthermore, the degree of environmental choice or empowerment older workforce feel they have through decision-making processes can also impact the QOL in the construction industry (Vischer 2007).

The physical environment deals with how tasks are performed within the construction industry. The level of satisfaction falls in between 'neither satisfied nor dissatisfied' and 'satisfied' according to the level of satisfaction scale adopted. The construction industry is dominated with repetitive tasks, manual handling of heavy materials, and wet works. Older workforce engaged in repetitive tasks such as hammering can lead to worsening joint problems and heavy manual tasks such bricklaying can result in MSDs, and wet tasks such as plastering can lead to rheumatic problems (Leaviss et al. 2018). Since the older workers are not very satisfied with the physical environment, it can be inferred that the physical environment is currently catalysing the deteriorating ageing changes of the older workers. This calls for alternative measures such as nail guns instead of hammer can make repetitive tasks less demanding, and the same applies to manual handling aide, lifting devices and alternative materials and methods to reduce wet task such as dry lining Leaviss et al. (2018), Eaves et al. (2016). Closely linked to this is how tasks are allocated in the construction. Adopting task allocation approaches such as job rotation and job sharing where older workers perform tasks with younger and more energetic workforce can increase the older workers physical environment satisfaction level.

The functional environment deals with engaging the older workers in construction work related task and activities where their functional competence overcome or match with the environment. The level of satisfaction falls in between 'satisfied' and 'very satisfied' according to the level of satisfaction scale adopted. The nature of work in the CWE is described as tough, heavy and physically demanding Schwatka et al. (2011, Eaves et al. 2016). Engaging older workforce in unskilled tasks which are more physically demanding will only catalyse the deteriorating ageing changes of ageing workforce (Eaves et al. 2016). Interestingly, most of the older workers that participated in the study were engaged in skilled works that are less physically demanding. For example, all the 60 and over aged group that participated in the study were health and safety managers or site managers. Therefore, it is not surprising that the older workforce perceived and ranked their functional environment as the most satisfactory amongst others. This is plausible because their functional competence increases when they are engaged in more skilled tasks. This environment deals with the policies and practices that are implemented to protect the older workforce from exposure to construction workplace hazards and risk of injury. The level of satisfaction falls in between 'neither satisfied nor dissatisfied' and 'satisfied' according to the level of satisfaction scale adopted. The older workforce seems to be somewhat satisfied with current policies such as health and safety policy and PPE policy. However, the older workforce will be more satisfied if these policies are modified to focus more on older workforce and adequately put into practice. The auxiliary environment deals with additional support and measures used to sustain and boost the performance of the older workforce. The level of satisfaction falls in between 'neither satisfied nor dissatisfied' and 'satisfied' according to the level of satisfaction scale adopted. Tools and equipment to some extent can minimise the demanding nature of task in the construction industry. However, tools and equipment that are not purposively designed for older worker can be a hindrance to the functioning of the older workers. Also, an excellent auxiliary environment should provide an opportunity for its members to interact and socialise. Social interaction with other people is a source of emotional support, companionship, instrumental help, and advice (Portero and Oliva 2007). The degree of loneliness and isolation experienced by older workforce somewhat depends on the interaction opportunities created by the auxiliary environment (Portero and Oliva 2007).

5 Conclusions

The study identified 18 CWE facets through a thorough review of the literature and was further evaluated using close-ended questionnaire survey. The 18 facets were further reduced using principal component factor analysis into five principal components termed as organisational-psychological environment; physical environment; functional environment; policies and practices environment; and auxiliary environment. The older workers were asked to rate how satisfied they felt about the 18 CWE facets. The level of satisfaction was measured with a five-point Likert scale ranging from 1 (very dissatisfied) to 5 (very satisfied). The mean scores of the responses were used to rank each facet to provide a clearer understanding of the agreement reached by all the respondents. The older workers were most satisfied with the functional environment, followed by the auxiliary environment, policies and practices environment, physical environment and lastly, organisational-psychological environment. The study recommended that the construction industry put in more effort in making the CWE very satisfying to all workers especially the ageing workforce. A very satisfying CWE should compensate and amend the losses accompanying ageing; critical attention should be given to the identified CWE facets to reinforce recovery, adaptation and psychological growth amongst the older workers.

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Image Based Inspection and Monitoring of Buildings

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Abstract

The rapid evolution of cameras and drones in the past few years has paved a way for image-based inspection and monitoring of buildings and other structures. This study presents a framework for the development of an automated image-based building inspection and monitoring system. Images acquired from multiple locations of the building can be used to construct a 3D model or a 2D elevation view which is then matched to its BIM (Building Information Modeling) model. The image of each structural member and its dimensions obtained from the matched model is fed to an image processing algorithm which detects cracks in concrete surfaces and measures crack parameters. A machine learning algorithm trained on several synthetic crack scenarios automatically predicts severity of each crack and the corrective action to be taken for maintenance. The detected cracks are color coded and the severity is mapped back to the BIM model so that the current structural state can be effectively visualized. Using several images of real structural members, it is demonstrated that the crack analysis system shows fairly accurate results. Apart from being a smart and convenient tool for structural inspection, the developed framework also results in better operations, planning and facility management.

Keywords

Structural inspection and monitoring • Drones • Image processing • Building information modeling • Machine learning

1 Introduction

Infrastructures need periodic inspection to ensure that they are performing as intended and do not pose risks to public health and safety. They are liable to deterioration due to environmental factors, overloading, excessive usage or aging (Feld and Carper 1997). Cracks appear as an earliest sign of deterioration in structures. These cracks may cause material discontinuities and decrease in local stiffness. An early detection of these cracks allows for intervention to be taken to avoid further damage.

Manual visual inspection is the most commonly used crack inspection method in the present scenario. This method however, has poor efficiency as it is time-consuming, uneconomic, may require use of expensive monitoring means for inaccessible regions and might even pose safety risks to the inspectors.

Fortunately, the rapid evolution of cameras and drones in the past few years have paved a way for image-based inspection of tall buildings. For crack monitoring in concrete, drone images combined with digital image processing has shown promising prospect for overcoming the shortcomings of manual visual inspection (Kim et al. 2052).

This study presents a framework for the development of a fully automated image- based structural inspection and monitoring system. In addition to detecting and measuring cracks in concrete surfaces, the developed system also assigns a severity index to each cracks and suggests corrective action to be taken for the maintenance. Figure 1 provides an overview of the proposed framework.

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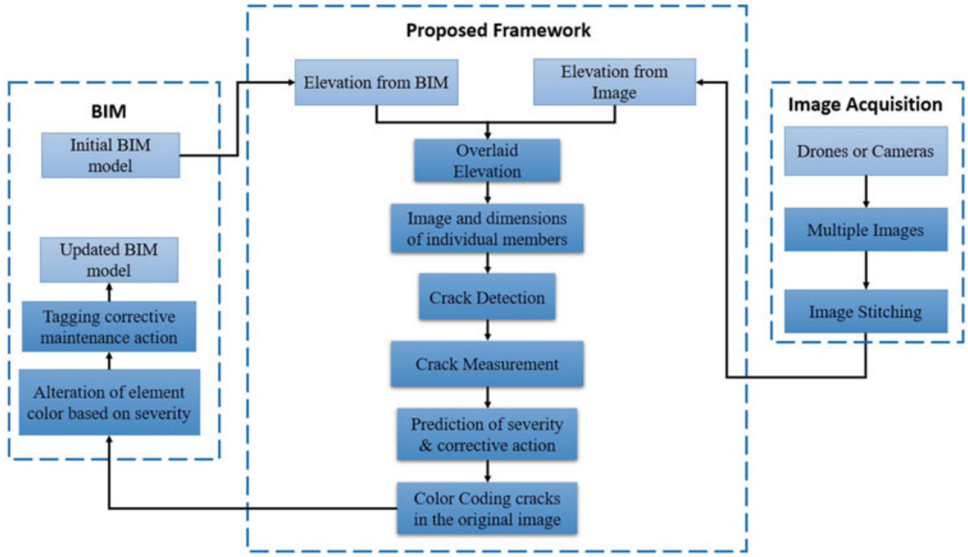

Fig. 1 An overview of the proposed framework

2 System for Image-Based Building Monitoring

2.1 Pre-processing

The images can be acquired by flying a drone vertically along the elevation of the building. Images obtained from multiple locations can then be stitched together so that an entire elevation appears as a single image. Furthermore, this elevation can be manually cleaned to remove unwanted materials in the background. An algorithm can also be developed for automatic cleaning. This elevation is then overlaid to its corresponding elvation in the BIM model. The BIM model contains informations such as the unique Element ID for each element along with its coordinate and dimensions. With the help of these coordinates, element level image of each structural member is extracted from the overlaid elevation. This image along with the dimensions and type of structural member is stored for each structural member under its unique element ID. This information and images will then be read by the crack analysis algorithm. Figure 2 illustrates an example of the process.

2.2 Crack Analysis

The crack analysis framework can be divided into three major parts: crack detection, crack measurement and severity analysis. The crack detection module takes the image of each structural member as an input. Using bilateral filtering followed by binary thresholding a potential crack map is created. Utilizing the slenderness of potential cracks compared to potential non-cracks (Dorafshan 2016), a module is developed that successfully isolates all cracks in the images and creates a binary crack map.

This binary crack map is taken by the crack measurement algorithm which draws rectangular bounding boxes around each crack shape to measure it's length, orientation (Zhu 2011) and co-ordinates of end points. For measurement of crack width, distance transformation is used. Likewise, for determining the generalized position of the crack with

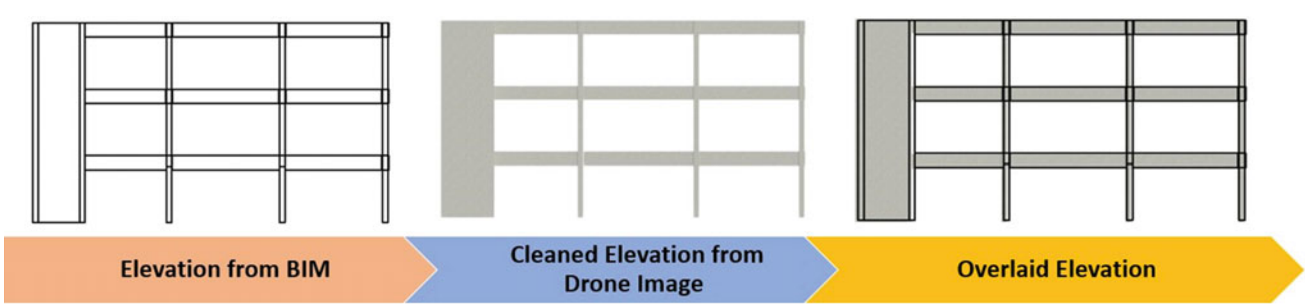

Fig. 2 An example of overlaying elevation from BIM to the elevation from Drone Image

respect to the structural member, it is transformed to a generalized local scale. Severity indexes are usually predicted solely based on crack width and/or density, examples of which can be seen in (Buildings Department 1998), (Ohkubo 1990) and (Melchor-Lucero and Ferregut 1996). A new severity index was created based on these guidelines and by combining engineering judgement and understanding of concrete mechanics about the effect of crack position and crack type on structural members. Based on the new index, several crack scenarios were created to train the machine learning algorithm. 1080, 1008 and 936 datasets were used for beams, columns and walls respectively with 80% data used for training and 20% data used for testing. Decision tree algorithm was found to give the best accuracy for the datasets. After the decision tree predicts the severity of each crack, a report file is automatically generated that contains the parameters of each individual cracks along with its severity and the corrective action to be taken for the maintenance of that structural element. The framework was built entirely on Python.

2.3 Post-processing

For post-processing, the cracks are color coded in the original image of the structural element based on their severity value. A color coding plugin reads the severity level of the element from an external CSV (Comma Separated Value) file by matching the element ID of the BIM element and the CSV file. It then transforms this severity value into its corresponding RGB (Red, Green, Blue) value. A function is created which takes this RGB value and overrides the color of the element so that the final output is the element with its color coded based on its severity. As a result, the current state of the structural member can be easily visualized. Figure 3 shows an example of the initial model and the model automatically color coded based on its severity. Each element is tagged with a report that contains the number of cracks, their measurements, severity and the corrective action to be taken for the maintenance of that element.

3 Monitoring of Some Case Study Structural Members

The presented approach of structural inspection and monitoring is applied to 35 sample images taken around the AIT campus. The images of the structural members were taken and manual measurements of the cracks were carried out on site. The comparison between the actual values measured on site and the values measured automatically by the algorithm was carried out. Figure 4 shows the comparison of these values for a sample beam, column and wall taken for the case study.

Based on the 35 samples of structural members, the measurement accuracies for length, width and orientation were found to be 94.16%, 90.57% and 95.92% respectively.

4 Discussion

The developed system functions as a novel method of using image processing and machine learning techniques for inspection and monitoring of structures. It presents a framework for matching elevation from drone image with the elevation from BIM model and then identifying the properties of each structural member. While past studies use image processing for crack detection or measurement, the developed

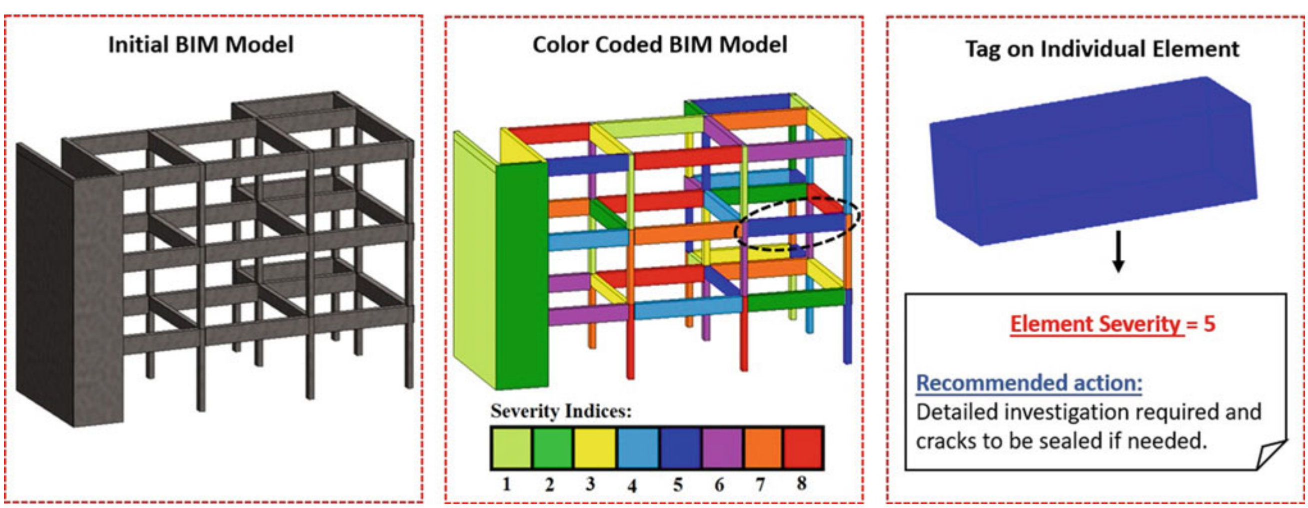

Fig. 3 Initial model and color coded model with tag on individual elements

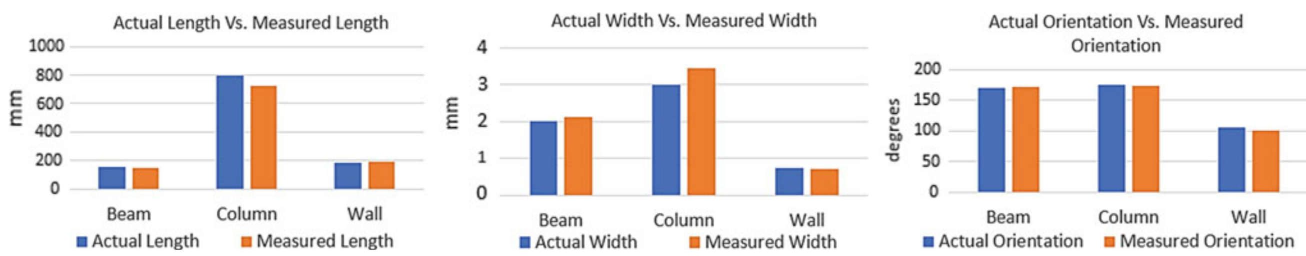

Fig. 4 Comparison of actual crack parameters versus parameters measured by the system

framework goes a step forward and also predicts the severity of the cracks and recommends the corrective action to be taken. The algorithms used for image-processing are simple, have fast execution speed and are fairly accurate. The algorithm transforms all the structural elements to a local scale so that all the elements are generalized and comparison among them is easier and more logical. For selecting the machine learning algorithm, eight different algorithms were evaluated and it was found that decision tree performs the best as the dataset was based on a set of predefined rules about crack severity. After the decision tree predicts the severity, a report was automatically generated with all information including the severity and the corrective action to be taken based on this severity. Then the cracks were color coded in the original image as well as back into the BIM model based on their severity. A tag added to each element in the BIM model helps provide additional information about the damage and the corrective action to be taken for the maintenance of that element. The final output helps even a person with limited understanding of structural engineering or the behavioral mechanics of concrete easily visualize the current state of the structure. As each operation in the overall framework is written as a separate module, additional features can be easily upgraded to it. The overall system is expected to act as a state-of-the-art tool for automated building monitoring.

5 Conclusions

This paper presents a framework for the development of a fully automated image-based building inspection and monitoring system. It aims at overcoming the shortcomings of the traditional way of manual visual inspection. The main limitation of the system is that sometimes it may falsely detect marks or other disturbances as cracks. This could be overcomed in future by identifying and filtering those false detections using deep learning. The developed system is mostly suitable for buildings without glass façade or cladding on its surface. With inclusion of crack scenarios to account for other types of structures, the developed system can be modified to inspect cracks in structures other than buildings. Moreover, the same principle can be applied with slight modification to detect water leakage or for other forensic engineering applications. Using several case study images, it is demonstrated that the measurements done by the developed system is close to the actual field measurements. The system not only acts as a smart and convenient tool for structural inspection but also results in better operations, planning and facility management.

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Risk Management in Procurement of Blue-Green Roofs—Supplier Perspective

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Abstract

Blue-green roofs are increasingly adopted as a measure to reduce risk related to stormwater events. However, as a novel building element, they present elements of uncertainty in themselves. The integrity of the roof is vitally important to long-term building operation, it is therefore important to understand the extent and impacts of this uncertainty. Documents from building product suppliers are investigated to chart how technical uncertainty and quality risk is managed regarding blue-green roofs. The main form of uncertainty management comes in the form of performance declarations, specifying the operating limits of the products. If a failure occurs, the supplier seeks to be able to document that the quality of the product was not at fault. The processes by which product performance is documented may be very challenging for anybody but the suppliers themselves to gain insight into.

Keywords

Blue-Green roof • Risk • Uncertainty management • Supplier perspective • Quality

1 Introduction

A blue-green roof is a roof assembly in which plants and water-detaining sub-layers are used to temporarily store rainwater, delaying stormwater runoff from the roof. Even though all green roofs have some capacity to detain water, the “blue-green” moniker is usually reserved for cases where the roof assembly is explicitly used for stormwater management purposes (Andenæs et al. 2018).

In Norway, climate is changing to become milder and wetter. In particular, intense precipitation events are expected to become more frequent and more intense, increasing the risk of urban flooding (Hanssen-Bauer et al. 2015). Data from Finance Norway (Hauge et al. 2017) shows that insurance payouts for damage incurred by weather events more than doubled in 10 years. Measures to mitigate the risks posed by intense precipitation and stormwater events are becoming ever more necessary.

The Norwegian sewage system is found to be in poor and deteriorating condition. The total cost to upgrade it to a satisfactory condition is estimated to be around NOK 110 billion (RIF 2015). This undertaking would be prohibitively expensive, and does not factor in the cost of capacity upgrades. Therefore, it is unfeasible to address the challenges posed by future stormwater events through the sewage system alone. Local solutions for stormwater retention and detention are required. Blue-green roofs are found to be effective in retaining and detaining stormwater, making it a feasible risk mitigation measure even in cold and wet regions (Johannessen et al. 2017).

However, while blue-green roofs can be a risk reduction measure from some perspectives, they also introduce a certain degree of risk in themselves. Blue-green roof assemblies are mounted on top of conventional compact roofs, adding additional layers to a building’s outer envelope. This addition changes the physical boundary conditions of the extant roof, and covers the watertight roof membrane whose long-term integrity is vital for avoiding water damage to the construction underneath. These changes introduce elements of uncertainty that have to be investigated thoroughly, in order to chart and minimize the eventual negative consequences of adopting blue-green roofs on a large scale.

The terms risk and uncertainty can be understood on many different levels, and from the perspective of many different actors. In order to present a suitable level of detail

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within the practical constraints of this article, it is decided to limit its scope to the technical level and to the perspective of the product supplier. Additionally, it is decided to focus on the procurement phase. This article aims to investigate how uncertainties related to the building's quality is handled in practice. The study is limited to the procurement phase and from the suppliers perspective. The following research questions are examined:

1. What challenges and risks do product suppliers face related to green and blue-green roofs?
2. What strategies are applied by product supplier to control and manage risk related to green roofs in the procurement phase?
3. What improvements can be made?

The research is performed as a desktop study, by examining documents from the design and procurement phase of construction projects featuring green roofs. It is investigated how construction product suppliers in Norway address technical uncertainties in their involvement in construction projects.

2 Theory

2.1 Green and Blue-Green Roofs

Blue-green roofs are green roofs specifically designed and used to function as a stormwater management measure (Andenæs et al. 2018). Like other green roofs, they exist either as *extensive* assemblies, where Sedum plants grow on a thin mat of substrate; or *intensive* assemblies with significantly thicker substrate layers, allowing lawns or even parks with trees to be planted on building roofs. Extensive green roofs are usually not meant for traffic, while intensive green roofs can be robust enough to allow vehicles to drive on them. A principle schematic of a blue-green roof assembly on a compact, flat roof is shown in Fig. 1.

A primary function of a blue-green roof is to retain stormwater (storing it in the roof assembly until it evaporates) or detain it (delay runoff), reducing the load on local stormwater drains by eliminating or reducing roof runoff. However, the key purpose of a roof is to provide a weather-tight cover for the building, a function that must not be compromised. The Norwegian building regulations specifically stipulate that water leakages must not occur (DiBK 2017).

2.2 Failure Modes of Blue-Green Roofs

Conceptually, a blue-green roof can fail in two ways: it may fail to deliver the stormwater management capacity that was requested or lose its capacity over time (performance failure); or it may suffer a defect that compromises the integrity of the roof assembly (quality failure). The latter failure mode generally has more serious ramifications for the long-term operation of the building than the former, and will receive the point of focus in this article.

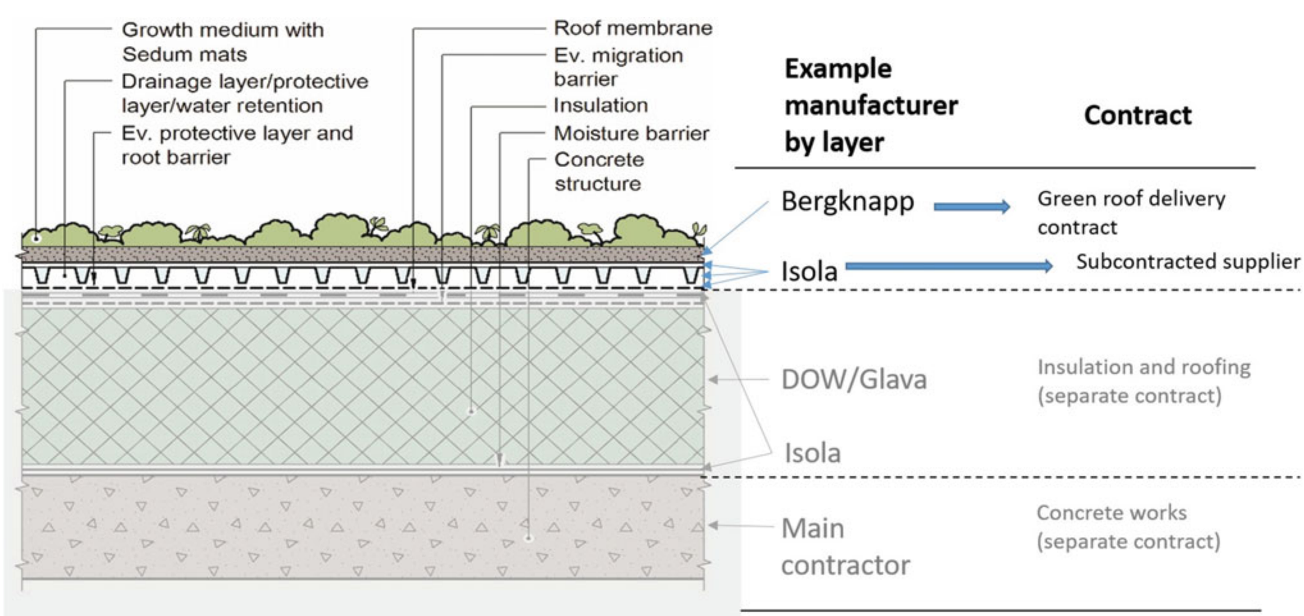

Fig. 1 Principle of a blue-green roof assembly on a compact flat roof, as well as examples of delivery contracts involved in its assembly and their product suppliers. Figure adapted from 86 (Skjeldrum and Kvande 2017)

Quality failures can generally be divided into three categories: Product failures, design failures or assembly failures. With this article focusing mainly on the suppliers, product failures will be most relevant in this case, although unclear or incorrect information from suppliers may be a contributing factor in design or assembly failures as well. Determining the exact cause of a roof defect may often be challenging, and several parties may share the responsibility.

2.3 Uncertainty Management Strategies

The term "uncertainty" within a project context is usually understood as "an event that, if it occurs, has a positive or negative effect on a project's objectives" (Torp et al. 2018). This definition includes risk when the outcome of uncertainty is negative, and opportunities when the outcome is positive. To manage opportunities, strategies as share, exploit, accept and enhance could be chosen, while when managing risks strategies like avoid, reduce, share and accept could be chosen (Hillson 2003). Different uncertainty management strategies could be chosen, based on whether risk or opportunity is considered, or based on the type of uncertainty (Torp et al. 2018). Uncertainty management strategies should include both proactive, interactive and reactive ways of thinking (Torp et al. 2018). Uncertainty management would also depend on one's perspective in the project.

From the supplier's perspective, the main risk related to blue-green roofs is to be declared responsible when a roof fails, and having to pay for repairs or replacements. A major priority will therefore be to specify a given quality level for their products, so it can be determined as accurately as possible the circumstances in which they are suitable. If the product is used in an unsuitable fashion, or its declared operating parameters are exceeded, *and* the relevant information was made available to designers and contractors, the supplier is less likely to be considered at fault for the failure, following (DiBK, 2017).

2.4 Phases of a Construction Project

Figure 2 shows the phases of a construction project, as well as the hierarchies involved in the construction process. The main focus in this article is on the design and construction phase, and from the supplier's perspective.

2.5 Knowledge Gap

Although a significant body of literature could be found on the subject of uncertainty management, the authors of this paper have not identified significant research literature on

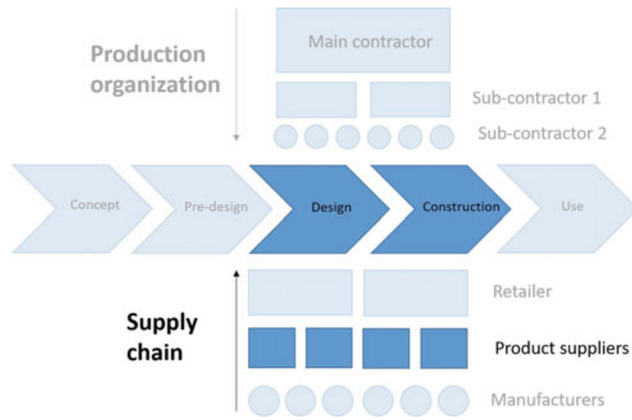

Fig. 2 Principle sketch of main actors in the production organization and supply chain of a construction project. The illustration is principal in nature and does not cover actual real-life processes. Highlighted parts illustrate the scope of this article

the management of risk from the supplier side. It remains uncharted what measures suppliers take to minimize quality risk or their exposure to it.

3 Method

This being a desktop study, a literature study was performed to gain insight into the composition of blue-green roofs and their common failure modes (Andenæs et al. 2018). The study was performed as a scoping study, retrieving 100 research articles for analysis. For this article, the results of the literature study have been used to write the Theory section. Uncertainty management literature was identified through literature review, and searched for uncertainty management from the supplier perspective. Much literature was found from the project owner's perspective, some from the contractor's perspective, but none from the supplier's perspective.

In a desktop study, the websites of suppliers of products used in blue-green roofs were examined, to map what measures the suppliers take to mitigate risks. Products available on the commercial market were studied through datasheets, assembly instructions and, if available, technical certification. Documents were retrieved both from supplier websites and the websites of a certifying body, SINTEF Certification (2019).

4 Results

4.1 Declaration of Performance

Product failures occur when operating conditions exceed the performance limits of the material. Suppliers will therefore need to chart the performance limits of their products as accurately as possible, so it can be formally declared under which conditions their product will perform as advertised.

Performance is declared based on tests following procedures codified in industry standards. This ensures that all products are tested with the same criteria under the same conditions. Each product category may have dozens of associated testing standards; for instance, the standard NS-EN 13707:2013 for definitions and characteristics concerning flexible reinforced bitumen sheets for roof waterproofing (NS-EN 1370) lists 23 other EN and ISO standards as “indispensable for its application”.

Suppliers provide a declaration of performance for each of their products, listing the vital properties of the product and the standards used to determine these. Examples of such properties and declarations are given in Table 1.

The multitude of relevant testing standards ensure that the relevant properties of the products may be determined according to standardized procedures. However, it may still be very challenging for the actors further down the supply chain to obtain a clear overview of the properties of the products. Knowing the parameters of the tests requires familiarity with the relevant standards, of which many exist for every product category. Gaining access to the full text of each standard is also fairly expensive, further limiting the designers or contractors from becoming familiar with the procedures by which the products are tested. Realistically, the persons responsible for design or assembly may not be familiar with the testing standards for more than a handful of products, increasing the risk of design or assembly failures.

4.2 Technical Approvals

Suppliers may enlist a third party controlling and verifying the performance of the product and its suitability for use. Certification bodies such as SINTEF (Norway), RISE (Sweden), BBA (UK) and TÜV (Germany) offer independent controls and certifications of the performance of the product in question, as well as assessments of whether the product is suitable for its intended use. Use of certifications is voluntary, but it is found to be a common practice in the Norwegian building sector to manage risk by requesting a certificate of approval from such governing bodies for all construction materials used in their project, which implies that certification is practically a requirement for a product to be competitive on the market.

4.3 Assembly/Use Instructions

A construction product is often highly specialized for one purpose and may be unsuitable if used in different contexts than it is designed for. For instance, a root barrier used to protect the roof membrane underneath a green roof may deteriorate quickly if not covered by a green roof assembly, since it is not designed to withstand solar radiation. To prevent product failure caused by faulty use or application, suppliers inform about the product’s intended use condition in product datasheets. Relevant information on storage and assembly is also applied; in some cases a separate, detailed assembly instruction is provided as well.

Table 1 Example of declared properties and standards used for products in blue-green roofs

Product	Isola Rotmembran (Roof membrane/root barrier)	Protan Titanium + (roof membrane)	Declared properties and standards
Root resistance Dimensional stability Reaction to fire Water tightness Tensile strength Tear strength Flexibility at low temperature	EN 13948 FLL EN 1107-1 EN 13505-1 EN 1928 EN 12331-1 EN 12310-1 EN 1109	Essential characteristics External fire performance Reaction to fire Water tightness Tensile strength Resistance to impact Resistance to static load Tear resistance Joint peel resistance Joint shear resistance Foldability at low temp Exposure to UV Root resistance	EN 13956:2012 EN 13501-5 EN 13501-1 EN 1928 (A) EN 12311-2(A) EN 12691(A) EN 12370(C) EN 12310-2 EN 12316-2 EN 12317-2 EN 495-5 EN 1297 EN 13948 FLL

5 Discussion

This article seeks to answer the following research questions: What challenges and risks product suppliers face related to green and blue-green roofs, what strategies are applied by product supplier to control and manage the risk, and what improvements can be made.

Quality failures related to green and blue-green roofs can generally be divided into three categories: Product failures, design failures or assembly failures. The supplier could be responsible for product failures, and the main risk from the supplier's perspective is being declared responsible and having to pay the costs incurred. There are many sources of roof failures, including poor workmanship and poor design in addition to product failures. Poor workmanship and poor design may also stem from a lack of knowledge about correct use of the products, which the supplier may be declared responsible for if the provided information is found to be insufficient.

With the main risk management strategies being to avoid, transfer, reduce or share risk, the supplier's best option is to reduce the risk related to product failiure. A proactive strategy is a must instead of interactive (handle risks as they happen) or reactive (fix after the damage has occurred). Risk is also transferred away from the supplier through detailed declarations of performance. If damages occur due to incorrect design or faulty assembly, where the stated performance parameters of the product were exceeded, the supplier will not be liable to pay compensation.

However, a certain challenge is posed by the relative obscurity of product standards by which the product's performance is determined. Designers or contractors may not be familiar with the limitations of the declarations, increasing the risk of design and assembly failures. Suggested improvements involve higher transparency in the product standards, with the goal to make actors further down the supply chain more familiar with the limitations of the standards (and therefore, the products). Further use of independent product certifications is another suggested measure, where the certifications include an assessment of the product's suitability for its intended use. These measures intend to set clear limitations about how the product is supposed to be used and how it will perform.

6 Conclusions

Quality risk appears to be a topic of concern for suppliers, although the key focus appears to be to avoid blame for failure rather than preventing failure in the first place. This is achieved through declaring specific limits of use for their products, both in terms of storage, assembly and operating conditions. The declarations of performance may also be verified by third parties. The methods by which the limits are determined are openly available through product standards. However, few actors involved in the construction process are fully familiar with the standards, and access to their full text is expensive. It may therefore be likely that the persons responsible for design and assembly will not have the required knowledge of the product's use parameters, increasing the risk of a design or assembly failure. Possible improvements identified through the research are increased use of third-party verification, clearer declarations of performance and proper use instructions, in combination with suppliers offering courses and training for the construction industry.

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BIM Awareness: The Kenyan and UK Scenarios

Thomas Njuguna Kimani, Haddy Jallow, Mugwima Njuguna, and Ahmad Alkizim

Abstract

In the global context, Building Information Modeling (BIM) is a catalytic agent for innovation, productivity, and efficiency in the construction industry. BIM adoption in Kenya is rare, whereas the volume of construction is poised to increase and the gains that can be achieved via its use could be enormous. In the UK, all projects are to use a minimum of level two BIM to enhance collaboration and coordination with visual aids and a common data environment that enhances communication with the project proponents and all the other stakeholders. The main aim of this study was to determine the BIM gaps in terms of awareness and use in order to form a basis for the development of future adoption strategies in infrastructure projects in Kenya. The research was carried out in Nairobi and London. The study was designed as a survey that started with a desk study followed by semi-structured interviews. Analysis of the data was done using content analysis. The findings identify significant differences in BIM awareness and use, the influence of which could provide insight for the developed and developing countries. The state of research, training, and practice pertaining to BIM in Kenya remains largely undocumented, whereas in the UK, there are national-level initiatives driving its adoption. This paper concludes that BIM success is dependent on close collaboration between the client, consultants, contractors, and suppliers along with the establishment of a well-developed BIM protocol and the lessons learnt from the UK can easily be used by Kenya as it embarks on its BIM journey for an efficient and harmonious working environment in this era of globalization.

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Keywords

BIM • Infrastructure projects • Collaboration • Project stakeholders • Sustainable development

1 Introduction

The World invests about $2.5 trillion annually in infrastructure projects. However, according to McKinsey and Company (2016), from 2016 to 2030, the world needs to invest an average of $3.3 trillion annually in economic infrastructure to support the expected population growth rates. This is an average increase in 32 % in infrastructure investment. According to World Bank (World Bank 2019), Kenya faces a significant financing deficit of about $2.1 billion annually which constrains growth and development.

Productivity is a major issue for the entities that plan, construct, and operate infrastructure assets with cost overruns averaging 20–45 % (Flyvbjerg 2009). This points to a colossal opportunity that can result in saving taxpayers money through increased productivity by embracing innovation and improving the planning, project management, operational capabilities of all stakeholders involved in infrastructure projects. There are many problems that make productivity growth in the construction sector slow or negative in many economies namely fragmentation, skill gaps, insufficient planning and design, risk aversion, performance dispersion, project mindset of companies, ineffective procurement processes, workflow split, and limited use of technology (BIM for Infrastructure and Autodesk 2012). These challenges arise because the construction process is usually complex and involves many processes and parties, information is usually exchanged through the use of sketches, texts, emails, images, documents, and drawings which can result in miscommunication and could hinder productivity in a construction project.

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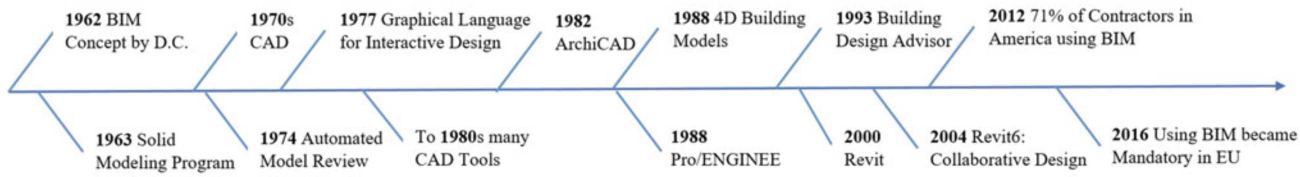

Fig. 1 The history line of BIM (*Source* Majrouhi Sardroud et al. 2018)

In the past three decades, technology has contributed immensely to the development of various nations. Building Information Modeling (BIM) is one of the most promising recent developments in digital engineering in the construction industry. The early concepts of BIM, date back to 1970 and 1980s when Computer-Aided Design (CAD) was introduced. A brief history of BIM is shown in Fig. 1.

BIM provides a new set of tools and new ways of working within the industry that are attributed to increase in efficiency and reduction of wasteful activities in infrastructure projects (Mattsson and Rodny 2013). Therefore, BIM is one of the most promising developments in digital engineering in the construction industry and it needs to be implemented in infrastructure projects.

The UK is known as a global leader in BIM implementation (McCullough 2016). However, it continues to face cultural-related challenges followed by management, legal, and financial problems (Majrouhi Sardroud et al. 2018). Kenya, on the other hand, is facing huge challenges from the construction industry players because they are reluctant to change the traditional processes, and this is closely related to human and organizational culture coupled with upgrading technology, interoperability, compatibility, and complexity of BIM processes.

In the UK, BIM for infrastructure has gained traction, increasing its adoption levels from 13 % in 2010 to more than 50 % in 2015 (Basri 2016). In contrast, BIM use for infrastructure in Kenya is largely undocumented because of its very low adoption rates. In the UK, there is a government mandate for the use of BIM maturity level two which is fully collaborative. The mandate specifies BIM to be used on all public projects. This means that BIM should be used in rail, roads, utilities, and energy projects that are longitudinal in nature compared to the generally vertical nature of building projects (Mattsson and Rodny 2013).

In view of the above, there are potential gains for the infrastructure construction industry through the use of BIM. This study aims to review existing research and industry development in order to determine the BIM gaps in terms of awareness and use, and to form a basis for the development of future adoption strategies in infrastructure projects in Kenya. With review of the UK construction industry, there are distinct and shared similarities in the adoption of BIM. This study presents lessons that can be learned by Kenya from the UK as an early BIM adopter in terms of implementation processes, expected challenges and solutions.

2 BIM and Infrastructure

BIM is the acronym for 'Building Information Modeling' which is commonly defined using the Construction Project Information Committee (CPIC) definition as the digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition (Sinclair 2012).

In civil engineering, infrastructure is defined as the basic physical and organizational structures and facilities needed for the operation of a society or enterprise (Basri 2016). Infrastructure projects range from transportation, energy, utility, recreational, and environmental, examples in each category are mass transit hubs, power generation plants, sewer lines, stadiums, and dams, respectively. In most infrastructure projects, there are longitudinal structures that connect point structures and in relation to BIM, this provides mark differences in data structures, collaborating teams and project sizes that are more expansive than traditional building projects (BIM for Infrastructure and Autodesk 2012).

When getting started with BIM for infrastructure, its best to understand what every project stakeholder wants to achieve with the model during and after project development considering that the model could be used to manage assets once the project is built. Gathering the key information, physical attributes, and relationships of objects within the model is important in defining the standards that help one get started on modeling (Mattsson and Rodny 2013).

The implementation of BIM needs the establishment of standards for the objects used in design. BIM standards can be Model templates, a library within BIM tools, or discipline-specific object libraries.

The use of BIM on an infrastructure project should start with the creation of an intelligent existing conditions model with some survey data of the area in question. Laser scanning-based survey/Geographical Information Systems (GISs) techniques generate detail-rich point clouds of data that can be imported directly into the BIM software (Fig. 2).

Fig. 2 Exploration of a new project in the context of existing conditions using BIM 119 (*Source* Ryan, BIM in infrastructure—Challenges & Solutions)

This shows that BIM can be used for better collaboration with clients and other projects stakeholders including the general public, for example, in traffic management. The stakeholders are able to gain insight as to how traffic management will be set up during and after construction, and the BIM platform gives opportunities for people to give feedback for the improvement of the project.

With the improved collaboration, communication is improved and there are additional benefits such as reduced changes and errors. Additionally, when ideas are communicated with the aid of a model, testing can be done and the most efficient and cost-effective solution should be chosen.

The objects within the model have intelligent attributes with a visually rich context that helps decision-makers make informed choices.

A project execution plan is crucial for effective implementation of BIM, this mainly because the design is usually based on intelligent objects and any changes effected on the model have a ripple effect on the whole design. The model should be detailed enough to support all intended uses over the structures' lifecycle (Fig. 3).

3 Methods

A qualitative approach was used to provide for an enhanced understanding and generate rich descriptions of the concept of BIM in the Kenyan and UK construction industries. Since there was no prior hypothesis that was to be tested, an exploratory study was used to inform the research. Literature review was conducted to examine the definition, concepts, application, and all related issues of BIM. Exploratory interviews were conducted to collect data from the perspectives of purposefully sampled construction industry players (The Government, the general public, Project Managers, Engineers, and Contractors) in Nairobi, Kenya and London, UK. 12 semi-structured face-to-face interviews were conducted over a 2-month period. An interview guide was used to collect data for the fulfillment of the research objectives. Materials from previous desk studies were used to prepare for the interviews, all interviews were approximately 1 h in length for each. The respondents had experience in using BIM in at least one of the projects they were involved in. The data was then analyzed by the authors using the technique of context mapping. The data was then analyzed by the authors using the technique of context mapping.

4 Findings

4.1 BIM in Kenya

In Kenya, BIM is facing huge challenges from the construction industry players because they are reluctant to change the traditional processes, and this is closely related to human and organizational culture. According to one of the

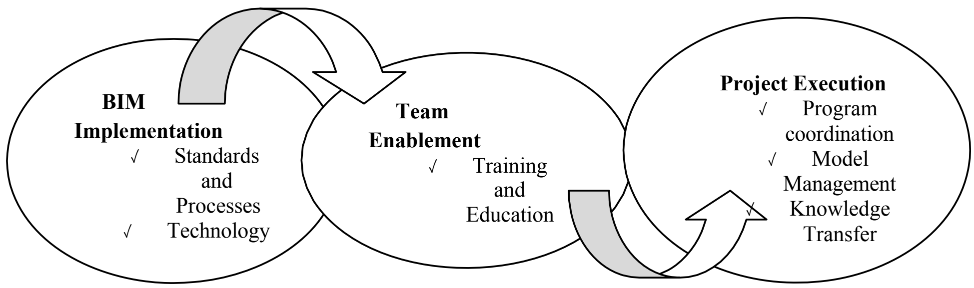

Fig. 3 BIM for infrastructure execution plan (*Source* Authors)

respondents, there are other challenges which include costs related to upgrading technology, interoperability, compatibility, and complexity while introducing BIM. Moreover, there is little knowledge about BIM and majority of the respondents believe that the key people in the construction industry do not know why, how, when, and what to start. This is mainly because there is no standard of BIM implementation at the national level for them to follow.

To manage these issues, one respondent stated that in his firms' case, they bought a BIM software and one of the key staff members was trained on BIM, then the staff member trained his co-workers and BIM knowledge was disseminated throughout the firm, they created a new role of BIM coordinator. This shows that companies and organizations can assess their individual challenges and develop a custom BIM roadmap which can be as simple as migrating from BIM level 0, to 1, to 2 within a specific time period and strategy.

The approach is different for one of the respondents, from an international civil engineering firm based in Kenya, he stated that their company had to act fast due to their international presence and now use BIM to add value in their profile while bidding for projects. Currently, the firm is working on BIM level 2 in selected projects. However, the civil engineer suggested that working together with a BIM expert should be mandatory for first-timers as it could speed up the BIM adoption process and minimize associated risks.

From the interviews, it is evident that the readiness for the Kenyan government and local firms to adopt BIM will be heavily influenced by top management support. This is because BIM will change established work processes to a new work process that will require bold decisions.

4.2 BIM in the UK

The minimum requirement by the UK government is level 2 BIM, which is operated by collaborative practices with all projects and asset information, documentation and data being electronic. This is the culmination of a 5-year staged plan which was instigated in 2011 with mandated milestones which showed measurable progress annually up to the end of 2016.

To assist with the adoption of BIM, the Construction Industry Council (CIC) and Building SMART were at the forefront in developing the best practice guidance for BIM adoption and improving the adoption process in data sharing, respectively (Metal et al. 2008). According to one of the respondents, the private sector also played an important role by forming a group called BIM Industry Working Group.

Findings from the study show that there were three major challenges associated with the adoption of BIM in the UK.

One respondent stated that there was lack of knowledge on how to implement BIM. This challenge was overcome through the formation of an Industry Delivery Team that assisted all the government departments in developing their own BIM adoption strategies in order to meet the government's mandate. The progress of the strategies was reported back to the Government Construction Board. Under the industry delivery team, a specific working group was formed to study and establish work processes and procedures to ensure the construction industry had a smooth transition in BIM adoption. According to Gardezi et al. (2013), Regional BIM hubs were also formed to enable SMEs and smaller clients get advice from local networks. The British Standard Institute (BSI) also worked with the teams to develop a BIM standard which includes BS 1192-2 and PAS 91.

There was also the challenge of the lack of technical skills which was overcome by the development of a core set of skills and training requirements. A '2050 Group' was also developed to motivate and capture the technical expertise from the younger generation within the industry.

Additionally, professional and trade bodies teamed up with the government to ensure BIM was embraced by all communities within the construction sector, especially the small practices. There was also risk management which was overcome by incorporating the governments soft landings into the BIM program. Moreover, according to Ryan et al. (2009), the government also worked with private clients to ensure the benefits of BIM were shared among parties which included giving incentives.

However, up to date, there is the challenge of making BIM fully collaborative across disciplines, this is because firms use different softwares and the interoperability with the different softwares is a big issue because sometimes data is shared in formats that cannot be opened with the available softwares.

5 Discussion

From the foregoing, the absence of clear guidelines is a hindrance for the implementation of BIM in Kenya. In the UK, BIM is in a rapid and pervasive dissemination stage, and this is mainly because it was adopted for its potential to address the challenges that the traditional construction technologies could not address. Although some of the companies in Kenya have experienced benefits through the use of BIM, adoption barriers are still being reported by the majority.

Below is a brief SWOT analysis for BIM adoption in Kenya.

Strengths

- Saves time and money (Reduces waste, the team gets it right at the first time).
- Improves 3D design capacity.
- Simulates construction sequences.
- Reduces risks and errors.
- Reduces energy use over a building's lifecycle.
- Can be used by SMEs.

Weaknesses

- There's no culture of collaboration across disciplines.
- The focus is on the infrastructure not information.
- The government needs to take the lead.
- Design firms and contractors need to work together.
- There are no universal design standards.
- There are initial hardware, software and training costs.

Opportunities

- Linkage with international leaders in BIM education.
- Integrating with simulated training innovations.
- BIM is the DNA of future construction.
- Development of new skills and knowledge for the local industry.
- Kenya can be a leader in BIM education and use in Africa.

Threats

- BIM will change the traditional ways of working in the local construction industry.
- New types of contracts/contract addenda will be needed.
- There's limited understanding of BIM.
- There are few firms working together, across disciplines.
- Resistance to change.

6 Conclusions and Recommendations

Global trends have indicated an increase in BIM implementation and this is set to continue accelerating into the future. Government initiatives in the United Kingdom are helping all construction industry stakeholders realize the benefits of this technology. Such developments should encourage BIM implementation on a wider scale as developing countries like Kenya might be left behind if they don't keep pace with the trendsetters in the BIM field.

The transition from the traditional approach to BIM in the Kenyan construction industry will not be an easy process. It will need decision-making and change management strategies which will be guided by top management in the government and private sector. The government will be very instrumental during the transition period from previous traditional workflows to BIM workflows, convincing professionals about the potential of BIM, developing education and learning strategies and understanding new roles.

Firms and practices should also understand that when implementing BIM, there will be initial costs. To reduce the risks associated with BIM, the management at the firm level will have to phase BIM implementation gradually moving from BIM level 0, to BIM level 1, 2, and 3 eventually.

Since current BIM implementation in Kenya lies between BIM level 0 and BIM level 1, recognition and support from the government will improve the productivity of the construction industry and implementing BIM in public infrastructure construction projects should lead the way. However, the strategic benefits of developing BIM expertise in Kenya will only be realized if the government and the private sector work together creating a push and pull situation.

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Urban Underground Future: The Potential of Subsurface Utilization in Nairobi, Kenya

Thomas Kimani and Mugwima Njuguna

Abstract

Rapid urbanization in Nairobi city is exerting pressure on the existing infrastructure and resources such as parking areas, the natural environment, freshwater supplies, roads, sewerage networks, communication lines, power lines, and the overall quality of life of city dwellers. While such association is vital, the city needs a new frontier that could provide a significant contribution to future spatial requirements as an essential part of improving the quality of the urban environment. Nairobi has long enjoyed being a hub of finance and culture in the East African region. It has high land values, clear and coherent legislation for surface solutions but lacks clear rules and standards for underground construction. The main aim of this study was to identify the main problems risking both the functionality and quality of life in Nairobi city and to explore the various approaches to development, planning, geology, policies, and projects being delivered and considered globally focusing on the need for good and professional planning of underground space. The research was carried out in Nairobi. The study was designed as a survey that started with a desk study followed by semi-structured interviews using an interview schedule. The findings show that underground space provides a strategic solution by providing an additional spatial and service layer for transportation and utility infrastructure freeing up surface space which can be used more efficiently and effectively. This has the potential to improve accessibility, safety, the competitiveness of cities, and the overall quality of life of the city dwellers. However, this comes at huge initial costs but lower lifecycle costs. This paper concludes that underground space can contribute to making the city sustainable, more resilient and cope with rapid urbanization. The paper recommends that in the not too distant future, the implementation of underground facilities should be considered equally as valuable as surface solutions in Nairobi, Kenya.

Keywords

Urbanization • Underground urbanism • Geology • Planning • Sustainable development

1 Introduction

Today, 55% of the world's population lives in urban areas, this proportion is expected to increase to 68% by 2050. Studies show that urbanization, the gradual shift in residence of the human population from rural to urban areas, combined with the overall growth of the world's population could add another 2.5 billion people to urban areas by 2050, with close to 90% of this increase taking place in Asia and Africa (Broere 2016).

More than half of the global population growth between now and 2100 is expected to occur in Africa (林伸行 2017). In 2017, the urban population growth rate for Kenya was 26.6%, this was an increase from 9.5% in 1968. This shows that the average annual urban population growth rate in Kenya is 2.12%. Nairobi, which is Kenya's largest city by population, has over 6.5 million residents, the number is expected to rise to 8.5 million by 2035 (UNFPA 2014). From the foregoing, Nairobi city will need to meet the increased demand for infrastructure. With the lack of an adequate and efficient infrastructure, Nairobi city will sprawl away from the urban core which will strain the environment by creating more traffic congestion and travel time, loss of valuable farmland, and unbalanced allocation of resources (Huanqing 2013).

The construction of sustainable urban areas which can survive a huge population growth rate, natural disasters, and

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the effects of climate change through urban resilience building is critical for urban planning and engineering in Nairobi. The urban underground contains a large intact potential that, if correctly managed and used, would contribute considerably to the urban sustainable development (Montazerolhodjah et al. 2015). This paper explores the best practices of designing and planning underground spaces for the achievement of a sustainable urban development and the creation of a resilient city.

While the history of underground construction dates back centuries, evolution of technology and construction methods has expanded its horizons. A vision once reserved for transport, storage, and utility solutions has grown to encompass limitless possibilities for future development, fueled by necessity in many cases (Hunt et al. 2014).

2 Background

Humans first used underground space as shelter and food storage, they resided in underground spaces such as caves for protection from harsh weather conditions and wild animals. In 4000 BC, people lived in semi-underground pit dwellings (Heba et al. 2012). Urban services such as drainage and water supply can be traced back to the ancient Babylonians who constructed water supply tunnels in about 2500 BC and to the Romans who had well-developed water and sewerage systems. Wherever civilization flourished, people found a use for underground space (Montazerolhodjah et al. 2015).

During the industrial revolution, tunnels were developed to facilitate transportation in Western Europe. The relatively flat grades requirements of canals and railways increased the use of tunnels in the nineteenth century. As excavation techniques evolved and became more reliable, underground transport systems became more extensive (Granny 1997). Urbanization followed the industrial revolution and major cities of the world such as London, Paris, and New York turned to subways to manage their congested traffic, with the first subway system being opened in London in 1863 (Dhabi et al. 1863).

Globally, underground space has continually become more attractive for development. The reasons sometimes differ among the countries but one major similarity is that the use of underground space is a means for achieving quality aspects such as an improved environment (International Tunnelling Association 2000). In countries like Japan and Italy, geographical conditions are some of the factors that make the use of underground space important. Extreme weather conditions in countries like Australia and Canada has led to an increase in the use of underground space for safety reasons. The city of Montreal, Canada has underground streets that also reduce traffic congestion, parking demands, and air pollution, this is similar to big cities in Germany, France, and Britain (Zhang 2018). In this context, underground development offers a feasible, long-term solution for Nairobi in line with sustainable development principles.

3 Methods

An inductive qualitative approach was used to provide for an enhanced understanding of the use of underground space in the global context. An interpretivist research philosophy was also adopted and since there was no prior hypothesis to be tested, an exploratory study was used to inform the research. Literature review was conducted to examine the definition, concepts, application, and all related issues of the use of underground spaces. Exploratory interviews were conducted to collect data from the perspectives of purposefully sampled construction industry players (The Government, Urban planners, Project Managers, Architects, and Engineers) in Nairobi, Kenya. 12 semi-structured face-to-face interviews were conducted over a 1-month period. An interview guide was used to collect data for the fulfillment of the research objectives. Materials from previous desk studies were used to prepare for the interviews, all interviews were approximately 1 h in length for each respondent. The data was then analyzed by the authors using the technique of context mapping.

4 Findings

The main aim of this study was to identify the main problems risking both the functionality and quality of life in Nairobi city and to explore the various approaches to development, planning, geology, policies, and projects being delivered and considered globally focusing on the need for good and professional planning of underground space. The findings show that the major challenges for Nairobi as an urban area are transportation, water supply, and sanitation.

4.1 The Case of Urban Transportation

Public transportation is an essential service and is very vital in the development of Kenya in line with vision 2030 and the millennium development goals. In Nairobi, majority of the population use the public transport since they do not own automobiles, this is because 60% of the residents live on less than 2 dollars a day in informal settlements (UNFPA 2014). The findings show that the main causes of urban public transport problems in Nairobi are rapid urbanization, inadequacy of the transport infrastructural facilities, and high concentration of economic activities within the central business district, Westlands, Upper hill, and Industrial areas of the city resulting in huge volumes of people and goods movements that become difficult to accommodate efficiently. As a result, this imposes an annual cost of Kenyan Shillings 40 billion o the economy. This is attributed to poor planning which includes construction of bypass roads that divert traffic from the city center, expanded feeder roads and reduced junctions which only create bottlenecks in parts of the city, for example, Pangani and serve as short term solutions.

From the foregoing, the only viable solution is underground mass transit systems. Globally, metros are considered a necessary and indispensable part of every large city's transit network. There are more than 12,000 km of metro lines providing services to over 150 cities around the world (Kaliampakos 2016).

4.2 Infrastructure

Today, Nairobi has a huge requirement in terms of infrastructure which includes but is not limited to energy, telecommunications, water supply, and waste management. The sustainability goals of the city can only be achieved if the infrastructure is placed in the underground space. The findings from the study indicate that Nairobi is trying to utilize underground space for freshwater collection from Murangá using the Northern collector tunnel of which the construction is ongoing at a cost of Kenya shillings 6.3 billion, the Kenya power electricity supplying company is building underground cables at a cost of Kenya shillings 13 billion, this is aimed at increasing power reliability, the city has been running sewer improvement programs aimed at upgrading underground sewer infrastructure and Safaricom, a telecommunication company has laid underground fiber-optic cables reaching thousands of homes in Nairobi.

However, the absence of an integrated land use plan for the underground space can result in significant problems. As stated by Kaliampakos (2016), the "spaghetti subsurface" problem compromises subsurface future utilization and utility tunnels are an efficient solution to it. The tunnels are meant to host a range of urban services and different cable links. This has many advantages such as centralized operational control, increased durability of utilities, enhanced safety, easier maintenance, and repairs which is done without any interference with the city environment and traffic.

All expenses can be mutually divided to all the services providers involved in the project.

From the foregoing, subsurface utilization should be based on the principles of sustainable development aiming to minimize environmental hazards, saving energy, increasing the functional diversity of the urban structure, reducing the need for local transportation, making services more accessible to residents, and protecting the urban landscape and culture. However, underground development is not an end in itself. It must be viewed as a means of achieving strategic objectives of the government (International Tunnelling Association 2000). Below is a brief SWOT analysis of building underground in the Kenyan context (Fig. 1).

4.3 Planning for Underground Space Use in Nairobi

As Nairobi looks forward towards a sustainable future, planners have to look for various ways to allow for economic growth while preserving the natural environment. However, underground development can only be realized if it's socially and politically acceptable, economically viable, and legally possible (Doyle et al. 2016). On the other hand, planning, zoning and building code regulations and standard forms of contracts do not necessarily reflect the nature of underground projects and they should be revised to reflect as such. Underground space can be divided into a number of different categories according to the user requirements (Fig. 2).

From the figure above, housing, working, and public use should focus more on surface development with underground space being developed only for parking's, storage, and service facilities. However, for the industry, traffic, and infrastructure, underground space plays a major role in

Strengths	**Weaknesses**
□ Allows for a compact urban structure □ The underground streets improve efficiency for the city's infrastructure services □ Reduces pollution	□ Connections with the above ground traffic may be challenging to arrange □ High initial costs □ Prejudice against underground solutions
□ Improves safety □ Helps protect the natural landscape □ Protects the townscape and cultural heritage of citied □ Saves time for the residents □ Reduces operational and maintenance costs for the town infrastructure	□ Geological limitations in some locations □ Job satisfaction of the workers is lower because of the lack of windows and sunlight
Opportunities	**Threats**
□ Formulation of underground planning policies □ Job opportunities in underground construction □ Formulation of an underground legal framework □ Freeing up above ground space for other uses	□ Unclear legal provisions regarding underground construction □ Planning policies are only focused on above ground activities □ lack of integrated decision making procedures for underground space □ Unfamiliarity with the possibilities of underground construction

Fig. 1 Underground construction in Nairobi, Kenya—SWOT analysis (Source: Authors (2020))

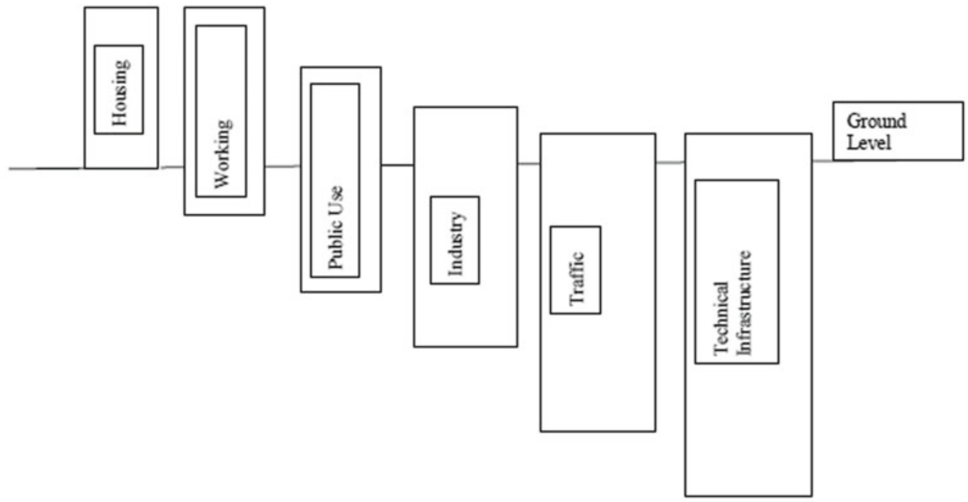

Fig. 2 Feasible Depths of different activities in the urban structures (Source: 167 Goel (2015))

maximizing land use. Therefore, in developing the underground space in Nairobi, a holistic approach has to be promoted which not only considers the geological and environmental effects but also the economic, political, and social acceptability of the underground developments. The rural to urban migration is an important factor in the developing Kenyan economy and the major goal should be to keep the growing Nairobi city functioning. While this study is far from exhaustive, it shows that underground space should be considered in future developments of Nairobi city and cooperation between urban planners, engineers, architects, and all the stakeholders in the city is required to exploit the potential of the societal and spatial asset.

4.4 Engineering by Substraction

Nairobi city is mainly underlain by pyroclastic volcanic rocks that were deposited during the formation of the East African Rift Valley (Caroline 2012). The city also has several spots of sensitive soils and variable ground profiles. Many borings and trial pits beneath and around building sites show that the thickness of the soft and sensitive deposits varies from 0.8 to 21 m below the ground surface (Onyancha et al. 2011).

In any underground project, groundwater is a prime factor in its successful development and use, this is since groundwater pressure and inflow affects the stability of excavation faces and the strength of the support structures required. In Nairobi city, groundwater levels vary considerably with surface topography and season and lie between 0.5 and 18 m below the ground surface (Onyancha et al. 2011). The variability of engineering properties of the subsurface materials in Nairobi calls for thorough geotechnical investigations before designing any underground structures (Fig. 3).

From the foregoing, a three-dimensional soil and rock structure data system should be developed and integrated into the city's Geographical Information System (GIS), this will assist in underground master planning of the city. The development of a better knowledge and representation of the geological medium and of existing underground structures is a critical need for Nairobi.

4.5 The Case of Urban Transportation

Nairobi city is mainly underlain by pyroclastic volcanic rocks that were deposited during the formation of the East African Rift Valley (Caroline 2012). The city also has several spots of sensitive soils and variable ground profiles.

As Nairobi looks forward towards a sustainable future, planners have to look for various ways to allow for economic growth while preserving the natural environment. However, underground development can only be realized if it’s socially and politically acceptable, economically viable and legally possible (Doyle et al. 2016). On the other hand, planning, zoning, and building code regulations and standard forms of contracts do not necessarily reflect the nature of underground projects and they should be revised to reflect as such. Underground space can be divided into a number of different categories according to the user requirements.

5 Conclusions

Urban underground space can contribute to making Nairobi city more resilient and cope with rapid urbanization. A disciplinary approach is required to make this a reality by

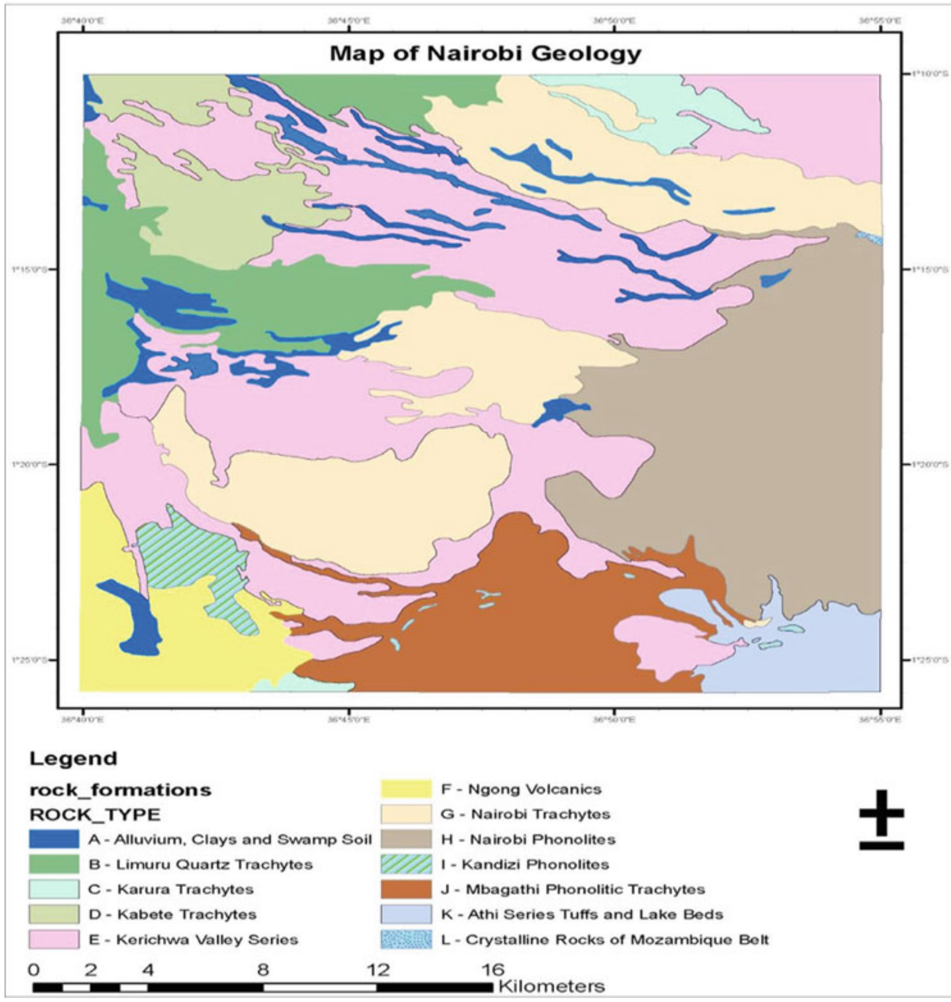

Fig. 3 Geological map of Nairobi City (Source: Onyancha et al. 2011)

coordinating the different interests and needs for building under the city, improving the legislative and administrative regulations. Placement of infrastructure and other facilities underground presents an opportunity for realizing new functions in urban areas without destroying heritages or negatively impacting the surface environment.

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Assessment of the Level of Awareness of Robotics and Construction Automation in South African

Opeoluwa Akinradewo, Ayodeji Oke, Clinton Aigbavboa, and Mashangoane Molau

Abstract

South African economy is dependent on infrastructural development, which plays a major role in the country's economy. The Construction Industry has shown a slow increase in the adaptation of robotics and construction automation. Hence, it is facing construction accidents, poor quality of work, and sometimes projects result in cost overrun of which accident occurs as the results of low level of supervision on site. The study focused on assessing the level of awareness of robotics and construction automation in South Africa. The research was carried out using information from the literature review and findings obtained from the questionnaire to achieve the objective of the study. A sample of respondents was chosen to represent the entire population of the construction professional, questionnaires were distributed to relevant respondents including Architects, Quantity Surveyors, Project Managers, Construction Managers and Contractors as well as Civil Engineers and the analysis was based on the returned questionnaires. Data obtained were analysed, and the study revealed that construction professionals are fully aware of robotics and construction automation in the South African construction industry. The study concluded by indicating that construction automation and robotics would have positive effects on the delivery of the construction project by increasing quality of the construction product, enhancing supervision, working conditions, cost effectiveness and it reduces construction accidents.

Keywords

Automation and robotics • Building information modelling • Computer-aided design • Computer-aided manufacturing • Industrialised building system

1 Introduction

Construction Industry plays a major role in the national and world's economy. The construction industry is faced with challenges of poor quality of the construction products and an increase in the risks associated with the occupational health and safety. Balaguer and Abderrahim (Balaguer and Abderrahim 2008) mentioned construction automation as a solution to the problems faced in the construction industry and further discussed that construction industries should implement fully and adopt the use of construction robotics since the construction professionals are interested in completing projects within short period of time to carry on with other investments. Robots are given certain characteristic to perform construction duties and automated by means of integrating robots with computer software. This advanced technology in construction is used to maintain and monitor the quality of the products to ensure that minimum standards can be achieved in order to encourage long life span of the construction product, which will reduce maintenance (Akinradewo et al. 2018).

Robotics and construction automation are deployed in the construction industry to mitigate human-related errors, with advanced computer software easier to detect defaults that cannot easily be detected by human and can be done repetitively (Kim et al. 2015). Automation can be integrated with lasers to improve inspection of the complete product with thin short period since robotics are more productive than using manual labour and feedback of the inspection can be stored in the database for future use. Since automation minimises the demand of skilled labour and substitute

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workers at workplace, it will decrease construction the number of construction accidents and insurance may be reduced to low level of risks associated with occupational health and safety. Robots and construction automation help with the development of new products such as construction equipment and tools used in the construction industry (Akinradewo et al. 2018; Kim et al. 2015).

Construction automation and robotics are modern types of technology used in the construction industry, this technology involves using combination of electronics, mechanical and computer software to operate robots by using special codes to perform required functions (Akinradewo et al. 2018). The use of construction technology is to improve working conditions, improve health and safety, scheduling and improving quality of the construction products. There is a lack of automation in the construction industry due to the cost for purchase of these equipments. Hence, there is a slow adaptation of this machinery in construction (Paulson 2008). Construction automation is an integration of information technology with robots, to assist in the designing of construction, planning and estimating cost of the project (Hosseini et al. 2017).

As shown in Fig. 1, the use of robotics for the construction of buildings is possible such that it reduces the workload on human power which will eventually result to reduction in the accidents on site and enhance the maintenance of standards in the quality of workmanship and it also doesn't eliminate the labour workforce as operators will still be required as well as setup labour. Computer technology assists the manufacturing industry to produce construction products at constant speed, which makes this technology more advanced because machines are accurate and assist in planning to avoid wastage of materials (Kim et al. 2015). Automated machines can estimate accurate amount of material that is required to finish the product hence can improve working environment by ensuring less wastage in the working environment that has an impact on the health and safety of the workers (Balaguer and Abderrahim 2008). This research seeks to the level of awareness of Robotics and Construction Automation in the South African Construction industry to determine areas in which the technology needs to be improved on for the development of the construction industry.

2 Methodology

Leedy and Ormrod (2013) defined methodology as the approach that the researcher takes in carrying out a research project. This research survey was conducted by using questionnaire to collect data from the respondent. Questionnaire was distributed to the construction professionals from different department in the Gauteng province specifically Johannesburg. Construction professionals that were involved in the collection of data were Architects, Quantity Surveyors, Project Managers, Construction Managers and Contractors as well as Civil Engineers because of their experience in the construction. The research questionnaire

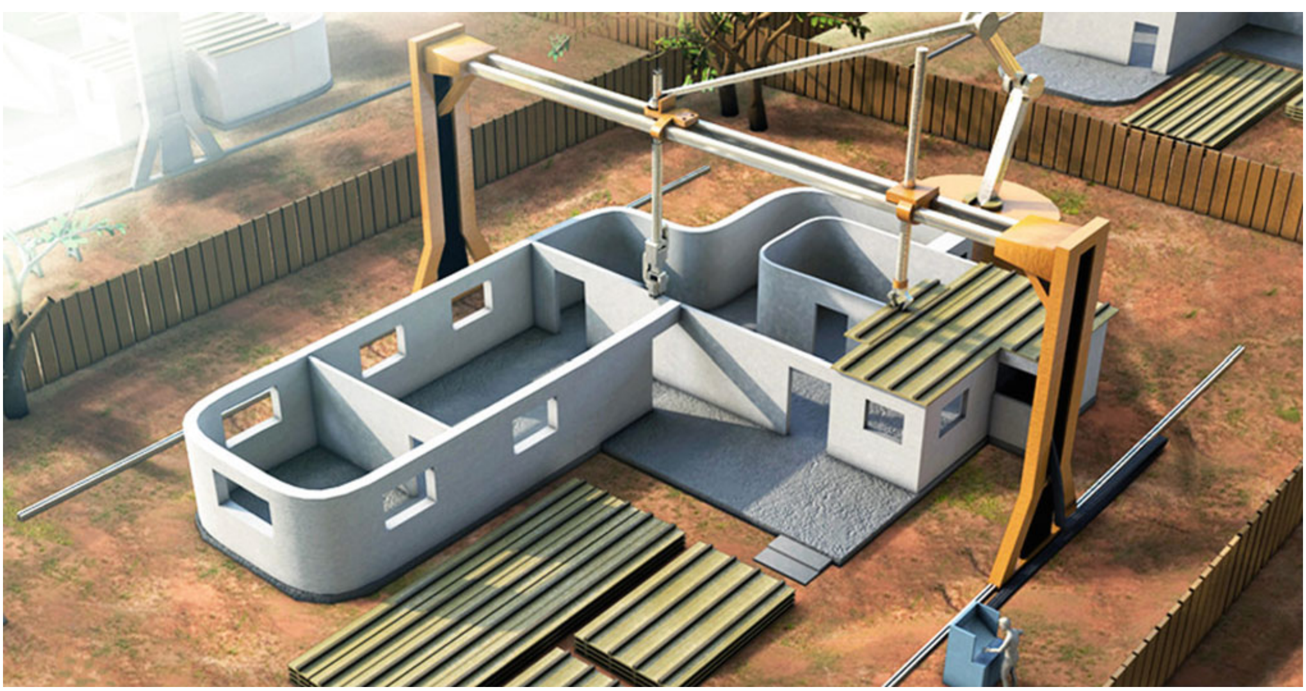

Fig. 1. 3D representation of the use of robotic for the construction of bungalow (*Source* Google 2018)

Table 1 Level of Awareness of Robotics and Construction Automation

Forms of robotics and construction automation	Mean item score	Standard deviation	Rank
Building Information Modelling (BIM)	4.02	1.089	1
Computer-Aided Design (CAD)	3.86	1.231	2
Computer-Aided Manufacturing (CAM)	3.77	1.118	3
Construction equipment reversing camera	3.75	1.241	4
Vehicle warning alarm	3.61	1.125	5
Automated welding machine	3.59	1.335	6
Vision sensors	3.52	1.229	7
Site monitoring camera vision	3.48	1.248	8
Global positioning system (GPS)	3.45	1.486	9
Equipment blind sport sensor	3.43	1.319	10
Automated cutting grinder	3.43	1.453	11
Inspection laser sensor	3.39	1.333	12
Proximity sensors	3.34	1.493	13
Concrete steam curing system	3.3	1.456	14
Automatized braking assistance	3.27	1.246	15
Concrete electric and infrared curing system	3.11	1.401	16
Non tactile sensor	3.09	1.395	17

used Likert scale for the respondents to rank the question that is required to answer the research questions and objective in this study. The respondents were required to rank each factor using the 5-point scale (1-very low, 2-low, 3-Average, 4-high, 5-very high). Factors for each question were extracted from the literature review which was obtained from the primary source of information including journal, internet source, textbooks and articles. Data for this research were analysed using the descriptive statistics to help describe, summarise data and organise data in a sequence. This information was computed by using special statistic software called SPSS.

3 Results

3.1 Respondent's Demographic Information

The research result shows 64 % of the respondents are males and 36 % females. Findings indicated that 14 % are Architect, 30 % are Quantity Surveyor, 20 % are Construction Engineers, 20 % are Project Managers and 16 % are Construction Managers. Years of experience of the respondents showed 43 % have between 1 and 5 years, 32 % are between 6 and 10 years, 20 % are between 11 and 15 years, 5 % are between 16 and 20 years and 0 % have 20 years and above of working experience. The study also discovered that 0 % of the respondents are with no qualification, 5 % have secondary qualification, 34 % have Diploma, 18 % have Degree, 32 % have Honours and 11 % have Masters Degree. With this demographic information of the respondents, it can be concluded that the respondents possess enough experience in the construction industry and their opinion on the level of awareness of robotics and construction automation in the South African construction industry can be relied upon.

3.2 Level of Awareness of Robotics and Construction Automation

Findings for level of awareness of robotics and construction automation forms in South African construction industry as shown in Table 1 indicated that Building Information Modelling (BIM) was ranked first with a mean score item of 4.02 and standard deviation (SD) = 1.089, closely is Computer-Aided Design (CAD) which was ranked second with a mean item score of 3.86 and Standard Deviation (SD) = 1.231, Computer-Aided Manufacturing (CAM) was ranked third with mean score item of 3.77 and Standard Deviation (SD) = 1.118, while non-tactile sensor was ranked lowest with a mean score item of 3.09 and Standard Deviation (SD) = 1.395.

4 Discussion

The findings from the respondents show a high level of awareness on construction automation and robotics with an average Mean Item Score of 3.50 coming to 70 %. Building

Information Modelling gained most awareness among construction professionals in Gauteng province, South Africa. This agrees with the findings of (Mohd Nawi et al. 2015) that although BIM is a new technology, it has gained high percentage of awareness due to the fact that it is generic among all the construction industry professionals in United Kingdom, Canada and Finland Construction Industries. This also agrees with (Wang and Chien 2014) indicating high level of awareness in BIM in the Middle East. CAD and CAM ranked second and third, respectively, which agrees with (Meganathan and Nandhini 2018) who are with the opinion that most construction professionals are aware of these two forms of construction automation and that only about half of the respondents were taught about them from their educational institution while other half has seen CAD and CAM machines/software. From this research, it is evident that the South African Construction industry professionals are aware of robotics and construction automation forms which is an indication that the industry is ready for the adoption of these technologies in order to advance project delivery to time, cost, quality while considering the safety of workers on construction site.

5 Conclusions and Recommendations

The study showed high level of awareness of robotics and construction automation in South Africa. The study concluded by indicating that construction automation and robotics would have positive effects on the delivery of the construction project by increasing quality of the construction product, enhancing supervision, improving working conditions, cost effectiveness and it reduces construction accidents. This will, therefore, reduce human error which the construction professionals are prone to making in carrying out their professional services to an extent. It is, therefore, recommended that the government should provide subsidies on automation and robotics so that South African construction industry can have full adaptation of such technology and the government should also organise training for construction workers to increase their level of awareness of robotics and construction automation. However, the major limitation of this study is that it was carried out in Gauteng province of South Africa only, therefore, it can be carried out in other areas of the country to have a general overview of Construction professional awareness of Robotics and Construction Automation. Further, studies can also be carried out in assessing the willingness to adopt the use of Robotics and Construction Automation in the South African Construction Industry.

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Challenges to the Implementation of Lean Construction Practices in the South African Construction Industry

Ayodeji Oke, Opeoluwa Akinradewo, Clinton Aigbavboa, and Mulongo Ndalamba

Abstract

Lean Construction (LC) aims at concentrating on improvement, reduction of waste, money value, focus of user, project quality management, supply management and improved communications. LC helps in reducing waste of materials, effort and time which, therefore, generates maximum possible value and provides a cohesive supply chain that reduces lead time. The Construction Industry performance is affected by waste. Such wastes are measured in materials, resources, time, movement, production and creativity. Hence, this study identifies the challenges of implementing LC practices in the South African Construction Industry (SACI). Data used for this paper were collected using well-structured questionnaire distributed to professionals within the SACI ranging from Quantity Surveyors, Architects, Civil Engineers, Project Manager, Construction Manager and Construction Project Manager. Findings emanating from the study revealed that poor work culture among project partners ranked highest followed by lack of good policies, complexity of lean construction process, poor organisation knowledge among others as the challenges facing the implementation of lean management in the SACI. It was concluded that the main significant aspect that lean construction evolves around is attitude, this, therefore, requires construction industry participants to have a complete attitude shift and practice lean construction on their everyday tasks.

Keywords

Construction industry • Lean construction • Project delivery • Construction waste

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1 Introduction

The word lean is a term adopted from the manufacturing industry, which was later introduced for use in the construction industry. In the 1950s, the promotor of the Toyota Production System Taiichi Ohno concentrated his efforts on finding ways of converting waste into value developed the Lean production management principles (Womack and Jones 1996; Sarhan and Fox 2013). Koskela (1992; Ogunbiyi et al. 2014) also affirmed that lean construction is an idea formed from the concepts of lean manufacturing. The term Lean Construction (LC) was pioneered by (Koskela 1992) who introduced the idea of understanding production as 0020 construction and establish the lean concept in construction (Ogunbiyi et al. 2014). (Egan 1998) defined LC as a dominant technique that delivers improvement efficiently, reduce waste and improve quality. Construction Industry Institute (2019), LC is described as a continuous method which helps to reduce waste, meet client's requirements, concentrate on the maximum amount and pursue excellence in the realisation of projects. Based on the definition of (Rubrich 2012) and (Warcup 2015) "LC is a business system that encompasses culture, planning, concepts, and tools to maximise value while minimising all forms of waste". LC aimed at concentrating on improvement, reduction of waste, money value, focus of user, project quality management and supply management, and improved communications. LC helps in reducing waste of materials, effort and time which, therefore, generates maximum possible value and provides a cohesive supply chain that reduces lead time. Such wastes are measured in materials, resources, time, movement, production and creativity (Warcup 2015; Liker 2004; Liker and Meier 2006; Akinradewo et al. 2018). By eliminating waste, LC practices enhanced the performance of the C.I using a minimum amount of resources.

Common et al. (Common et al. 2000; Mossman 2009) explained that the lean concept exists since the beginning of 1900s. It is Henry Ford who presented the philosophy of the

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assembly line that revolutionised car production. The adoption of lean concept in production as established by Toyota Motor Company in Japan brought about the principles of lean construction. Engineer Taiichi Ohno, the company head of production engineering, devoted his time into discovering how to convert waste in the industry into value (Womack and Jones 1996; Sarhan and Fox 2013; Howell and Tommelein 1999). With the adoption of lean concepts in the construction industry, benefits have been recorded in reducing construction waste during the execution of projects on site. LC helps to eradicate time and materials waste as a means to generate value in more possible ways (Koskela 1992). According to (Naim and Barlow 2010), time is reduced by the cohesive supply chain of LC. By clearing project objectives, LC shows the difference in it compared to project management method (Howell and Tommelein 1999), and the function of LC is highlighted in maximising the performance of projects by eliminating waste throughout the design to delivery lifecycle of the project. Improvement in the construction process came as a result of these principles of waste reduction. Conclusively, the adoption of LC helps to meet the requirement of clients, reduce the value stream and it also pursuit perfection in construction projects. Its application spans across construction project design through delivery and use.

In the last decade, several research efforts have been geared towards the classification of construction waste. These relate to various characteristics such as type and magnitude. (Hosseini et al. 2012). Waste can also arise from procedures of work, resources, time, operations and equipment (Alarcón 2010; Formoso et al. 2002). Waste in construction could be because of design errors, redoing work, defects, modifications and using more materials (Formoso et al. 2002). However, waste in construction and manufacturing industry comprises waiting times, excess inventory, rework, lack of safety, quality costs, unnecessary transportation trips, set up, motion, handling, expedition, prioritising, inspections, improper choice or management method or requirement and lack of constructability (Rahman et al. 2012).

2 Methodology

This survey adopted a quantitative approach to achieving the objective. Quantitative research is a numerical representation and manipulation of observations which examines and gives an understanding of the phenomena that those observations reflect (Sukamolson 2000). The research method helped to determine the challenges that the SA construction is facing in the implementation of LC practices. With the use of a questionnaire survey, the primary data were obtained. Respondents for this study are Architects, Quantity Surveyors, Project Managers, Construction Project Managers and Civil Engineers who have been involved in construction projects. Data collection was done by using a structured questionnaire which was designed based on information from the literature review. Descriptive statistics, Mean Item Score (MIS) and Standard Deviation (SD) were used in analysing data for this study through the use of SPSS.

3 Results

3.1 Respondent's Demographic Information

The research result shows the professional qualification of the sampled respondents, and it reveals that 35.0 % are Quantity surveyors, 18.3 % construction managers, 12.2 % Project managers, 23.1 % civil engineers and 9.2 % Architects. Result also showed 62.2 % had experience that ranged from 1 to 5 years, 20.0 % 6–10 years, 11.1 % 11–15 years, 4.4 % 16–20 years while 2.2 % had more than 20 years of experience in the construction industry. Further, result showed 16.5 % of the respondents work for private clients, 39.9 % consultants, 36.4 % contractors and 7.2 % works for public client/government. The result revealed that 17.8 % of the respondents have been involved in 1–2 projects, 26.7 % in 3–4 projects, 37.8 % in 5–6 projects, 8.9 % in 7–8 projects and 8.9 % of the respondents were involved in more than 8 projects. The research result shows that 20.0 % of the respondents weren't involved in projects in which Lean Construction was practiced, 51.1 % of the respondents were involved in 1–2 projects, 22.2 % in 3–4 projects, 6.7 % in 5–6 projects, and none of the respondents have been involved in more than 6 projects that LC was practiced on. It was also gathered from the result that out of the projects in which Lean Construction was practised, 23.6 % are school projects, 21.3 % are hospital projects, 15.6 % are housing estates projects, 8.2 % are road construction projects, 4.6 % are other civil works (dams, etc.) projects, 14.5 % are government offices projects and 12.2 % are renovation projects (residential, civil, etc.). With this demographic information of the respondents, it can be concluded that the respondents possess enough experience in Lean Construction Practices in the South African construction industry and, therefore, their opinion can be relied upon for this study.

3.2 Challenges to the Implementation of Lean Construction Practices

The ranking of the challenges in Table 1 was done using the combined opinion of the respondents for an overall interpretation. Findings on the challenges of implementing Lean Construction practices in the South African construction industry as shown in Table 1 from contractor respondents' point of view show that the top five most dominant challenges are poor culture among project partners, lack of good policies, lack of understanding of lean construction, lack of skills on lean construction process and complexity of lean construction process.

Table 2 indicates client and consultant respondents' point of view and the top five most dominant challenges are inherently knowledge-intensive, poor organisational knowledge, lack of resources, poor culture among project partners and complexity of lean construction process.

Table 3 shows combined respondents' view with the top five most dominant challenges being poor culture among project partners, lack of good policies, complexity of lean construction process, poor organisational knowledge and lack of understanding of lean construction.

4 Discussion

This survey agrees with the study carried out by (Senaratne and Wijesiri 2008) who identified the human attitudinal issues of implementing lean construction; Absence of a lean culture in the company; cultural change; poor team spirit; misconceptions about lean practice—seen as too complex—and fear of unfamiliar practices as the major challenges facing the implementation of Lean Construction practices. On the other hand, client and consultant respondents viewed inherently knowledge-intensive, Poor organisation knowledge, Lack of resources, Poor culture among project partners and Complexity of lean construction process as the top five most common challenges of implementing lean construction. These findings agree with the survey of (Mwacharo 2013; Aigbavboa et al. 2016) which identified inherently knowledge-intensive as the most common challenge during the implementation of LC practices. As a result of this, the combined opinion (Contractor respondents and Client/Consultant respondents) using calculated MIS and SD showed that the most significant challenge is Poor culture among project partners. However, they both agreed that there are common challenges such as complexity of lean construction process with a mean gap of 0.03 and that lean concept takes time to adopt with a mean gap of 0.00. The findings also agree with similar research carried out by (Oguntona et al. 2019) which focused on Gauteng province of South Africa. From this research, it is evident that the South African Construction industry professionals are faced with some challenges in implementing LC practices with Poor culture among project partners playing a major role together with Complexity of LC process and the long time it takes to adopt LC concept.

5 Conclusions and Recommendations

From the research work carried out, it can be concluded that the main significant aspect that lean construction evolves around is attitude, this, therefore, requires construction industry participants to have a complete attitude shift and practice lean construction on their everyday tasks. This will consequently reduce human error which the construction professionals are prone to making in carrying out their professional services to an extent. It is, therefore, recommended

Table 1 Challenges to lean construction practices implementation (Contractor's view)

Challenges of implementing lean construction	Contractors		
	MIS	SD	R
Poor culture among project partners	4.97	7.228	1
Lack of good policies	4.1	0.712	2
Lack of understanding of lean construction	3.93	0.98	3
Lack of skills on lean construction process	3.93	0.583	3
Complexity of lean construction process	3.9	0.923	5
Takes time to adopt	3.87	1.137	6
Poor organisational knowledge	3.83	0.874	7
Human attitude	3.8	0.714	7
Ineffective management	3.83	0.874	7
Inherently knowledge-intensive	3.7	0.651	9
Financial boundaries	3.67	1.061	11
Poor time management	3.67	0.884	11
Creates stress on contractors	3.6	0.932	13
Lack of resources	3.57	0.935	14

Table 2 Challenges to lean construction practices implementation (Clients and Consultants' view)

Challenges of implementing lean construction	Client and consultants		
	MIS	SD	R
Inherently knowledge-intensive	4.2	0.56	1
Poor organisational knowledge	4.07	0.8	2
Lack of resources	4.07	0.88	2
Poor culture among project partners	3.93	1.1	4
Complexity of lean construction process	3.93	0.8	4
Takes time to adopt	3.87	0.92	6
Financial boundaries	3.87	0.99	6
Lack of understanding of lean construction	3.8	1.21	8
Human attitude	3.73	0.96	9
Poor time management	3.73	0.7	9
Reduction of inventory	3.67	0.72	11
Lack of good policies	3.6	0.99	12
Lack of skills on lean construction process	3.6	0.99	12
Creates stress on contractors	3.47	0.64	14
Ineffective management	3.33	1.23	15

Table 3 Challenges to lean construction practices implementation (Combined Opinion)

Challenges of implementing lean construction	Combined view		
	MIS	SD	R
Poor culture among project partners	4.41	0.712	1
Lack of good policies	4.08	0.968	2
Complexity of lean construction process	3.89	0.748	3
Poor organisational knowledge	3.87	0.888	4
Lack of understanding of lean construction	3.85	0.419	5
Takes time to adopt	3.79	0.571	6
Inherently knowledge-intensive	3.74	0.865	7
Lack of skills on lean construction process	3.7	0.663	8
Human attitude	3.69	0.795	9
Financial boundaries	3.67	1.004	10
Lack of resources	3.65	0.591	11
Poor time management	3.61	0.621	12
Ineffective management	3.55	0.902	13
Creates stress on contractors	3.54	0.801	14
Reduction of inventory	3.49	0.826	15

that there should be initiation of stakeholders with positive culture and behaviour because they are the ones who can sustain the changes over time in the industry while Clients are encouraged to employ lean expert managers because lean management plays a vital role in the successful delivery of projects. This study was carried out in Western Cape Province of South Africa only which is a major limitation, it is, therefore, advised that it should be carried out in other areas of the country to compare opinions of construction professionals. Further, studies can also be carried out on the determination of the relationship between lean management and traditional management within the South African Construction Industry.

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Effectiveness of Contractors' Competitive Bidding Strategies in the UAE Construction Industry

Dima Arouk and Sameh El-Sayegh

Abstract

Contractors seek different competitive bidding strategies in order to increase their opportunity in winning projects. The United Arab Emirates (UAE) construction industry is competitive. Additionally, nowadays, UAE companies tend to expand globally, entering new international markets. Therefore, effective bidding strategies need to be implemented to compete profitably in the UAE and the international markets. The objective of this research is to identify the effective competitive bidding strategies for construction companies in the UAE and international markets. Common competitive bidding strategies were identified through review of related literature. A questionnaire was then prepared and distributed to construction companies in the UAE. Sixty-five surveys were completed and analysed. As a result, the top five effective strategies in the UAE market are lowest bid, value management, achieving a combination of price and performance, application of high technology, and public relations strategy. The top five effective strategies in international market are noted to be achieving a combination of price and performance, lowest bid, value management, application of high technology and public relationship. The results are particularly useful for international contractors who want to enter the UAE construction market.

Keywords

Bidding strategies • Construction industry • UAE • International construction

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1 Introduction

Construction projects are normally awarded through the practice of competitive bidding. Competitive bidding occurs when the client invites contractors to bid for a project. The invitation is usually made through public advertisement. Bidding is the process of submitting a bid proposal to the client for undertaking the construction project at a certain price. During the bidding stage, the contractor analyses the project documents and submits the bid price along with the required deliverables to the client. The client evaluates the contractor bid submittals, and ultimately awards the project to an eligible contractor. With low-profit margins required to win bids in tight and competitive construction markets, careful and accurate bidding is necessary for contractor success (2009). The contractors' ability to win the right project at the right price level is important for survival and making a profit (Oo et al. 2008). Competitive bidding allows all capable contractors to bid for the offered projects. Shash (1995) defined competitive bidding as a system in which the contractor is selected based on specific criteria to perform a set task. This style of bidding is considered a stable bidding practice in the construction market and is the most familiar method of distributing construction contracts among contractors (Harris and McCaffer 1995). Direct competition through bidding is the most common method of job distribution in the construction industry (Oo et al. 2008).

The construction industry witnessed an increase in the size and complexity of construction projects during the past years (El-Sayegh and Al-Haj 2017). Contractors adopt various competitive bidding strategies in order to meet specific objectives (Tan et al. 2010) and to improve their chances of winning projects (Drew et al. 2001). Bidding strategies differ from one construction firm to another, where each contractor will have a different degree of sensitivity towards the factors affecting their bidding decisions (Oo et al. 2010). The lowest bid strategy is one of the main strategies used by contractors. Submitting a lowest bid is usually accepted as being the key

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to winning a contract (Oo et al. 2008). However, the lowest bidders may not be competent enough to carry out the task (Halpin and Senior 2012). Enshassi et al. (2013) considered that the selection of the lowest bidder is the main cause of problems in the construction industry. El-Sayegh and Rabie (2016) stated that choosing a contractor based on the lowest price may not be the best approach as it may lead to delays and/or quality problems. Risk management is vital for successful project completion (El-Sayegh 2014).

The UAE is one of the largest construction markets in the Middle East. The construction industry is still productive despite the decline in the number of offered projects. Due to the high number of contractors in the market, the competition for winning projects remains fierce. During recessions, contractors are forced to become more competitive (Odusami and Onukwube 2008). It is found that competition between contractors to bid becomes brutal in bad years when few projects are available (Assaf and Al-Hejji 2006). The current economic situation has resulted in high competition between UAE construction companies to win projects locally and internationally. Therefore, effective bidding strategies should be implemented to compete profitably in the UAE and international markets. The objective of this paper is to assess the effectiveness of the competitive bidding strategies for UAE construction companies, in both local and international markets.

2 Methodology

The first step was to identify the common competitive bidding strategies based on the review of related literature. Seventeen strategies were identified. A questionnaire was used to get the perceptions of construction professionals in the UAE construction industry. Sixty-five questionnaires were collected. The respondents were asked to indicate the effectiveness of the identified strategies using a 5-point Likert scale. The scale ranged from 1 (not effective) to 5 (very effective) to measure the effectiveness of the different strategies. There were separate questions for competitive strategies in the local and international markets. The weighted average of the responses was then calculated for each strategy. The Spearman rank correlation coefficient was used to study the strength of relationships between the competitive strategies in the local and international markets.

3 Results

The bidding strategies were examined in terms of their effectiveness. The effectiveness is defined as winning the contract as a result of implementing a particular competition strategy in bidding (Tan et al. 2010). Table 1 shows the weighted averages and rankings of the effectiveness of the bidding strategies in the UAE and international markets.

4 Discussion

For the UAE market, the lowest bid strategy is the most effective way to guarantee winning project's bid, especially when the contractor is dealing with familiar client. The second most effective strategy is the value management strategy indicating the importance of value management in terms of bidding. By applying this strategy contractors save cost and time which allow them to compete effectively. The third effective strategy is achieving combination of price and performance. This strategy allows the contractors to meet the client's requirements (apart from the lowest bid price), such as the technical submissions. The lowest effective bidding strategy is clearly random bidding when work level is low. Overall, responses from UAE construction market disagree with private finance options strategy.

Achieving combination of price and performance strategy is the major strategy used and most effective while bidding for international projects. The results indicate that in the international market, complying with clients' requirements is the most effective strategy. The lowest bid price comes in second place. This is where the contractor has an experience in the market environment, as he will be in the safe side when submitting a reasonable low bid price. Value management is very effective strategy, as it saves cost and time, which allows the contractor to remain competitive. Application of high technology and public relation strategy is clearly explained by the fact that the international market is highly competitive. Applying high technology on the bidding process or on construction methodology attracts clients and enhances a contractor's chance to win the bid. Public relation strategy also operates as an effective strategy to win bids, especially when coupled with a good reputation and relationship with construction parties, e.g. the client, designer, etc. On the other hand, the analysis shows the most ineffective three strategies are random bidding (when work level is low), claim back strategy and private finance options.

As shown in Table 1, lowest bid is the most accepted strategy used as bidding strategy for winning local construction projects in UAE, while in bidding for international projects the main applied strategy is achieving combination of price and performance. A further analysis of the strength of relationship between the UAE and international market was performed using the Spearman Rank Correlation Coefficient analysis. The correlation coefficient is 0.92 which indicates a strong positive correlation between the two rankings. The comparison between the UAE and international market shows that the lowest bid was ranked as the most effective strategy in the UAE market, while it was

Table 1 Bidding strategy effectiveness

Bidding strategy	UAE		International	
	Rank	Average	Rank	Average
Lowest bid	1	4.51	2	4.29
Value management	2	3.97	3	4.25
Achieving combination of price and performance	3	3.95	1	4.44
Application of high technology	4	3.86	4	4.15
Public relations strategy	5	3.82	5	4.15
Technology transfer	6	3.58	8	3.87
Application of management innovation	7	3.52	9	3.77
Application of risk management strategy	8	3.49	7	3.92
Sustainable practices	9	3.28	13	3.06
Social responsibility	10	3.14	10	3.69
Contractor shares risks in project	11	3.06	12	3.21
Joint venture	12	2.97	6	3.94
Design and Build	13	2.77	14	2.88
Partnership	14	2.54	11	3.67
Claim back strategy	15	2.34	16	1.94
Project finance options	16	2.26	15	2.37
Random bidding	17	1.83	17	1.46

ranked 2nd in the international market. This difference is due to the uncertainty of the international market and the clients' multi-requirements for submitting the bid. A major discrepancy is the sustainable and environmental practices strategy. For UAE projects, it ranked 9th while for international projects it ranked 13th. This is because the UAE municipality and government are deeply concerned with sustainability applications, with most projects containing sustainability application. Thus, the contractors frequently use these applications as a strategy to gain the client's attention. However, for international projects, not all countries apply sustainability practices, thus limiting this strategy's effectiveness. Another discrepancy is the joint venture strategy. For the UAE market, it was ranked 12th while it was ranked 6th for the international market. In order for a contractor to enter a new country and be able to know how to deal with the new environment, a joint venture partner is highly complementary, increasing the chance of winning a project in the international market. For the UAE market, JV is not as effective, as the contractor may only need a partner when bidding for a large, complex project that needs other contractors' support.

5 Conclusions

The UAE is one of the largest construction markets in the Middle East. Due to the current global financial recession, the number of available projects declined, while the number of contractors remained relatively constant. This has led to an increased competition between contractors to win projects. As a result, UAE contractors are currently concerned with developing effective bidding strategies that can potentially increase their chances in winning projects.

In terms of effectiveness, the top five common effective strategies in the UAE market are lowest bid, value management, achieving combination of price and performance, application of high technology, and technology transfer. The top five effective strategies in international market are achieving combination of price and performance, lowest bid, value management, application of high technology and public relationship strategy.

This paper provides an in-depth focus on the effectiveness of the competitive bidding strategies in the UAE and the international construction markets. This is particularly useful for international contractors who want to enter the UAE construction market. Due to the changing economic conditions, contractors need to adapt their competitive bidding strategies to increase their chances of winning project. Contractors need to pay special attention to the clients' requirements. There is a shift towards sustainable construction practices in the UAE and contractors need to capitalise on that as they compete for projects. This paper helps contractors formulate the appropriate and effective bidding strategies in local and international markets.

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Objectives of Competitive Bidding in the UAE Construction Industry

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Abstract

Competitive bidding is one of the main methods for procuring construction work. Contractors compete based on bid prices where the lowest responsible bidder is selected. Competitive bidding is both costly and time-consuming without a guarantee of contract award. Therefore, contractors are selective on which projects to bid on. Contractors have several objectives from participating in the bidding process. The aim of this research is to identify and assess the key objectives of bidding in the UAE and internationally. The main objectives are identified through literature review. A questionnaire was used to get the perceptions of construction professionals in the UAE construction industry. Sixty-five questionnaires were collected. The most common objectives for bidding in general are building a reputation with the client, followed by the company's need of work and survival. The most common objective for bidding in the international market is to target an international market when its economy is expected to boom, followed by bidding internationally to gain advantage of the opportunity offered by global market. This paper sheds the light on some of the key practices of contractors in the UAE construction industry and may be beneficial to those international companies who wish to compete in the local market.

Keywords

Bidding • Construction industry • UAE • International construction

1 Introduction

Contractors can potentially have multiple objectives of competitive bidding, ranging from normal economic profit goal to the need for survival (Paranka 1972). Ravashadnia et al. (2011) highlighted that for some construction companies, bidding is a strategic decision to ensure survival. After all, the only promising approach for a contractor firm to survive and obtain its aims is winning bids and achieving profit (Egemen and Mohamed 2007). Friedman (1956) addressed the existence of multiple bidding criteria by listing objectives of profit maximization, maximizing return on investment, minimization of loss expectation, minimizing competitor profits and maximizing operational continuity. Another objective for bidding is to enter a new market and win project for its strategic value (Fayek et al. 1999). These objectives are influenced by factors internal to the company, such as the company's need for work and its availability of resources, and external factors, such as the degree of the competition, the prevailing economic conditions and the availability of future work (Fayek 1998).

Contractors compete internationally for several reasons counting to enhance long- term profitability, to balance company growth, and to alleviate the cyclical impact of construction demands in established construction markets (Oo et al. 2008). Also, contractors have a better chance to balance their growth by expanding to new overseas construction markets (Han et al. 2010). For international projects, the objective of bidding might be to win a project because of its characteristics, expand geographically by entering a new region and capitalize on the profit (Fayek 1998).

The construction industry witnessed an increase in the size and complexity of construction projects during the past years (El-Sayegh and Al-Haj 2017). Competitive bidding is one of the main methods for procuring construction work. The most commonly used system is the low bid system where clients choose the successful bidder based on the lowest price (El-Sayegh and Rabie 2016). Contractors compete based on

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bid prices where the lowest responsible bidder is selected. Competitive bidding is both costly and time-consuming without a guarantee of contract award. Therefore, contractors are selective on which projects to bid on. Contractors have several objectives from participating in the bidding process. The aim of this research is to identify and assess the key objectives of bidding in the UAE and internationally.

2 Methodology

The first step was to identify the main objectives of competitive bidding based on the review of related literature. A questionnaire was used to get the perceptions of construction professionals in the UAE construction industry. Sixty-five questionnaires were collected. The survey targeted bid managers, estimators, planners, general managers and business development managers. Therefore, 92 % of the respondents had more than 10 years of experience. 97 % of the respondents work in projects greater than AED 100 million in value (US$ = 3.67 AED—2019 Currency). The respondents were asked to indicate level of agreement with the identified objectives using a 5-point Likert scale. The scale ranged from 1 (strongly disagree) to 5 (strongly agree). The weighted average of the responses was then calculated for each objective.

3 Results

Based on the review of related literature, the objectives for bidding include profit maximization, need for work and survival, keep presence in the market, resource utilization, entering new market, reputation and experience. In the construction industry, the bidder's goal is not purely to be the lowest bidder, but also to acquire the contract at a profit (Cook 1985). Bidding in the construction industry is a strategic decision that assists a contractor to survive (Ravashadnia et al. 2011). The only possible way for construction firms to achieve their goals is through winning bids and making profit (Egemen and Mohamed 2007). The need of work is the most frequent factor making a construction company believe that they have to win this work (Fayek et al. 1999). A construction firm might have a desire to be seen as competitive in the construction market and build a good reputation with the owner or consultants which will establish a good relationship with them (Fayek et al. 1999). For some construction firms, it may be very important to win the project if, for instance, it needs to generate revenue and to utilize their idle resources (Fayek et al. 1999). As keeping the resources idle without working is a costly process and terminating them might not be a wise decision. Some researchers have mentioned that there are many objectives for bidding for a project, such as resource utilization and maintenance of cash flows (Ravashadnia et al. 2011).

Due to the Globalization pressures contractors headed to enter new international construction markets (Han et al. 2005). Contractors have a better chance to balance their growth by expanding to new overseas construction markets (Han et al. 2010; El-Sayegh 2014). For international projects, the objective of bidding might be to win a project because of its characteristics, expand geographically by entering a new region and capitalize on the profit (Fayek 1998). Another objective is to balance risks. Construction companies respond to risks by adopting various risk management practices (El-Sayegh 2014). One of which is to expand internationally. Construction projects are naturally risky, and there is a need to address risks properly (El-Sayegh 2008). Contractors who have bidding experience are more competitive in bidding than inexperienced contractors (Fu et al. 2002). Contractor's experience in special type of projects may affect client selection of the bidder, where measuring the contractor past experience is one of the vital measurements for bid evaluation (Watt et al. 2009). Table 1 shows the various objectives of bidding and their literature sources.

Respondents were asked to evaluate the different objectives for bidding using a scale from 1 (strongly disagree) to 5 (strongly agree). Figure 1 shows the objectives of bidding ranked according to their weighted averages.

There are several reasons for bidding internationally. One of the important factors that make a local contractor divert to international market is the company need of spreading and reducing risk (Gunhan and Arditi 2005). In the current economic situation, contractors need to focus on the global markets and opportunities offered in their growing markets in order to survive and accomplish advance growth (Tiong and Yeo 1993). Some contractors adopt a strategy of operating in more than two countries. This is to ensure that a recession arising in one country can be balanced by a boom or stability in the other country (Gunhan and Arditi 2005). Some international markets might have a promising future, where the construction boom occurs in the form of a very high demand on construction projects. This also allows contractors to include a high profit margin to their project due to the higher levels of confidence in winning the project (Baldwin et al. 1995). One of the main objectives of bidding is to gain and enhance experience (Fayek et al. 1998). Table 2 shows the various objectives of bidding internationally and their literature sources. Figure 2 shows the objectives of bidding internationally ranked according to their weighted averages.

Table 1 Objectives of bidding (Literature Sources)

Objectives of bidding	Sources
Profit maximization	Paranka (1972), Friedman (1956), Fayek et al. (1998, 1999), Fayek (1998), Oo et al. (2008), Tan et al. (2010), Shash (1993), Dulaimi and Shan (2002), Seydel and Olson (2001)
Company need of work and survival Keep the presence in the market as a competitive	Paranka (1972), Fayek et al. (1998, 1999), Fayek (1998), Han et al. (2005, 2010), Shash (1993), Dulaimi and Shan (2002)
Company resource utilization	Ravashadnia et al. (2011), Fayek et al. (1998, 1999), Seydel and Olson (2001), Banki et al. (2008), Gunhan and Arditi (2005)
Entering new markets	Ravashadnia et al. (2011), Fayek et al. (1998, 1999), Fayek (1998), Han et al. (2005, 2010), Gunhan and Arditi (2005), Oo et al. (2007)
Build a name and future opportunity with the client	Fayek et al. (1998, 1999), Han et al. (2005)
To get experience in special types of project	Han et al. (2005), Fu et al. (2002), Watt et al. (2009), Fayek et al. (1998)

Fig. 1 Objectives of bidding (Ranked)

Table 2 Objectives of bidding internationally (Literature Sources)

Objectives of bidding	Sources
Bid international when stagnant domestic markets	Gunhan and Arditi (2005), Tiong and Yeo (1993)
Bid international to reduce risk through diversion to new market	Gunhan and Arditi (2005), Baldwin et al. (1995)
Bid international to competitive use of resource	Fayek et al. (1999), Gunhan and Arditi (2005)
Bid international to get advantage of opportunity offered by the global market	Fayek et al. (1999), Gunhan and Arditi (2005), Tiong and Yeo (1993), Ling and Liu (2005)
Target international market when its economy is expected to boom, thus higher profit	Fayek et al. (1999), Fayek (1998), Oo et al. (2007, 2008), Fayek et al. (1998), Gunhan and Arditi (2005)
Break into a new market	Fayek et al. (1998, 1999), Oo et al. (2008)
Test a new geographical area in which it will be bidding for several future projects	Fayek et al. (1999), Fayek (1998), Fayek et al. (1998), Gunhan and Arditi (2005)
Get experience of bidding in a new country	Fayek et al. (1998, 1999), Fayek (1998)

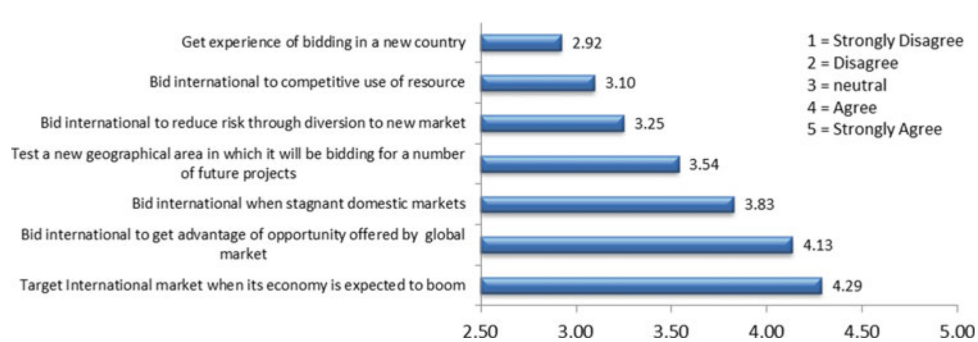

Fig. 2 Objectives of bidding internationally (Ranked)

4 Discussion

As seen in Fig. 1, Building reputation and future chance with clients have the highest weighted average and ranked as the most important objective for bidding. This result reflected the concern of a majority of UAE contractors to be well-known in the market in order to get the trust of the clients and consequently increase their chance of obtaining projects. The second most important objective is the company's need of work and survival. The current stagnant construction market in the UAE made contractors focus on surviving and keeping their presence in the market. Those objectives were ranked as the second and third important objectives. The fourth-ranked objective is company resource utilization, where many construction firms in the UAE try to avoid termination of their resources in order to avoid losing qualified employees. Thus, companies try to win projects to utilize their resources and not to be idle. Profit maximization is ranked fifth. This result contradicts with the results obtained in the top objective of bidding in the Canadian market (Fayek et al. 1999), where profit maximization was ranked as the second most vital factor. This difference is explained by the fact that the current construction market makes contractor think more about building a good reputation and surviving even with the minimum amount of profit. Entering new markets and enhancing their experience in special types of projects was ranked last. However, these are still relatively important objectives as they have a weighted average above 3 (i.e. the average importance). Entering new markets and getting experience in special types of project allows the contractor to have a wider knowledge and experience. In fact, some contractors bid with high mark-up value just to be present in the list of bidders and be qualified in the international country.

As seen in Fig. 2, the main aim for construction companies to bid for international projects is to target markets expected to boom. Thus, several contractors in the UAE are targeting Saudi Arabia, Qatar and Oman markets due to the construction movement in those regions. The second factor is gaining some of the perks that are contingent upon international opportunities. For example, many contractors nowadays are trying to get opportunities in Qatar as the country is hosting the FIFA world cup 2022, signalling a potential high boom in construction. The third-ranked objective is to bid internationally when the local UAE market is stagnant. The fourth-ranked objective is to get to know a new construction market in which the UAE contractor will bid for future projects. The fifth-ranked objective is to reduce the risk the company may face because of the construction situation in the UAE. The lowest-ranked objectives are to effectively use of company resources and to gain experience of bidding in a new country.

5 Conclusions

Contractors have several objectives in competitive bidding. It is important to understand the key objectives of competitive bidding as this helps understand the bidding environment in the UAE. The most common objectives for bidding are building a reputation with the client, followed by the company's need of work and survival. The most common objective for bidding in the international market is to target an international market when its economy is expected to boom, followed by bidding internationally to gain advantage of the opportunity offered by global market. This paper sheds the light on some of the key practices of contractors in the UAE construction industry and may be beneficial to those international companies who wish to compete in the local market.

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Physical and Mental Health of Construction Workers: A Worse Status?

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Abstract

A physical and mental health profile of construction workers is lacking in Hong Kong. This paper aims to compare the behavioural risk factors, biomedical risk factors and self-rated health status between construction workers and the general population. A basic medical examination and a questionnaire survey were administered at 117 construction sites December 2017 to March 2019. A total of 2,396 Chinese workers were included for analysis. The data of the general population were derived from the published papers and reports. The results showed that construction workers consumed less alcoholic beverages and more fruit-vegetable than the general population but had heavier smoking and consumed less milk products. Although construction workers tended to have less working hours per day than the general population, they had less rest days per month. In general, objective and subjective physical health of construction workers was worse than the general population. But female workers had better self-rated mental health. Gender-specific health programmes should be developed in future.

Keywords

Behavioural risk factors • Biomedical risk factors • Self-rated health status • Construction workers • General population

1 Introduction

Safety and health in the construction industry have received ample attention by industry practitioners and academics. In addition to fatalities and injuries caused by construction accidents, work-related illnesses and diseases have posed considerable threats to workers' health and their quality of life (Arndt et al. (2005)). Male construction workers have higher incidence of cancer, disease and musculoskeletal disorders than the general population (Arndt et al. 2005; Stocks et al. 2010). This is probably because the worse working conditions in the construction industry, such as physically demanding work, harsh environment, noise and dust, pose greater strains to construction workers (Arndt et al. 2005). More recently, research showed that male construction workers had higher incidence of mental distress than the general male population (Borsting Jacobsen et al. 2013). A higher suicide rate among construction workers than that among other occupations has been observed in many countries (Kposowa 1999; Andersen et al. 2010; Meltzer et al. 2008). Mental health problem is one of the key risk factors causing suicide (Stack and Wasserman 2007; Scourfield et al. 2012).

Despite abundant studies on investigating physical and mental health of construction workers in Western countries, relevant research is limited in Hong Kong. Prior studies mainly focused on physical health of the Hong Kong construction workers (Fung et al. 2008; Yi and Chan 2016; Chung et al. 2018), whilst studies on mental health are rare. To bridge the research gap, the aim of the present paper is to develop a physical and mental health profile of construction workers by comparing behavioural risk factors, biomedical risk factors and self-rated health status between construction workers and the general population.

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2 Materials and Methods

2.1 Participants

This paper is part of a large-scale study aiming to promote physical and mental health of construction workers in Hong Kong. The volunteers who have registered under the Construction Worker Registration System were invited to participate in the study. The participants were briefly introduced with the research purpose and procedures and were requested to fill in a consent form prior to the study. The study was approved by the Human Subjects Ethics Sub-committee of authors' organisations. To ensure a representative sample size, the study population was sampled based on the total number of registered construction workers in Hong Kong, confidence level and margin error (Eq. (1)).

$$n = \frac{P(1-P)\ \times\ z^2}{\frac{P(1-P)\times z^2}{N} + e^2} \tag{1}$$

where n is the sample size required, $N = 465{,}735$ is the number of participants in the population in 2018 (Industry and Council 2019), $z = 1.96$ for desired confidence level at 95%, $e = 2\%$ is margin of error, $P = 0.5$ is the estimated variance in population. Thus, the required sample size is 2,389.

A total of 2,437 construction workers have been involved in the study. However, the current study focused on the Hong Kong Chinese population (n = 2,396), while ethnic minorities were excluded in terms of a small sample size (n = 41).

2.2 Procedures

The study consists of a basic medical examination and a questionnaire survey at each construction site. The study was administered at 117 construction sites between 11:00 am and 1:00 pm from December 2017 to March 2019. Medical examinations including blood sampling and blood pressure measurement were conducted by a professional clinic. Blood samples were analysed by a certificated laboratory to examine workers' glucose and total cholesterol. The questionnaire survey was administered by the research team to assess workers' demographic characteristics and lifestyle behaviours. Workers' self-rated health status was assessed by the 12-item Chinese (Hong Kong) Short Form Health Survey (version 2) (SF-12v2 (HK), Optum®). The SF-12v2 is one of the most widely used generic tools to examine health-related quality of life (Webster and Feller 2016). Workers' height, weight and peak expiratory flow rate (PEFR) were also measured by the research team.

2.3 Measurements

Three of eight sections of the questionnaire were included for analysis. The first section is demographic characteristics which investigate workers' age, trade, educational attainment, working experience and work trade. The second section is to assess workers lifestyle behaviours including daily sleeping time, working time, working days, the current smoking and alcohol drinking habits, and dietary. Table 1 summerises a number of questions about the quantity and frequency of eating, tobacco smoking and alcohol drinking consumption during the past four weeks. The third section is the SF-12v2 (HK). The SF-12v2 (HK) scores are made of eight domains, namely, physical functioning (PF), role physical (RP), bodily pain (BP), general health (GH), vitality (VT), social function (SF), role emotional (RE) and mental health (MH).

PEFR test was performed to assess the airway obstruction and lung function of construction workers. PEFR (in liters per minute (L/min)) was the highest value of the repeated measurement with three times by a portable peak flow metre (Mini- Wright™, Clement Clarke International Ltd.). Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured from workers in the sitting position of workers after they took a rest for at least of 5 min.

Lifestyle behaviours and SF-12v2 scores of the Hong Kong general population were obtained from Statistics on Behavioural Risk Factors (Department of Health 2019) and the Report of Population Health Survey 2014/2015 (Centre for Health Protection 2014), respectively. SBP, DBP, random plasma glucose, total cholesterol, daily sleeping time, daily working time and rest days per month of Hong Kong Chinese were collected from Ko et al. (2007). PEFR reference values in Chinese in Hong Kong were extracted from Yip and Chan (2010).

2.4 Data Analysis

Descriptive analysis (mean and standard deviation SD) of the studied variables was presented. Lifestyle behaviours and health status between construction workers and the general population in Hong Kong were compared by Chi-square test. Non-linear regression analysis was performed to determine the relationship between PEFR, age and height. Effect sizes (Cohen's d) were calculated to determine the mean difference of biomedical factors between construction workers and the general population. A Cohen's d of <0.2 is classified as a trivial effect, 0.2–0.4 as a small effect, 0.4–0.7 as a moderate effect and >0.8 as a large effect (Christensen and Christensen 1977). A simple t-test was performed to detect any significant difference in SF-12v2 domain scores between construction workers and the general population.

Table 1 Summary of questions about eating, smoking and drinking habits (four-week recall)

Question	Answer
On average, how many days do you eat or drink fruit/vegetables/ milk products within a week, respectively?	None, 1–3 times per month, 1 day, 2 days, 3 days, 4 days, 5 days, 6 days, 7 days
On the day(s) that you have eaten or drunk fruit/vegetables/milk products, how many fruit/bowls of vegetables/milk products do you eat or drink, respectively?	0, 1, 2, 3, 4, 5 or above[a]
On average, how many days do you drink beer/wine/liquor within a week, respectively?	None, 1–3 times per month, 1 day, 2 days, 3 days, 4 days, 5 days, 6 days, 7 days
On the day(s) that you have drunk beer/wine/liquor, how many standard drinks do you drink, respectively?	0, 1, 2, 3, 4, 5 or above[b]
On average, how many days do you smoke cigarettes?	None, 1–3 times per month, 1 day, 2 days, 3 days, 4 days, 5 days, 6 days, 7 days
If yes, how many cigarettes do you smoke on average per day?	

Note [a]A fruit equals to a medium-sized apple or orange, or half bowl of small fruit. A bowl refers to the size of a rice bowl. One serving of milk product is roughly equal to 1 cup of milk, 150 ml of yogurt or two slices of cheese, according to (Department of Health 2019).
[b]Three types of alcoholic beverages, namely, beer, wine and liquor, are typically consumed in Hong Kong (Department of Health 2011). A standard drink equivalent to 10 g of ethanol of each type of beverage is 1.3 units of beer (1 can of 330 ml), 1 unit of wine (1 glass of 125 ml) or 1 unit of liquor (1 glass of 9530 ml).

3 Results

The mean age of the 2,396 participants was 46.7 (12.08) years. Their average working experience was 13.6 (11.52) years. The majority of the participants were obtained secondary education (65.1%). 23.4% and 11.5% of them were obtained primary education or below and post-secondary education, respectively. 10.9% of the participants were engaged in bar bender and fixer, concrete, and formwork that are regarded as the most physically demanding work trades in Hong Kong. The percentages of outdoor workers other than the above three trades, indoor workers (such as electrical and mechanical workers, painters and plumbers) and general labour were 30.0%, 23.9% and 35.3%, respectively.

Behavioural risk factors included smoking (Fig. 1a), alcohol drinking (Fig. 1b), eating, sleep and rest habits. While there was no significant difference in smoking habits between male and female construction workers, construction workers tended to have heavier smoking than the general population regardless of gender ($p < 0.001$). Male construction workers drank alcohol more frequently than female workers ($p < 0.05$). Female workers drank less than the female population in terms of a significantly higher proportion of none alcohol drinking and a significantly lower frequency of drinking less than once per week ($p < 0.001$). Male construction workers tended to drink alcohol less frequently than the male population given that nearly half of them did not drink alcohol. However, higher frequencies in drinking "daily" and "4–6 times per week" among male construction workers than the male population were found ($p < 0.001$). Construction workers ate more fruit and vegetables per day than the general population, but fewer milk products ($p < 0.001$). Daily sleeping time between construction workers and the general population was identical (i.e. about 7 h). The male population tended to have longer daily working hours than male constructions (9.4 h vs. 8.9 h), while female construction workers worked slightly longer than the female population (8.9 h vs. 8.5 h). Rest days per month of construction workers were shorter than the general population (4.0 days vs. 4.7 days).

Biomedical risk factors included BMI, SBP, DBP, random glucose, total cholesterol and PEFR. Construction workers had higher SBP and random glucose than the general population (moderate effect), while male construction workers had higher blood pressure than females (moderate effect) (Table 2). The frequency of construction workers being overweight and obese was significantly higher than that of the general population, regardless of gender ($p < 0.001$, Fig. 2). The results of the non-linear regression analysis showed that PEFR was positively related to body height but negatively related to age (Fig. 3). The relationship between PEFR, age and height for the general population (Yip and Chan 2010) was also shown in Fig. 3. Given the same body height, PEFR of construction workers decreased with the increase of age, whereas that of the general population increased. PEFR of male construction workers was larger than that of the male population at their younger ages, whilst it became lower than the general population at their older ages. Given the same body height, PEFR of female construction workers was always lower than the female population.

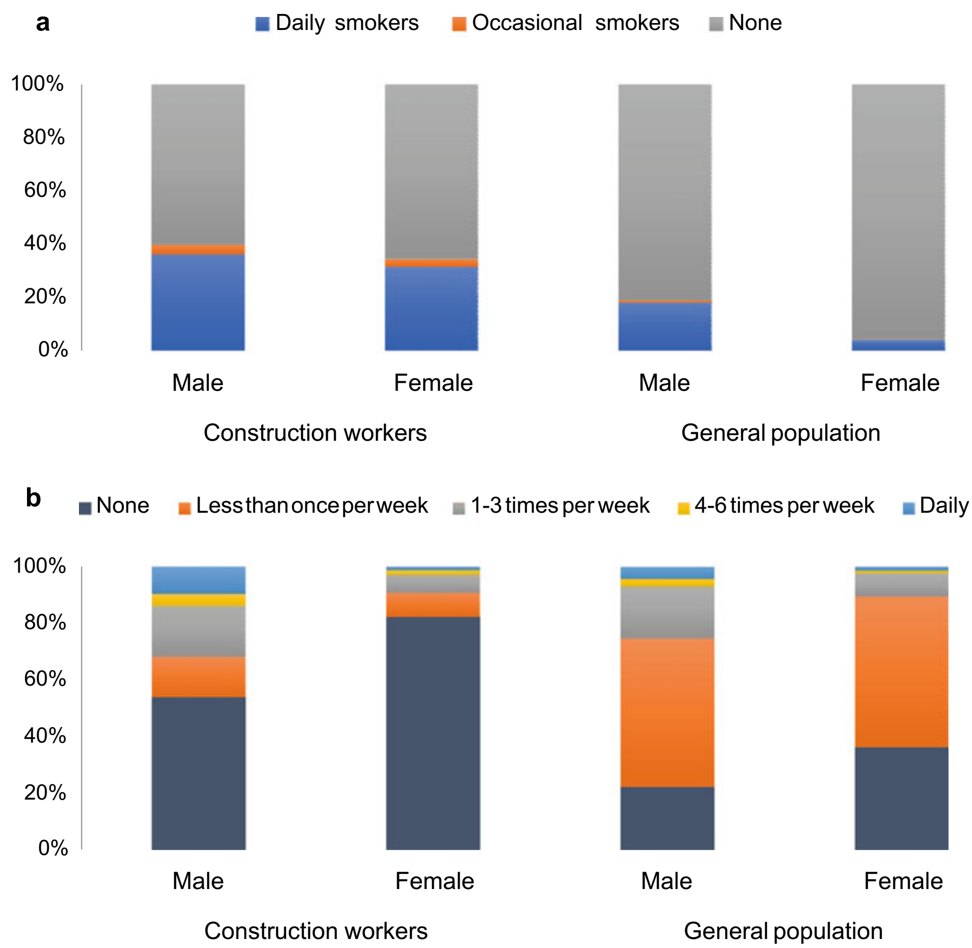

Fig. 1 Smoking (**a**) and alcohol drinking (**b**) habits among construction workers and the general population (Department of Health 2019)

Table 2 Means and standard deviations of biomedical risk factors

Factors	Male construction workers	Male General Population 2000–2002 (Ko et al. 2007)	Female construction workers	Female General Population 2000–2002 (Ko et al. 2007)	All construction workers	General population 2000–2002 (Ko et al. 2007)
SBP (mmHg)	135 (16)	131 (18)	128 (18)#	119 (18)*	134 (17)	125 (19)*
DBP (mmHg)	79 (10)	80 (11)	74 (11)#	72 (11)	78 (11)	76 (12)
Random glucose (mmol/L)	5.5 (1.8)	4.8 (1.6)*	5.4 (1.6)	4.5 (1.5)*	5.4 (1.7)	4.7 (1.6)*
Total cholesterol (mmol/L)	4.9 (0.9)	5.0 (0.9)	5.0 (0.8)	4.8 (0.8)	5.0 (0.9)	4.9 (0.8)

Note # donates the moderate effect between male and female construction workers
*donates the moderate effect between construction workers and the general population

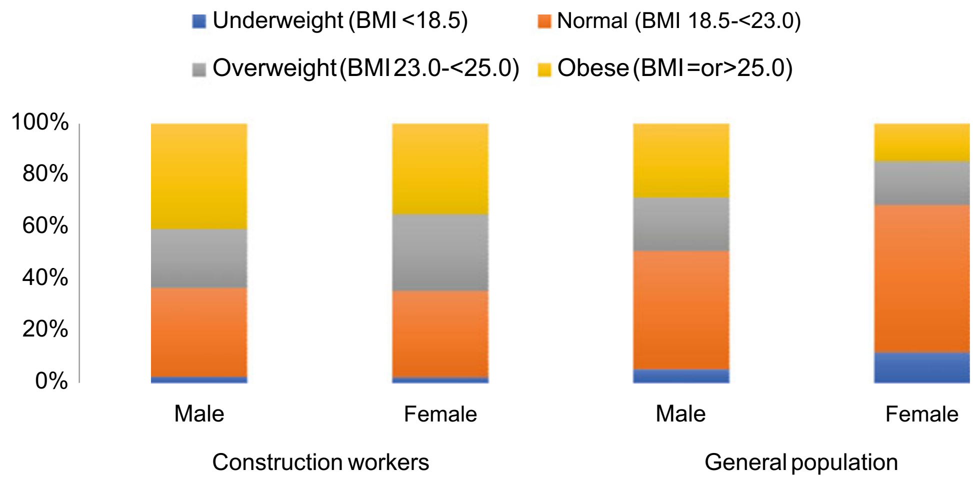

Fig. 2 BMI distribution of construction workers and the general population (Department of Health 2019)

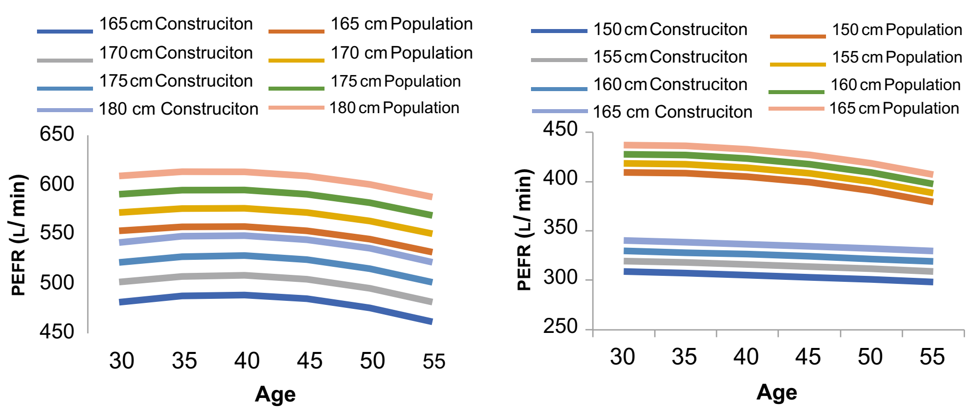

Fig. 3 Relationship between age, body height and PEFR of construction workers and the general population (Yip and Chan 2010) (left: male; right: female). Note: Solid line indicates construction workers, dotted line indicates the general population

Self-rated health status of construction workers and the general population was shown in Table 3. Female workers had significantly better health conditions than male workers in terms of RP, BP, VT, SF, RE and MH. Generally, construction workers had significantly worse health status than the general population ($p < 0.05$). Female construction workers tended to have better PF, RP, BP, SF, RE and MH than the female population, whereas male workers had worse health status than the male population.

4 Discussion and Conclusions

This is one of the first studies to compare the behavioural risk factors, biomedical risk factors and self-rated health status between construction workers and the general population in Hong Kong. There has been a saying that construction workers commonly had poorer health conditions than other occupations or the general population (Arndt et al. 2005; Stocks et al. 2010). The current findings, however, did not fully support the statement, particularly considering gender difference.

Male construction workers had heavier smoking than the male population. Although the proportion of male workers who drank alcohol 4 times per week or over was significantly larger than that of the male population, over half of workers did not drink alcoholic beverages. It implies that male workers have better drinking habit than the male population. Male construction workers consumed more fruit and vegetables than the general population, indicating a better dietary habit. However, they are recommended to consume more milk products that can provide a rich source of protein. Similar to male construction workers, female workers had worse smoking habit but better drinking habit than the female population. They also had better dietary habit but are recommended to consume more milk products. Male construction workers had less working hours per day than the general population but female workers had more working hours per day. Both male and female construction workers had fewer rest days per months than the male population. This is because their average working days per week are six days. It implies that the workload of construction workers could be heavier than that of the general population. The heavy workload of construction jobs may be

Table 3 Means and standard deviations of health components

Health conditions	Male construction workers (n = 2,016)	Male HK 2014 General population (N = 5,665) (Centre for Health Protection 2014)	Female construction workers (n = 380)	Female HK 2014 General Population (N = 6,357) (Centre for Health Protection 2014)	All construction workers (n = 2,396)	General population (Centre for Health Protection 2014) (n = 12,022)
Physical functioning (PF)	90.4 (20.08)	91.6 (20.55)*	90.2 (18.37)	88.4 (24.54)*	90.3 (19.81)	89.9 (25.51)
Role physical (RP)	87.5 (18.69)	92.9 (16.45)*	91.9(16.68)#	91.0 (18.75)	88.2 (18.46)	91.9(19.59)*
Bodily pain (BP)	89.2 (17.90)	89.3 (18.14)	91.4(19.38)#	86.6 (20.73)*	89.5 (18.16)	87.9(21.68)*
General health (GH)	51.7 (26.10)	58.7 (28.72)*	52.0 (25.62)	54.7 (30.40)*	51.8 (26.02)	56.6(34.37)*
Vitality (VT)	64.9 (25.64)	77.7 (23.47)*	71.1(26.21)#	75.2 (24.90)*	65.9 (25.82)	76.4(28.02)*
Social function (SF)	86.9 (19.82)	92.1 (17.21)*	92.3(18.02)#	90.6 (18.87)*	87.7 (19.64)	91.3(20.34)*
Role emotional (RE)	88.0 (18.41)	94.2 (14.05)*	93.1(16.37)#	93.1 (15.87)	88.8 (18.20)	93.6(16.73)*
Mental health (MH)	76.9 (19.22)	83.3 (15.85)*	83.5(18.13)#	82.2 (16.47)	78.0 (19.20)	82.8(18.08)*

Note #Donates the significant difference between male and female construction workers;
*Donates the significant difference between construction workers and the general population.

one of the reasons resulting in a worse physical condition of construction workers in general. Despite this, it is observed that construction workers had some better lifestyle habits than the general population.

Male construction workers had higher BMI, SBP and glucose than the general population. The lung function of construction workers was worse than the general population, regardless of gender. Further research should be conducted to explore the underlying reasons behind this. Self-rated health status indicated that male construction workers had worse physical and mental health than the male population. Female construction workers had worse physical health than the female population but their self-rated mental health was better. It is recommended that gender-specific health promotion programmes are needed.

Last but not the least, similar to any research involving the use of self-reported food, alcohol or tobacco consumption, the accuracy and validity of such an approach has been questioned (Bhandari and Wagner 2006). Moreover, this study investigated the current alcohol drinking and tobacco smoking habits, while the patterns of quitted smoking or stopped drinking alcohol were unexplored. Better instruments should be designed in future studies to enhance the reliability and validity of healthcare surveys. Furthermore, the relationship among behavioural risk factors, biomedical factors, and self-rated status by gender and age should be investigated in future studies to offer a comprehensive health profile of construction workers.

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Developing a Sustainable Concrete Using Ceramic Waste Powder

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Abstract

The change from a traditional utilization based society to a sustainable society is urgently needed because of the contamination of the natural environment, the depletion of the natural resources and the reduced capacity of the final waste disposal arrangements. Concrete is regarded as an advanced and major construction material which needs continuous innovation and improvement to reduce environmental impact. In the future, the demand for concrete will be increasing with the increase in population. This article presents an experimental study of using ceramic waste as a limited replacement with cement in structural concrete. Ceramic waste deposit, on one side, poses a number of environmental challenges, ranging from air, water and soil contaminations but on another side, it has cementitious properties. Concrete mixtures with different percentage of ceramic waste powder were produced, tested and compared in terms of compressive strength. As a result, the maximum compressive strength achieved with a 30% ceramic waste. The purpose of this study was to examine the performance of cement concrete with different percentage of ceramic waste powder, it needs to be noted that such performance may be varied when the grade of cement or chemical composition of ceramic waste powder will be changed. The long-run performance (after 28 days) of such concrete and especially when used with reinforcement need to be investigated further.

Keywords

Concrete technology & manufacture • Pollution • Sustainability • Natural resources

1 Introduction

Now a day in many developing countries, sustainability is the major issue. The concept of sustainability requires building societies in a specific way so that everyone can live easily without using much of the natural resources. Collective and individual roles and contribution are significantly important in this regard. The United Nations Sustainable Development Goals (UNSDG 2017; Umar and Egbu 2018) for the next 15 years that include, (a) Industry innovation and infrastructures and (b) Sustainable cities and communities, are closely related to the construction industry. While the advanced and industrialized states are called upon to decrease emission and their part of the utilization of the earth's reserves, including energy, the developing states require to refrain from the mistakes of the past (Umar et al. 2019). It is expected that cement production in coming years will significantly increase in developing countries thus the greenhouse emission problem seems to be acute.

Several environmental factors have raised the concern now that the selection of construction materials needs to be also governed by ecological considerations. At the starting of the 20th century, the total earth population was estimated at 1.5 billion, which was raised to 6 billion at the end of the 20th century. It tool approximately, 10,000 years from the last ice age and the earth population was raised to 1.5 billion, however from 1.5 billion to 6 billion growth in population is very significant.

Interestingly, at the start of 20th century, only 10% of the world population was living in the cities, however, in 2001, it is revealed that 3 out of 6 billion people were living in cities (UN 2002). Tragically, the world technological

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advancements have shown to be destructive due to the facts that all these decisions are normally based on some usual expectation which focus on the profit without considering the long term consequences. Today, approximately 6% of the total earth flow of materials, which is equal to 500 billion per year, realistically ends up in buyer products. Majority of the remaining portion of the materials are returned in solid, liquid or gas forms of waste.

In the past 100 years, climate change and global warming problems have been arises due to the increased emission of greenhouse gases to the atmosphere. In nature-focused industrialization, the environmental factors will be considered as important as of production. Environmental sustainability will be an important element of the whole economy.

Due to several advantages, a concrete requirement is expected to be growing and it is estimated that this requirement will become double in the next 30 years. There is a possibility that this requirement of concrete can be achieved without further addition to green-houses gases if the cement is replaced by another material which has cementing properties. The use of cement concrete in structural results into excellent performance in all modern construction projects around the world and coping with the increased demand for urbanization. Along with this fact, concrete also utilizes the largest portion of natural resources during the manufacturing process of cement. One of the elements which are heavily utilized in the cement production process is the energy. In developing countries, especially those which are struggling with energy and have no renewable sources of energy, the significance of utilizing industrial waste become more. Ordinary Portland cement (OPC) is commonly used on a larger scale in the construction industry. To produces 1 ton this type of cement, the same quantity of CO_2 is emitted to the earth atmosphere. Senthamarai and Manoharan (2005) noted that the use of different wastes produced by a variety of industrial sectors, in concrete can reduce the impact on the natural environment. Construction is a major industry of Oman which account for the 10% of the total GDP (Umar 2017; Umar et al. 2018). The current and future cement requirement in Oman is huge as the infrastructure projects are at a peak. The ongoing and planned development projects in different sectors, including construction, for the financial year 2015–2016 is shown in Fig. 1. The construction sector projects stand out as the largest one, amounting to US$ 43.16 Billion. According to the budget report, spending on development projects is estimated at US$ 3.12 Billion (OMR1.2 Billion), representing the amount to be paid during the year 2017, as the actual work progresses. The cement industry is producing up to 5% of the total world CO_2 emissions (EA 2012). Cement production capacity in Oman currently stands at 8.81 Megatton/year (Global Cement 2016). Manufacturing 1 ton of cement needs 4.7 million British Thermal Unit (BTU) of energy, which is roughly equal to 400 lb of coal, and produces nearly 1 ton of CO_2 (Pacheco-Torgal and Jalali 2010; Umar 2017). Thus the total production of CO_2 by the cement industry in Oman is equal to 8.81 Megatton/year.

To save the environment from global warming there is a need to replace the cement with a variety of binding materials which have cementitious characteristics like a ceramic waste, hypo sludge, fly ash, silica fume, Ground-granulated blast-furnace slag (GGBS), Metakoline and other industrial waste products. Using these waste materials in construction can reduce the environmental impact. In this regard, the use of ceramic waste in cement concrete is one of the most appropriate approaches. Utilizing ceramic waste in cement concrete can solve two problems. At one side, it will help to effectively dispose-off the ceramic industry waste in construction and at another side, it will help to reduce the use of cement which will further results into reduction of CO_2 emission and natural resources (Raval et al. 2013). Globally ceramic production is estimated at 100 million ton per year. The waste from the ceramic industry is estimated to be 15 ~ 30% of the total production. It is very difficult to recycle this waste. With the chemical and physical properties, ceramic waste is considered to be durable, hard and highly resistant to biological, chemical and physical degradation forces (Awoyeraa et al. 2013). The ceramic waste deposit also poses a number of environmental challenges, ranging from air, water and soil contaminations (Subaşı et al. 2017). The consumption of materials used in concrete can be reduced by using advanced concrete technology. Using waste and recycled materials in cement concrete provides several benefits including a reduction in cost, saving energy and reduction in different environmental hazards. The dressing and polishing process of ceramic products result in ceramic waste. During the manufacturing process of ceramic products, 15 ~ 30% of the waste is produced from the raw materials. Some percentage of this waste is normally utilized at construction projects during exaction and backfilling;

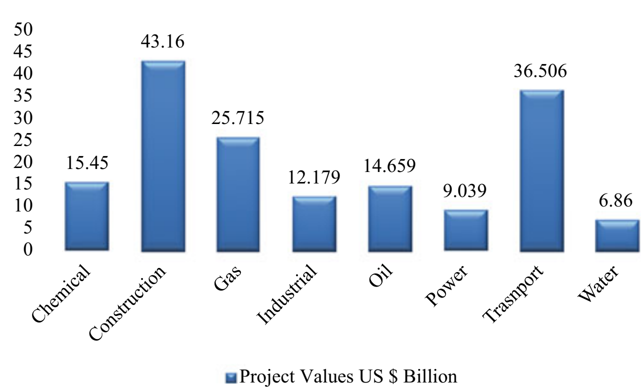

Fig. 1 Values of Ongoing and Planned Projects in Different Sectors of Oman 96 (Umar 2017)

however, the remaining is just used for dumping. Such disposal further needs a large area and results in several environmental issues. Raval et al. (2013), in their research on ceramic waste concluded that such waste could be utilized in concrete production which can also enhance the compressive strength and other performance. The work conducted by Subaşı et al. (2017), on the use of crushed ceramic waste powder as fine aggregates in self-compacting concrete found that the use of waste ceramic powder results into a positive impact on the viscosity of fresh concrete. Rashid et al. (2017), in their experimental and analytical investigation, conventional aggregate is replaced by different amounts of ceramic waste aggregate. Both the research conducted by Subaşı et al. (2017) and Rashid et al. (2017), however, was not aiming to replace the quantity of cement in concrete.

The chemical composition of ceramic waste may further change this percentage at which the strength is reducing. The earlier research conducted by Torkittikul and Chaipanich (2010), on the use of ceramic waste as filler material in ordinary cement and fly-ash concretes observed that the strength of concrete made with ceramic waste was found to be grown with ceramic waste content while the maximum compressive strength was noted when the ceramic waste content was at 50% of the cement. They further observed that the compressive strength of such concrete was reduced when the percentage of ceramic waste was increased beyond 50%. In this experimental research, however, the ceramic waste was used as an alternative of fine aggregates rather than cement.

This article presents the results of laboratory experiments of cement concrete with the use of different percentages of ceramic power. The concrete grade selected for the laboratory work was M 25 (IS 456 2000) prepared with 0–50% of ceramic waste powder (IS 456 2000). The results show that the maximum strength can be obtained with 30% of ceramic waste powder.

2 Methodology

This research aims to use ceramic waste powder in concrete and to see its performance (compressive strength) at seven and 28 days. The concrete mix used in this research was M 25 (IS 456 2000) which was made with different percentage of ceramic waste (0, 10, 20, 30, 40, and 50%). The description of materials used in this work is given as under:

2.1 Cement

The ordinary Portland cement of grade 53 was used in this research. The initial and final setting time test was carried out to know these values. The recorded value for the initial setting time was 35 min and the final setting time was 60 min. 3.15 was the value of the specific gravity of cement used in this research work.

2.2 Fine Aggregate

The fine aggregate used in laboratory experiments was obtained from a local sand supplier. The specific gravity of fine aggregates was observed to be 2.61.

3 Coarse Aggregate

Well-graded aggregates of size less than 20 mm, with a specific gravity of 2.81 were obtained from a local supplier. The particle size of both fine aggregates and coarse aggregates were checked through the sieve analysis (ASTM C136) as shown in Fig. 2 (ASTM C136).

3.1 Super-Plasticizer

For the purpose of improving concrete workability properties, a specific super-plasticizer (Conplast-SP430) was used at a rate of 0.5% of the weight of the cement.

3.2 Ceramic Waste

The ceramic powder used in the experiment was obtained from Muscat industrial area in Oman. The chemical composition of cement and ceramic powder is used in this research is shown in Table 1.

Fig. 2 Sieve Analysis for Fine and Coarse Aggregates (ASTM C136)

Table 1 Chemical Characteristics of ceramic powder and cement

Chemical composition	Ceramic powder (%)	Cement (%)
Lime (CaO)	4.47	62.00
Silica(SiO_2)	63.30	22.00
Alumina	18.30	5.55
Magnesium	0.73	1.00
Calcium sulphate	4.06	4.00

4 Laboratory Experiment

To produce a sustainable concrete by utilizing ceramic waste powder to replace some quantity of cement, the different mix was produced with by adding 0, 10, 20, 30, 40 and 50% of ceramic waste powder. To determine the proportion of each material in concrete, in each mix, cement was taken as 250 kg in each one cubic meter. For increasing the workability of freshly made concrete, super-plasticizer (Conplast-SP430 was added to each mix. For the workability, the slump test was conducted as per ASTM C143 as presented in Fig. 3. The relative quantities of each material are presented in Table 2. All the required materials were mixed in an automatic mixing machine. The concrete was then poured into the standard moulds of 150 mm × 150 mm × 150 mm (BS 1881-116:1983). It is ensured that the surface is well finished. The casted samples were demoulded after 24 h and were kept in the curing tank for 7 and 28 days. The mix proportion for M25 grade of concrete. A total of 60 cubes (10 cubes for each percentage of ceramic powder) were casted. Half of them were crushed after 7 days of curing and remaining after 28 days of curing.

Fig. 3 Slump Test for Checking Workability (ASTM C143)

5 Test Results and Discussion

5.1 Compressive Strength

After properly curing the prepared concrete cubes for seven and 28 days in the water tank, were then tested for compressive strength through a compression testing machine as shown in Fig. 4 (BS 1881-116:1983). The average value of compressive strength was recorded. It was noticed from the results that there is steep growth in compressive strength with the addition of ceramic powder. This is possibly because of the silica content present in the ceramic powder. Beyond 30% replacement, there is a decrease in strength. This is possibly because of less amount of cement in the mix. Based on this statement it can be concluded that a 30% replacement is optimum. The results are presented in Fig. 5. It can be observed from the Fig. 5, that the compressive strength of concrete having ceramic waste powder of up to 40% reduced from 36.95 to 25.9 MPa, which is, however, meeting the minimum requirement of the compressive strength for this grade of concrete. This, however, indicates that increasing the ceramic waste from more than 30% will result in a reduction in compressive strength. Although it is observed that the variation of ceramic waste can change the strength of concrete, however, the chemical composition of the ceramic-waste can play a significant role. A ceramic waste with a different chemical composition will defiantly give a different strength of concrete.

6 Conclusion

It is estimated that at least 18 billion tons of concrete will be required every year after 2050. The ordinary cement which is largely used in concrete production, not only consume a significant share of energy but also produce a considerable quantity of CO_2, which result in environmental problems. Concrete is a major construction material which needs continuous innovation and improvement to reduce environmental impact. This article presents the results of laboratory

Table 2 Mix proportion used in laboratory analysis

Particulars	Normal concret e with 0% ceramic waste	Using 10% ceramic-waste	Using 20% ceramic-waste	Using 30% ceramic-waste	Using 40% ceramic-waste	Using 50% ceramic-waste
Cement: Kg/m^3	250.00	225.00	200.00	175.00	150.00	125.00
Ceramic-waste: Kg/m^3	–	25.00	50.00	75.00	100.00	125.00
Coarse	1420.00	1420.00	1420.00	1420.00	1420.00	1420.00
Aggregate: Kg/m^3 fine	711.00	711.00	711.00	711.00	711.00	711.00
Aggregate: Kg/m^3 water: Kg/m^3	125.00	125.00	125.00	125.00	125.00	125.00
Admixture: Kg/m^3	1.25.00	1.25.00	1.25.00	1.25.00	1.25.00	1.25.00

Fig. 4 Compaction Test of Different Cube Trough Compaction Testing Machine 219 (BS 1881-116:1983)

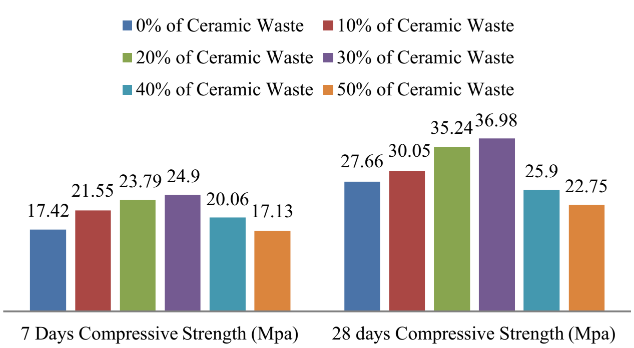

Fig. 5 Compressive strength (7 and 28 days) of Concrete with different percentage of Ceramic Waste

investigation of using ceramic waste to reduce the quantity of cement of a specific grade of concrete and compare its compressive strength. An ordinary portland cement concrete with 0, 10, 20, 30, 40 and 50% of ceramic waster powder is prepared and tested for compressive strength. The result shows that the maximum compressive strength of concrete is gained with 30% of ceramic waste powder. The strength was, however, reducing when the percentage of ceramic waste powder was increased than 30%. By using 30% of ceramic waste powder in concrete can reduce the use of cement and a similar portion of CO_2 emission by cement production will thus reduce. In Oman, the CO_2 emission by cement production is currently stood at 8.81 Megaton/year, 30% reduction will bring the emission to 6.167 Megaton/year. The results of the compressive strength of concrete may be different when a different grade of cement or a ceramic waste with different chemical composition will be used. Since ceramic waste deposit poses a number of environmental challenges, ranging from air, water and soil contaminations, thus this is a sustainable solution to unitize such waste. This investigation shows the results of compressive strength after 28 days, it is, therefore, necessary that observer the long-run performance of such concrete and especially when used with the reinforcement.

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Life Cycle Costing for Decision Making in Construction and Demolition Waste Management: A Critical Review

I. M. Chethana S. Illankoon and Vivian W. Y. Tam

Abstract

Construction and demolition (C&D) waste poses many environmental issues. There are many issues due to C&D waste landfills and construction industry has to face many costs when managing C&D waste. Currently there are many research studies carried out focusing on the C&D waste management. Even the environmental impacts of C&D waste is significantly researched, there is a minimum focus on the economic impacts of C&D waste management. Therefore, this research study aims to review the research carried out in C&D waste management focusing on its life-cycle costs. VOSviewer was used to develop the bibliographic networks and analyse the literature. Researchers conducted searches separately and both in conjunction of these two research domains. Most of the C&D waste management research focused on recycling and recycled aggregates. There is a clear lack of research on costs and economic point of view on C&D waste management. Few studies on costs for C&D waste management merely presented cost comparisons for specific waste management plans. Research on economic evaluation and specifically on life-cycle costing perspective for in C&D waste management paradigm is highly desired. Recycling is highly regarded in C&D waste management research. However, the life-cycle perspective of the extended life of recycled material is rarely discussed. There is minimum research carried out on monetising social benefits of C&D waste management.

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Keywords

Cost • Construction and demolition waste management • Life-cycle cost

1 Introduction

Life cycle cost (LCC) approach is widespread across many disciplines by now. After analysing over 7000 published papers related to LCC since 1966, Naves et al. (2018) illustrated that there is a growing use of LCC methodology in the industry, infrastructure, construction, building sectors and so on. LCC enables comparing different options based on the discounted cash flows of various costs incurring during the entire life-cycle of the project.

There are many definitions for LCC is put forward by many researchers, yet it can be simply identified as a tool for assessing the total cost performance of an asset over time, including the acquisition, operating, maintenance, and disposal costs Goussous and Al-Refaie (2014). According to Addis and Talbot (2001, p. 1), LCC can be identified as

> the present value of the total cost of that asset over its operational life. This includes initial capital cost, finance costs, operational costs, maintenance costs and the eventual disposal costs of the asset at the end of its life. All future costs and benefits are reduced to present-day values by the use of discounting techniques.

This definition by Addis and Talbot (2001) can be adopted in C&D waste management as well. LCC for C&D waste management can be illustrated as the sum of the recurring costs during economic life of the considered project (i.e. building) from pre-decision, design, construction, completion and acceptance, until users stop using it and also including the sum of research development fee, manufacture fee, installation fee, operation maintenance fee and scrap back charges in the determining life cycle of the project or at a predetermined period of validity Zhang (2014). Therefore,

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LCC can be divided into five parts: decision costs, design costs, commissioning costs of construction, operating and maintenance costs and recycling scrap costs based on the stage of the life-cycle Yin and Bai (2014). ISO 15686-5:2017: Building and construction assets—service life planning –Part 5: Life cycle costing standard (Building and construction assets 2017a, b) is the international standard governing life-cycle costing. Therefor, according to ISO satandards initial cost including the construction cost, operationa and maintenance cost and demolition costs are included in life-cycle cost calculation while excluding externalities and social benefits (Building and construction assets 2017a, b). According to International Organisation for Standardization [ISO] (Building and construction assets 2017a, b), when externalities and social benefits are included, it is termed as 'whole life cycle cost' (WLCC). However, many research studies used words LCC and WLCC interchangeably. Islam et al. (2015), carried out a systematic review on LCC implication on residential buildings. According to Islam et al. (2015), the outcomes of life cycle environmental impacts and cost are dominated by different life stages of buildings and LCC is dominated in construction phase. Zuo (2017) presented a critical review of green building evaluation from life cycle perspective, in particular, the use of life cycle assessment and life cycle costing in green building evaluation. According to Zuo et al. (2017), the uptake of LCC is generally low and also suggested that, LCC is suitable for use in the early design phase. Further, there are other review articles on LCC for pavements (Hamdar et al. 2016) and sustainable cities (Hamdar et al. 2016). Construction industry has a significant considerations on C&D waste management. Due to rapid urbanisation, C&D activities cause significant negative impacts to the environment and the society (Lu et al. 2011; Wu et al 2014). Therefore, this review article aims to analyse the extent of using LCC as a decision making for C&D waste management. This research used science mapping approach for research domains LCC and C&D waste management. This is a novel technique with bibliometric literature analysis minimizing subjectivity and biasness (Naves et al. 2018; Jin et al. 2019).

2 Research Methodologies

For this review article, Scopus Elsevier database is used for retrieving articles. Therefore, researchers conducted searches separately and both in conjunction of these two research domains on February 2018. Initially, the publications relating to the two broader research areas namely; LCC and C&D waste management were extracted. Prior to refining the search results, C&D waste management search obtained 8,182 documents and LCC retrieved 18,574 publications. Afterwards both the search results were refined, based on the subject area, language and applicability. Finally, after refining, there were 927 research publications for C&D waste management and 10,363 documents for LCC.

Once the search results were refined, all the selected research publications were exported as command separated format (csv) files. Bibliometric software VOSviewer was used to develop the bibliographic networks (Van Eck and Waltman 2014). According to van Eck and Waltman (2009) the distance between two nodes in VOSviewer network approximately indicates the relatedness between them. Further, this software is suitable for visualizing larger networks and also includes text mining features. This software is now used in the construction related disciplines as well. Naves et al. (2018) use this software to review literature on Solar energy sector and LCC, Jin et al. (2019) used this for C&D waste review. Further, there are other research studies using VOSviewer such as for building information modelling (BIM) and public private partnerships (PPP) review articles (Illankoon et al. 2017; Song et al. 2016). The main objectives from using VOSviewer are as follows; (1) To visualize and analyse the keywords in the main research domains and (2) to study the inter-relations ships between the keywords. The search combinations used for this research study is as follows:

- Search 1: Search with the key word 'construction and demolition waste management' in the title and abstract fields, limited to English language. Different variants of this word were used when searching for the relevant publications. As an example, various ways of writing 'C&D waste' is adopted such as "Construction and demolition waste", "CDW" and so on. Each of these variants is separated by "OR" function. This search result resulted in publications from 1974 onwards.
- Search 2: Search with keywords "LCC" in title and abstract fields, limited to English language and Engineering discipline. As mentioned in the previous sections, LCC is often identified as WLC as well. Therefore, when conduction the search both of these words were used. This search result resulted in publications from 1960 onwards.
- Search 3: Search with keywords "cost" and "C&D waste" in title and abstract fields, limited to English. The LCC is excluded from this search. Similar to search one, different variants of search keywords were used.
- Search 4: Search with keywords "LCC" and "C&D waste" in title and abstract fields, limited to English. Other variants of cost other than the LCC and its variants were excluded from the search. Similar to previous search processes, different variants of search keywords were used.

3 Results and Discussion

3.1 Brief Analysis on Reviewd Articles

Bibiliometric analysis considered more than 10,000 research publications related to LCC. Due to the larger number of research articles, closely related highly cited 100 journals article from 2008 onwards were selected. These articles have the highest citations varying from 28 to 337 citations. When analysing these papers it is evident that most of these research studies are closely focused on the energy sector. There are many LCC studies comparing energy related options while using LCC as one of the technique for comparison (Fu et al. 2008; Raman and Tiwari 2008; Kumar and Tiwari 2009; Al-Karaghouli and Kazmerski 2010; Marszal and Heiselberg 2011; Pantic et al. 2011; Uygunolu and Keçebasç 2011). In most of these research studies the energy savings from the proposed systems were calculated by using LCC. Further, most of these publications were focusing in renewable energy generation such as solar power, photovoltaic panels, wind power and so on. Most of the LCC studies were carried out for bridges and residential houses. Apart from that, LCC is combined with cost-benefits analysis (Carter and Keeler 2008; Kappos and Dimitrakopoulos 2008; Thoft-Christensen 2009; Cusson et al. 2010; Padgett et al. 2010) and there are studies on optimising the LCC (Al-Karaghouli and Kazmerski 2010; Hasan et al. 2008; Okasha and Frangopol 2009; Turan et al. 2009; Mohamad et al. 2014; Wang et al. 2014a; Gidaris and Taflanidis 2015; Feng et al. 2016). Case studies are also used for LCC calculations. Further, there are LCC studies coupled with life cycle assessment as well (Islam et al. 2015; Ristimäki et al. 2013; Islam et al. 2014; Petrillo et al. 2016) (Fig. 1).

Similar to the LCC analysis, C&D waste management research domain also included almost 1000 articles. Therefore, closely related highly cited 100 journals article from 2008 onwards were selected. These articles have the highest citations varying from 26 to 215 citations. Most of these research articles are closely related to recycling and sustainability. The C&D waste management significantly considered about the environmental impacts, thus sustainability has always become mostly considered. In the research domain of recycling, the C&D waste management significantly considered recycled aggregates. Further life-cycle assessment in C&D waste management is also discussed in the literature (Butera et al. 2015; Mercante et al. 2012). Construction waste disposal and waste minimisation through design are also widely discussed in these research studies (Li et al. 2015; Osmani et al. 2008; Wang et al. 2014, 2015).

3.2 LCC and C&D Waste Management

Keywords usually represent the main content of the research studies. According to Van Eck and Waltman (2014) keywords represents the knowledge among the relationships of research themes. For the VOSviewer analysis the minimum occurrence of a keyword was set to 10 and initially 38 keywords out of 1896 met the threshold. Afterwards, the general items such as ‘C&D waste’, ‘waste management’ and ‘construction’ were excluded and the keywords with same meaning were combined together. Finally, a total of 18 keywords were selected and given in Fig. 1.

Based on Fig. 1, the most frequently studied areas are recycling, sustainability, reuse, life-cycle assessment, Hong Kong and recycled aggregates. Further, there are 6 clusters

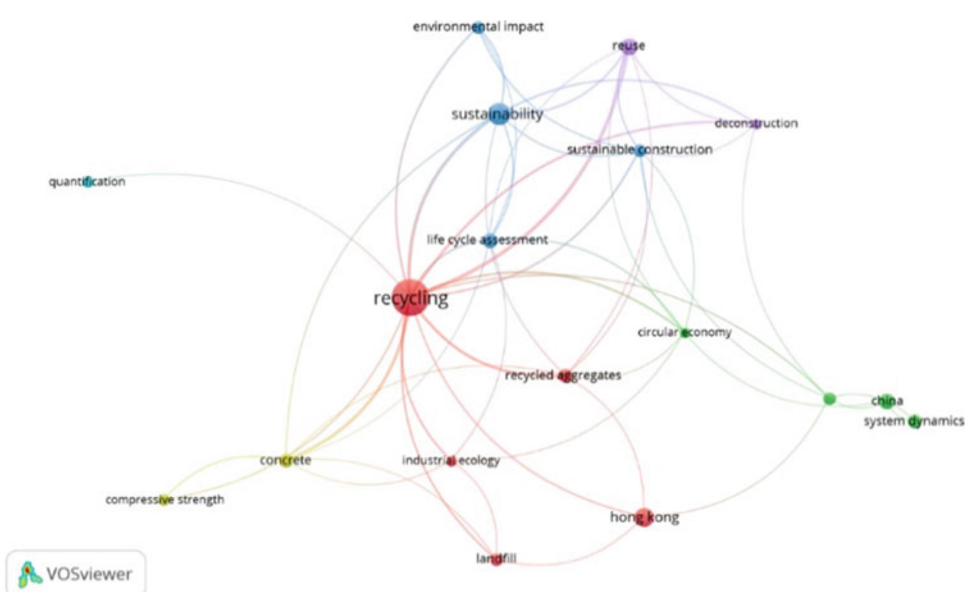

Fig. 1 Mapping C&D waste management research

in this network and there are strong intra-cluster relationships among recycling and sustainability, recycling and concrete and recycling and deconstruction. Within the same cluster, there are strong relationships among recycling and recycled aggregates. There are many research studies on recycled aggregates and more specifically on concrete (Behera et al. 2014; Martín-Morales et al. 2011; Pacheco-Torgal et al. 2013). Further, the environmental impact is discussed in these research studies, and there are articles on life-cycle assessment as well. Bovea and Powell (2016) conducted a research study on developing a life-cycle assessment to measure the environmental performance for C&D waste. Sustainability comprises of the triple-bottom-line, namely, environmental, social and economic sustainability. However, when analysing Fig. 1, it is evident that economic parameters are hardly discussed.

Research on LCC was also analysed using VOS viewer with the minimum occurrence of a keyword to 10. After excluding and combining the similar meaning key words, total of 17 keywords were selected and reported in Fig. 2.

According to Fig. 2, there are 4 clusters in the network and maintenance and optimisation are prominent in LCC research. Further, there are strong intra-cluster relationships between maintenance and bridges, optimization and reliability and optimisation and sustainability. It is interesting to note that even though sustainability and life-cycle assessment is captured in this network map there is no indication on C&D waste management when LCC is considered.

The first search result on C&D waste management illustrated that there is minimum concern on the cost and economic considerations. This fact was further proven by the third and the fourth research results. Third search focused on cost and the C&D waste management. Figure 3 presents the network for the third search results. It has 17 key words in 3 clusters.

According to Fig. 3 there are no strong relationship among parameters of cost and C&D waste. Although, cost is

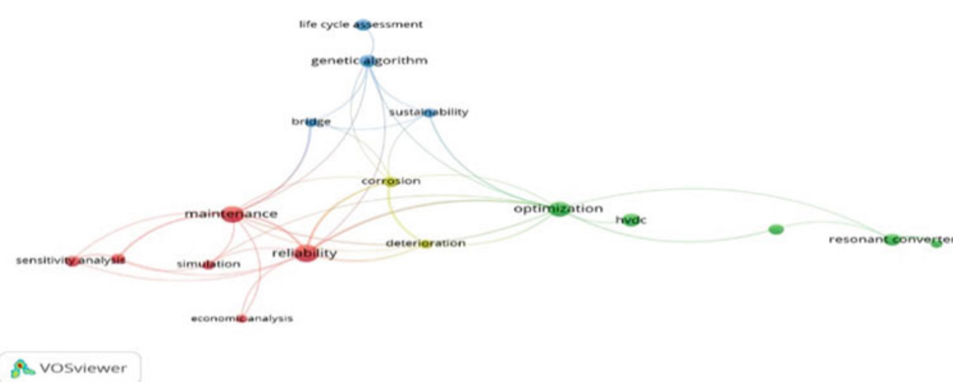

Fig. 2 Mapping LCC research

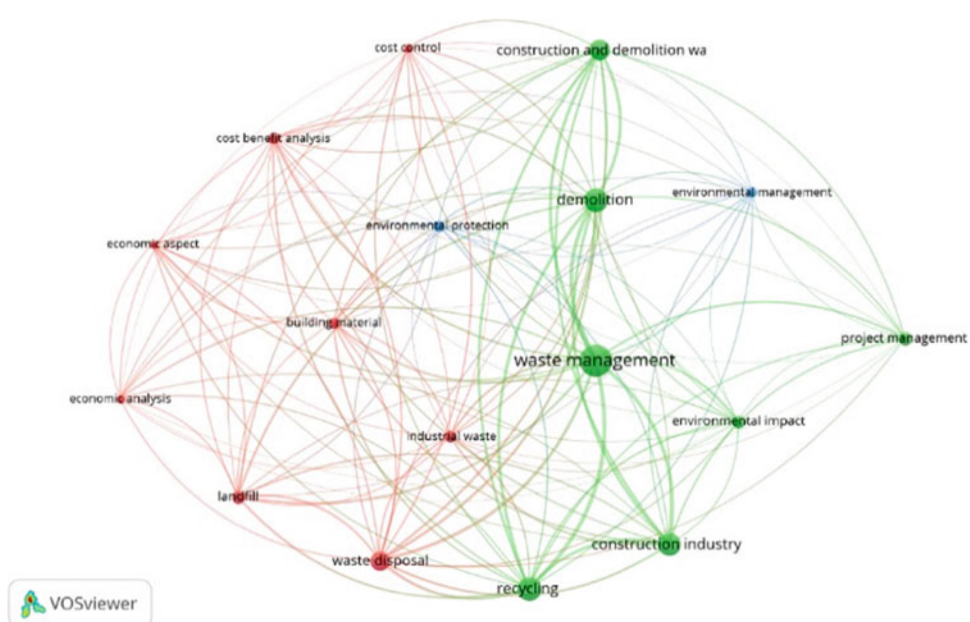

Fig. 3 Mapping cost and C&D waste management research

identified as one of the key word for most of the research papers, it is evident that, no rigorous calculations on cost or economic factors researched in any of these papers. After refining the search there are 181 research papers considered for this analysis, yet there had been no or minimal consideration of cost.

There were couple of research on cost effective waste management plans (Mills et al. 1999; Bassan et al. 2008; Yahya and Boussabaine 2010; Liu and Wang 2013), cost-benefit analysis on a specific project or option (Begum et al. 2006; Liu et al. 2014) and so on.

It is interesting to note that there is only two research articles identified through the fourth search result. Hu et al. (2013), proposed a life cycle sustainability analysis and validated it for concrete recycling. Therefore, though this research paper is selected and for LCC and C&D waste management, it is specifically focused on concrete recycling.

Further, Di Maria et al. (2018) combined life cycle assessment (LCA) and LCC methodologies to analyse the environmental and the economic drivers in four alternative C&D waste end-of-life scenarios; namely, landfilling, downcycling, advanced recycling and recycling after selective demolition. According to Di Maria et al. (2018), landfilling is the scenario bearing the highest total economic costs due to high landfill tax and recycling after selective demolition bears the second highest cost. This research study was the only research study that was published directly related to LCC and C&D waste management.

4 Conclusions

This research study focused on reviewing the literature on the LCC and the C&D waste management. There are many research studies carried out in both those areas of research yet, there are minimum research combing LCC and C&D waste management. C&D waste pose a significant threat to environment and has become one of the mainly discussed topic in the construction. There are many research carried out focusing on the environmental impacts on the C&D waste management but fails to consider its economic impacts. Recycling is one of the highlighted areas C&D waste management research. Recycle aggregates are highly discussed, yet the economic impacts are once again disregarded. Recycled aggregates and recycling basically extends the life-cycle of the building materials. The economic impact of this extended life of building materials is highly desired. Further, in C&D waste management research, there is significant discussion on the positive impacts on the environment, yet monetising those social benefits is rarely or never discussed. These are the areas that require further research.

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Quantitative Assessment of Resilient Safety Culture Model Using Relative Importance Index

Arun Garg, Anwar Alroomi, Fahim Tonmoy, and Sherif Mohamed

Abstract

Resilient safety culture (RSC) is a socio-technical safety system that is made up of the employee's capabilities as well the protocols and systems in an organization to deal with hazards. Oil and gas industry sites in Kuwait were chosen for this study. Both urban and rural sites were chosen to gauge the level of resilience in their respective safety cultures. Employees in remote sites experience high stress which may lead them to develop mental health disorders over time. High stress can also be caused due to loneliness of being aloof from the social circle and from an urban surroundings. Expatriates or employees in remote work sites experience greater stress at work due to these factors as compared to urban settings. Stress and mental illness have been identified to affect safety negatively. This, in turn, impacts on safety culture which is the focus of this paper. This study ranks constructs and indicators based on data analysis to show which constructs play important part in this case study.

Keywords

Safety behaviour • Mental health • Resilient safety culture • Remoteness

1 Introduction

Understanding RSC within an organization through modelling is important as it allows for identifying major drivers of safety culture. This can help identify weak links that can lead to future compromise of safety. Remoteness on job location has been previously linked with mental distress of employees. However, its effect on RSC has not been studied. In this paper, we briefly describe the RSC model that the authors have conceptualized in a previous study (Garg 2018) and demonstrate how that can be applied to measure the impact of remoteness of job location on RSC. This study also assists in further validating the various constructs associated with the RSC model.

1.1 Resilient Safety Culture Model

RSC is a safety culture with resilience, learning, continuous improvements and cost effectiveness (Shirali et al. 2016). It is based on three constructs: (1) Psychological/cognitive capabilities (2) Behavioural capabilities and (3) Managerial/contextual capabilities to anticipate, monitor, respond and learn in order to manage risks (Shirali et al. 2016; Pillay et al. 2010). The psychological/cognitive capabilities enables an organization to notice shifts, interpret unfamiliar situations, analyse options and figure out how to respond. It relates to sustaining pressures in a company environment and is a personality trait. Behavioural capabilities is comprised of established behaviours and routines that enable an organization to learn more about the situation, implement new routines and fully use its resources (Hollnagel and Woods 2006). Managerial/contextual capabilities are a combination of interpersonal connections, resource stocks and supply lines that provide a foundation of quick actions (Lengnick-Hall et al. 2011). These three capabilities are then divided into various factors or indicators as shown in Table 6. They are 42 items in total.

1.2 Remoteness, Mental Health and Safety Behaviour

Remoteness in the current study is defined as physical isolation combined with the condition of being a worker in

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isolation from one's family, friend and familiar surroundings. It has been found that working in an intensive and pressured work environment involves demands that can lead to psycho-social problems, including sleep disorders, stress, anxiety and depression (Love et al. 2010; Reichenberg and MacCABE 2007). Anxiety and depression, in particular, are found to be two major causes for mental health disorders. Mental illness has been identified directly to affect safety negatively (Zheng et al. 2010; Siu et al. 2004). Alroomi and Mohamed (2018) developed a conceptual model in order to better understand the relationship between remoteness, mental health and safety behaviour.

Study done by Haslam et al. (2005) found effects of anxiety and depression, and of their treatment on both performance and safety in the workplace Haslam et al. (2005). The study revealed an association with impaired work performance and safety for workers with anxiety and depression, both treated and not currently treated. In the oil and gas industry, a study found that an offshore environment increases the anxiety of workers compared with an onshore one (Parkes 1992). Chen et al. (2009) reported that 19% of offshore workers had obsession and phobic anxiety Chen et al. (2009). Another study concluded that health and safety of workers were affected by offshore work due to restrictions which include isolation from family and community (Chen et al. 2009). Loneliness and being aloof from the social circle and working in remote areas lead to feeling more stressed at work as compared to urban settings. Number of indicators of isolation which lead to poor health are living alone, having small social network, low participation in social activities, lack of social support and feelings of loneliness. In another investigation in Hong Kong, the psychological distress (depression and anxiety) level was found to predict accident rates, with direct mediating effects on accident rates and a negative relation with safety attitudes (Siu et al. 2004).

The foregoing studies points to reduction in level of safety behaviour and perception (safety climate) which can cause reduction in an organization's safety culture resilience levels for remote sites more than urban ones. This reduction in resilience reduces the effectiveness of an organization to deal with risk in a dynamic scenario. This study thus focuses on job location either remote or urban as an important parameter to test the hypothesis that the resilience of safety culture changes with change in workplace location. A survey was generated to understand how the various constructs and indicators of RSC respond with respect to change in work sites, and how it effects the resilience levels. It is assumed that the resilience variation in various organizations is not due to difference in organizations but due to its urban or rural settings.

2 Research Methodology

2.1 Survey

In this study, two organizations X and Y were surveyed. Both are working in the oil and gas sector in Kuwait with sites located remotely and urban areas. The surveys were completed by employees (i.e. engineers, supervisors, managers) who were English language conversant. There were 42 items in the survey. Nine items were for "psychological capability", 15 items were for "behavioural capability" and 18 items were for "managerial capability". The items were inferred using the various indicators of RSC model (Garg 2018). Likert scale from 1 to 5 was used, where 1 on the low side or lower expectancy and 5 on the higher side or higher expectancy. A total of 139 complete survey sheets were collected. Out of 139, 117 were remote data and remaining 22 was urban data. It should be noted that oil and gas industry in Kuwait is generally located in remote areas so getting more urban data was rather difficult. For comparison between remote and urban sites, companies X and Y data was first analysed using t-tests since the sample size was small for both urban and remote and then an analysis of variance (ANOVA) test was done for all remote data.

2.2 Un-Paired T Test

Unpaired t-test was performed for companies X and Y which provided comparable sample size data for urban and remote sites. The unpaired t-test is used if the population means estimated by two independent samples differ significantly. For unpaired t-test for company X, the two tailed P value is less than 0.0001. By conventional criteria, this difference is considered to be extremely statistically significant. Table 1 shows unpaired t-test results for company X.

Company X data can be used to decipher conclusions based on t-test significance. Data was further analysed for company X based on resilience safety culture constructs between remote and urban data. Table 2 shows urban capabilities in all the three constructs of RSC higher average mean as compared to remote data. The standard deviation was lower for remote on an average as compared to urban showing more consistency in answers in remote sites as compared to urban sites. This may be due to employees in remote sites being generally from same department or occupation where as in urban sites the occupations may be different which can increase the spectrum of answers. It can be seen that remote sites show that RSC indicators are impacted by site location and hence it can be inferred that resilience level in remote sites is less as compared to urban sites.

Table 1 Unpaired T-test of company X for remote and urban sites

Group	Remote	Urban
Mean	3.032	3.662
Std dev.	0.478	0.423

Table 3 Unpaired T-test of company Y for remote and urban sites

Group	Remote	Urban
Mean	3.083	3.302
Std dev.	0.235	0.385

For the unpaired t-test of company Y, the two tailed P value equals 0.0023. By conventional criteria, this difference is considered to be highly statistically significant. Table 3 shows unpaired t-test results.

Company Y data can be used to decipher conclusions based on t-test significance. Hence, data of company Y was further analysed based on resilience safety culture constructs between remote and urban data.

Table 4 shows urban capabilities in "psychological" and "managerial" show higher average as compared to remote data whereas for "behavioural capability" data was similar. Comparing X and Y results, it is found that they have a similar trend, hence it can be inferred that remote sites have less resilience capacity as compared to urban ones.

2.3 Anova

To further analyse the remote site data, ANOVA test was performed. ANOVA test focuses on difference of variances. ANOVA is the best method to use (Kim 2017) for finding differences in the mean for two groups or more that are mutually independent and satisfy the normality and equal variance assumptions. This ANOVA is called one way because the two or more samples being compared in the analysis differ on a single independent variable (Diekhoff 1992). There were 42 items asked in the survey.

The null hypothesis in comparison of all the groups would be that the population means of all groups are the same whereas the alternative hypothesis is that at least one of the population means of all groups is different. Therefore, among the 42 group of items, if the means of any two groups are different from each other, the null hypothesis can be rejected. When the null hypothesis is rejected from a single comparison, then the entire null hypothesis can be rejected. There are two types of variability in the data. One is within group variance and other is between group variance. Within group variance variability is observed within any group given group's distribution. The means of all groups differ. This variability between means is referred to between group variance. Examining the data, results of ANOVA are obtained and as shown in Table 5. The F test or ANOVA test shows the F distribution which is formed by variance ratios. F statistic provides a numerical index that reflects the amount of separation between the group's frequency distribution.

For degree of freedom(df)-between is 41 and degree of freedom(df)-within is 4872, the critical value of F marking the upper 1% (alpha which is the confidence level for the individual statement about the parameter of interest) of the sampling distribution is 1.293. Obtained value of F is 5.308 which exceeds this critical value and thus has probability of less than 0.01 of occurring in samples that received identical treatment. It is most probable then that these samples have not been treated identically. The null hypothesis is thus rejected and declare our obtained value of F to be significant at the 0.1 level. This shows that means of resilient safety indicators are not same and they differ.

2.4 Ranking

Relative importance index method (RII) is used to quantify the relative importance of all the 42 indicators of RSC for remote sites. Various past studies have used RII method in different areas to understand the relative importance for the concerned factors identified and evaluated (Gündüz et al. 2013; Sambasivan and Soon 2007). Equation 1 shows the RII, and how it is calculated.

$$\mathrm{RII} = \frac{\sum w}{(A * N)} \tag{1}$$

where RII = relative importance index, W = weighting given to each factor by respondents (Likert scale range from

Table 2 Resilient safety culture construct data of company X

	Remote		Urban	
	Average mean	Average std dev	Average mean	Average std dev
Psychological capability	3.4	0.341	3.7	0.455
Behavioural capability	2.7	0.493	3.6	0.487
Managerial capability	3.1	0.341	3.7	0.376

Table 4 Resilient safety culture construct data of company Y

	Remote		Urban	
	Average mean	Average Std Dev	Average mean	Average Std Dev
Psychological capability	3.0	0.217	3.4	0.455
Behavioural capability	3.1	0.195	3.1	0.242
Managerial capability	3.1	0.264	3.5	0.357

Table 5 ANOVA results for 42 groups

Source	SS	DF	MS	F	F critical
Between group	14.29	41	3.47	5.308	1.293
Within group	3185.56	4872	0.654		
Total	3327.85	4913			

1 to 5), A = highest weight (in this case it is 5) and N = total number of respondents. The RII value has a range of 0–1 where 0 is not inclusive, the higher the RII, the more important is the factor or indicator. Table 6 shows the RII calculated and then ranked. Following abbreviations were used in Table 6: G#- group number, VLI-very low importance, LI-low importance, MI-medium importance, HI-high importance, VHI-very high importance.

Table 6 shows "development of useful practical habits" indicator in "behavioural capability" construct ranked first. This indicator comes under "practical habits" construct which addresses the development of "practical habits" that are useful especially repetitive, over-learned routines that provide first response to an unexpected threat in an organization (Akgün and Keskin 2014). Likewise other ranked indicators are shown. These results show on which indicators, importance need to be focused on by the surveyed organizations. Further, sub-constructs (Table 7) and constructs (Table 8) relative importance index are calculated and ranked. The sub-constructs heads a set of survey questions and those are tabulated as a column in Table 7.

Table 7 shows "practical habits" as the most important sub-construct which is the same sub-construct where the highest ranked indicator is located as well followed by "conceptual orientation". Table 8 ranks "behavioural capability" as the most important construct followed by "psychological capability".

3 Discussion and Conclusions

For the two surveyed organizations, it was found that overall RSC is lower in remote sites as compared to urban. This can be due to the fact that remoteness effects the mental capability of its employees as learnt in previous studies. Thus, it impacts the safety behaviour leading to low resilience as compared to urban one as shown in Tables 2 and 4. The most important construct to focus on is "behavioural capability" which relies on development of "practical habits" which in turn are useful in providing first response to an unexpected threat. This construct has the maximum relative importance index of 0.585 as shown in Table 8 followed by "psychological capability" and then lastly "managerial capability".

In the sub-construct category, "practical habits" is ranked first which offcourse comes under "behavioural capability". It is described as organizations which develop values that lead to habit of investigation as compared to assumption, routines of collaboration rather than antagonism and traditions of flexibility rather than rigidity.

How these values are developed? This is through the reporting culture and that is the real emphasis which is shown in this research. These results are constrained to remote sites for oil and gas industry and it can differ for other industries and that can be part of the future research to find if

Table 6 RII and ranking of resilient safety culture indicators for remote sites

G#	RSC indicators	1:VLI	2:LI	3:MI	4:HI	5:VHI	RII	Rank
Psychological capability (just culture)								
1	Sense of purpose	2	64	77	28	3	0.636	2
2	Strong core value	1	13	48	25	2	0.576	17
3	Prevailing vocabulary	1	43	59	21	2	0.581	15
4	Highly visible moral purpose	2	38	55	20	2	0.569	27
5	Having attitude	0	22	78	14	3	0.597	9
6	Mindset	0	51	44	20	2	0.554	25
7	Ingenuity to develop new skills	3	34	56	21	3	0.578	16
8	Common language	2	38	51	19	3	0.550	27
9	Situation specific interpretations	1	49	51	51	1	0.542	35
Behavioural capability (reporting culture)								
10	Disciplined creativity	1	62	69	19	2	0.591	10
11	Combine originality and initiative	2	42	50	21	2	0.564	22
12	Ability to follow different course of action	1	17	78	20	1	0.605	8
13	Engaging in non-conforming repertoires	1	49	47	19	0	0.540	38
14	Have varied and complex action inventory	1	32	76	13	1	0.552	26
15	Have diverse competitive actions	0	53	44	18	0	0.530	40
16	Development of useful practical habits	0	10	59	46	1	0.660	1
17	Develop habits of investigation	0	16	58	41	0	0.632	3
18	Develop habits of collaboration	0	19	44	50	0	0.632	3
19	Develop habit of flexibility	2	20	40	52	0	0.632	3
20	Creating robust responses	0	15	59	40	0	0.627	7
21	Ability to spot an opportunity	0	29	72	13	3	05.83	12
22	Developing new competencies	1	43	54	17	0	0.42	35
23	Unlearning obsolete information	7	40	49	19	0	0.530	40
24	Benefit from situations that emerge	0	46	25	16	2	0.530	27
Managerial capability (flexible and learning cultures)								
25	Respectful interactions within organization	1	12	74	27	3	0.632	3
26	Face to face honest interaction	1	39	54	20	3	0.574	18
27	Disclosure oriented intimacy	2	47	52	14	2	0.544	34
28	Exchanging resources	0	36	54	25	0	0.571	19
29	Sharing tacit information	1	45	49	21	0	0.550	27
30	Cross-functional collaboration	1	46	38	22	2	0.521	42
31	Forging relationships	1	22	69	20	2	0.585	11
32	Relationships with strategic alliances	0	48	48	19	0	0.540	38
33	Bond with various environmental agents	1	45	55	14	2	0.550	27
34	Promote organizational slack	2	54	36	23	2	0.547	32
35	Communicating without getting ignorant label	3	32	53	27	0	0.571	19
36	Communicating without getting incompetent label	7	43	37	28	2	0.557	24
37	Communicating without getting negative label	7	35	40	31	4	0.583	12
38	Communicating without getting time waster label	7	43	38	26	2	0.549	31
39	Sharing decision making	2	36	62	17	0	0.561	23
40	Creating organization structure	3	21	74	16	2	0.583	12
41	Members have discretion and responsibility	1	42	52	16	3	0.547	32
42	Replying on self-organization	3	45	49	18	1	0.542	35

Table 7 RII and ranking of sub-constructs

Groups	RSC sub constructs	Survey groups	RII	Rank
1	Conceptual orientation	1–4	0.591	2
2	Constructive sense making	5–9	0.564	6
3	Learned resourcefulness	10–11	0.578	3
4	Counterintuitive agility	12–15	0.557	8
5	Practical habits	16–20	0.637	1
6	Behavioural preparedness	21–24	0.515	10
7	Deep social capital	25–30	0.566	4
8	Broad resource network	31–34	0.556	9
9	Psychological safety	35–38	0.565	5
10	Diffused power and accountability	39–42	0.558	7

Table 8 RII and ranking of constructs

G#	RSC constructs	Sub construct groups	RII	Rank
1	Psychological capability (just culture)	1–2	0.576	2
2	Behavioural capability (reporting culture)	3–6	0.585	1
3	Managerial capability (flexible and learning cultures)	7–10	0.562	3

these indicators which are shown as high importance for this sector does change or remains similar for other sectors as well or not. Loneliness thus can be inferred to reduce resilience as habit of investigation and reporting culture is reduced as these characteristics need vigilance and active responses.

"Behavioural capability" refers to how people act which is related to human resources available to the organization. This also shows that some organizations just focus on "managerial capability" which is structure of the organization, its policies, procedures, management systems in place as being presented in Sect. 1.1 as compared to on its human resources. This human resources are employees and expatriates working in remote sites who need to feel satisfied, be in right state of mind, and have some means of reducing their loneliness which gives them impetus to lead the "reporting culture" construct.

Focus should be on "psychological capability" which is the safety climate or perception an employee makes of the organization. RII for this construct was 0.576 and "conceptual orientation" in sub-construct category ranked second. This perception enhancement is when the organization has strong ideological identity, has strong core values, sense of purpose and clear sense of direction along with capability, influence and competence. All these characteristics of an organization, collectively, comprise "conceptual orientation". This "conceptual orientation" seem to be reduced for remote employees due to the fact that safety perception gets somehow reduced for expatriates due to loneliness and depression giving a perception that the company is not doing enough for giving them a good work environment to live.

In conclusion, it is understood that remote sites need to enhance their resilience levels as compared to urban sites. The "behavioural capability" should be the primary focus of remote sites. Also, this study promises to show that the original model conceptualized for RSC does give good pointers regarding where the focus should be in regards to enhancing resilience levels. In this study, loneliness and mental health effect either the "psychological capability" or "behavioural capability" construct of the model.

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Innovation and Immersive Vocational Education Training for Construction Site Supervisors

Valerie Francis and Vidal Paton-Cole

Abstract

Significant population growth has occurred, and is set to continue across all major Australian cities. Currently, the State of Victoria is the fastest growing amongst all the Australian states and territories, recording the highest growth of 2.3% in 2017, with forecasts indicating a 50% increase of the state's current population over the next three decades. These demographic changes have necessitated higher demand for critical building and infrastructure services. However, there is endemic shortage of skilled labour across the entire construction industry, which could impact ongoing development and delivering of strategic infrastructure over the coming years. This occupational skills shortage has further economic implications by reducing productivity and delaying development and growth. The lack of investment in training in recent decades, the increase in rework, the decline in interest in site roles and the continued growth in the industry means that it is not well placed to deal with current requirements. This paper outlines the case for an alternative education method and presents an innovative framework to create transformation change for workforce training and skills development for the construction industry through the "Maker Immersion Project". The innovative project, funded by the state government, will developed a world-first fully deployable, technology enhanced education package that creates an immersive learning by blending traditional face-to-face training with Virtual Reality simulations.

Keywords

Construction • Skills shortage • Immersive education • Virtual reality

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1 Introduction

The necessity to educate and train more construction site supervisors for an industry facing imminent skills shortages has been the driver for developing better vocational education for the construction industry in Victoria, Australia. The new education package, referred to as the "Maker Immersion Kit (MIK), will develop a fully deployable, technology enhanced education program for the Certificate IV in Building and Construction (Building). This certificate program is taught in vocational collages utilising the traditional "face-to-face" method and is the entry level requirement for those individuals seeking to work in site supervisory roles. The basis of the new program is rooted in the "Maker Movement", and the program will create immersive learning by blending traditional face-to-face training with virtual reality simulations and opportunities to physically construct flat packed building components. The curriculum will include eLearning packages, virtual reality simulations and flat-packed physical building components and will be made available in both urban and regional locations around Australia. The purpose of this paper is to review the literature identifying the need for the program, outline key aspects of the proposed MIK and briefly describe how the MIK will be evaluated against the normal delivery method[1].

2 Demographic Changes Are Driving Construction Demand

There is a growing imperative for the construction workforce to expand to meet the needs of Victoria, Australia and this is expected to continue for the foreseeable future. The State

[1]The Program is being developed by Exner Education in conjunction with Real Serious Games, Built and AECOM through funding by the Victorian state government. The University of Melbourne will evaluate the program.

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needs new infrastructure to cope with population expansion. According to the Australian Bureau of Statistics (2018), for the 12 months period up to Sept 2017, Australia has one of the fastest growing population amongst major OCED countries with a population growth rate of 1.6% and above that of the worlds at 1.1%. Victoria recorded the highest growth at 2.3% with Net Overseas Migration (NOM) being the strongest driver of population change in Victoria accounting for up to 70% of growth (Department of Environment, Land, Water and Planning 2016). The availability of work opportunities and easy access to amenities has made it a sought-after destination for international migrants. According to current projections (Department of Environment, Land, Water and Planning 2016), by 2031, it is expected that the population of Victoria will be 7.7 million and a further 2.4 million people to be added two decades later by 2051, growing the population to 10.1 million in the next 3 decades. Demographic characterisation indicates that 8.0 million will be in Melbourne, up from 4 million in 2018, and 2.1 million in Victoria's regions (Department of Environment 2016). It is thus evident that if Victoria is to cope with these changes in demographic trends over the next 30 years, choices need to be made around how these growths are accommodated (Deloitte Access Economics 2016).

3 Construction Is Critical

As part of the government strategy to combat the challenges associated with population growth, Infrastructure Victoria-toria was established in October 2015 with a mandate to improve public debate and build consensus on priority infrastructure projects in Victoria. This aligns with recent trend in other Australian jurisdictions to create bodies to advise governments on infrastructure planning (Deloitte Access Economics 2016). It has set out a pipeline of initiatives to be delivered over the next three decades and the subsequent report (Infrastructure Victoria 2016) recommended decisive action, including:

- increasing densities to make better use of existing infrastructure and bring people closer to jobs and services,
- providing more affordable housing for people at risk and improving communications infrastructure, particularly in regional and rural Victoria.

The report emphasised that cities are expanding, and government must continue to plan and provide infrastructure for new communities (Infrastructure Victoria 2016). However, the more Victorian cities sprawl, the harder it is for people to get around, and the more onerous the task of providing high quality infrastructure. Importantly, for effective implementation of the initiatives in the infrastructure strategy report, there is a reliance on increasing workforce capability for both build and non-build solutions.

The construction industry itself is one of the key economic drivers in the Victorian state economy, employing hundreds of thousands of Victorians and a significant state economic contributor. As infrastructure would be a critical driver for effective operation of the state, planning and implementation of the necessary structures is imminent to better manage disruptions and ensuring Victorians access necessary services. Thus, for successful implementation of infrastructure initiatives, it is imperative that the construction workforce capability be continually improved through efficient training. Construction has always been and remains very much reliant on a skilled motivated workforce.

4 The Construction Workforce

Forecasts for 2046 indicate that the construction industry in Victoria will need to more than double its employment, with an annual growth of 3% (Deloitte Access Economics 2016). The construction workforce has two major groupings—those who manage the process and those who carry out the physical work, with reports indicating that the number and skill level of those undertaking construction worker roles has declined (Toner 2003), resulting in skills deficits at all levels, including those in site supervisory roles. Several studies have been undertaken to better understand apprenticeship training in Australia. These have reported that Australia has experienced a sustained decline in apprentice training rates (Toner 2003); declining completion rates (Smith et al. 2007); cancellations of apprenticeships (Mangan and Trendle 2008); and apprentices with multiple episodes of training (Mangan and Trendle 2017), with the residual effect contributing to shortages in core vocational occupation such as the construction sector (Toner 2003). Besides the financial, social and economic loses to the apprentices, Bilginsoy (2003) describes the high cancellation rates as a costly disincentive to employers, despite employers benefitting from providing these apprenticeship places through increased productivity (Department of Education and Training 2017).

The Infrastructure Victoria report (2016) highlighted the need for workforce development, including an increase in the quality and efficacy of training being crucial over the next decade. The shortage of occupational skills has several negative consequences. Firstly, the skills shortage has lengthened construction times, particularly in the volume building industry (Dalton et al. 2013). Workers tend to transit between building and high utilisation of low skilled workers, with or without training, by sub-contractors has become a common practice. As a result, the second conseqence of skills shortage becomes apparent, namely defects. There have been numerous complaints associated with construction workmanship and subsequent defects characterised by poor quality of work conducted on-site, deficient supervision skills, wrong application of materials and inadequate skills (Georgiou 2016). Skills shortage across the construction industry is therefore linked to poor work quality and workmanship that leads to construction defects.

Love (2002) defined rework which addresses these defects as "the unnecessary of redoing a process or activity that was implemented incorrectly the first time". Several researchers have attributed rework in the construction industry as a chronic problem (Barber et al. 2000). Rework has three significant consequences. First and secondly the cost and time overruns due to the necessity to remediate the work. Research has revealed that direct rework costs during construction could range from 2–5% of contract value (Love and Li 2000). They suggested that direct rework costs could amount up to about 6.6% of the contract value and as profit margins are ultimately tight rework cost could put contractor's profit at risk and further impact productivity. A third consequence can be the impact on safety. In addition, when rework requirements go undetected, they may lead to building failures that can have negative consequences, including severe injuries and possible fatalities. It is therefore evident that there is need for better skills training for the construction sector, not only to improve the capabilities of construction trades but also the skills of site supervisors.

5 Current Vocational Training of Site Supervisors

The Certificate IV in Building and Construction (Building) qualification was originally designed to meet the needs of builders and managers of small to medium-sized businesses in the building sector of the construction industry. The Vocational Education and Training (VET) qualification is currently offered through what is known as the TAFE[2] sector and by various private training organisations. Its primary purpose is to provide supervisory skills for managing a construction site or running a domestic building company and competencies required to meet builder registration requirements in various States and Territories (Master Builders Association 2018). An new educational program is being developed through the MIK program.

From the late 1980s vocational education and training (VET) moved towards a competency- based training approach (Goozee 2001). Competency-based education and training came to prominence in the 1960s and 1970s and was implemented in Australia as part of the National Training Framework aimed at increasing Australia's business competitiveness (Velde 1999). This approach is quite prescriptive enabling consistency across the Australian states and territories providing VET. Each unit of competency has a list required elements which "describe the essential outcomes of the unit" and performance criteria which describe "the performance needed to demonstrate achievement of the element". In addition, a list of skills and knowledge required for each unit is outlined.

The Certificate IV document (Commonwealth of Australia 2017) states that "training and assessment leading to recognition of skills must be undertaken in a real or very closely simulated workplace environment and this qualification requires all units of competency to be delivered in this context." Anecdotal advice indicates the majority of the current VET education is undertaken in a classroom situation.

6 Issues with Current Educational Models

Around 75% of the construction industry employers identified technical and job specific skills as lacking in the industry (Department of Education and Training 2017). This lack of skills was reportedly affecting operating costs, increasing the workload for other staff and result in subsequent loss of business to competitors, which will evidently impact productivity. In addition, 37% of employers agreed that that the construction industry candidates were lacking job ready skills. As a mean of employees developing the necessary and/or required skills, in 2016,[2] 63% of the construction industry employers supported training through private training providers, TAFEs and/or industry association (Department of Education and Training 2017). These training reportedly yielded a positive contribution to productivity and success, with 75% of employers agreeing on the positive return on investment with an enhanced impact on productivity. This therefore raises questions about the effectiveness of the current traditional construction training methods and adequacy of delivering vocational education training.

While traits, abilities, and skills explain a substantial proportion of the variation in learning performance, research in these areas have been less successful at providing insights into the specific manner in which students acquire new knowledge. Understanding how different people learn, and the different styles of learning can help in guiding best methods for training. Some learners may benefit more from a spatial or kinesthetic approach that is emphasised in

[2]TAFE is the acronym for Technical and further education. It relates to post-secondary (high school) level education and provides a range of vocational based programs.

vocational training (Darling-Hammond et al. 2011). The ways in which trainees process information will impact on how engaged they are in the training activities and their own. Learning (Oakes and Lipton 1999). Learning styles refer to the different ways in which people approach learning and they can have a huge impact on ability to absorb training. Trainees will have different styles and research has demonstrated that adjusting training styles to suit individuals can lead to improvement. The most effective approach is to immerse trainees in their own learning and the environment in which that learning takes place (Curry 1990). Once trainees begin to understand their own learning style they will find it much easier to engage with training.

Darling-Hammond (2011) states that some trainees learn better using a model of watching and then doing which is aligned with the immersive model approach. She advocates for making learning more visible by engaging trainees in cognitive apprenticeships, making the competencies they are learning more explicit during training. One assumption of a cognitive apprenticeship is that trainees are engaged in interesting and challenging tasks that motivate them to develop their craft. Research has indicated that authentic, relevant and collaborative tasks provide learning environments that develop understanding (Bransford et al. 2000).

Trainees who engage in self- regulated learning monitor their own progress toward self-set goals and are therefore are able to reflect on the effectiveness of their learning approaches (Duncan and McKeachie 2005). These trainees tend to view the learning task as intrinsically interesting and worthwhile while having high levels of self-efficacy and engage in and persist with learning behaviours that maximize the degree to which learning occurs. There is much research which indicates the factors affecting engagement in learners. Studies around immersive learning environments have indicated it can be a positive factor towards engaging learners.

7 The MIK Education Program

The global “Maker Immersive Movement”, is at the centre of this new educational approach which will look to transform the Certificate VI education of construction supervisors. The program’s key feature is the use of virtual reality (VR) simulations along with e-Learning packages and flat-packed physical building components. The training model focuses on an immersive learning experience. Immersive learning experiences focus on fully engaging students in well-designed activities harnessing the advantages of technology and collaboration (De Freitas et al. 2010). The advantage of immersive learning, particular when embedded in technology, is that the learner is presented with experiences and learning opportunities in a real life, real time context that may otherwise not be readily available to them (Gazzard 2009).

Across the world education and training systems are still mainly organized around subject matter focused curricula and trainers generally just transmit knowledge to learners via lectures and textbooks (Schleicher 2012). The focus is on developing conceptual understandings of a discipline and learners are given little opportunity to apply skills or have the chance to do this collaboratively. The current century revolves around education and occupations that are technology-driven, and that involve increasingly non-routine tasks, collaborative efforts and complex skills (Salas et al. 2008). Educators globally have begun to recognize these shifts and are beginning to integrate technology advances and into their curriculum and practices. In addition, to the integration of technology, higher education and vocational training providers need to focus on the skills and competency demands of industry, and how they can attend to various learning styles, and orientate sufficient learning environments to meet these needs. The use of serious games in learning environments is one of the increasingly relevant trends transforming education, because new digital innovations have significantly changed our pedagogical perspectives (Lajoie and Derry 1993). Not only can virtual realities contribute to content learning, they can assist in developing skills such as collaboration, since the opportunities for social interactions are provided, and this in turn can produce feelings of relatedness and belonging leading to greater achievement (Cole and Griffiths 2007). There is much research to suggest that virtual reality and serious games are effective in learning and training scenarios (Annetta 2008). However, the focus of the aforementioned studies typically only focusses on learning outcomes without considering feedback, perspectives, and engagement of learners (Connolly et al. 2012). Empirical evidence of how virtual realities are linked to curriculum, and how engaging and effective they are from the perspective of trainees and trainers is really needed (Van Eck 2006).

8 The MIK Evaluation

The evaluation will focus specifically on five specific areas, namely: The acquisition and retention of knowledge and skills by students; perspectives of changes in learning and teaching behavior of students and trainers; insight into student reactions to different ways of learning; identifying learning outcomes and student behaviors; and identifying benefits to students, training organisations, government and industry.

The intention is to evaluate: The Intended curriculum—during the development of the modules; The Enacted curriculum—during the delivery of the modules; and The Experienced curriculum—after the completion of the modules.

All modules associated with the Certificate IV will be evaluated, with five undergo a standard evaluation and three being subjected to a more in-depth evaluation comparing the previous mode of delivery with the new mode. In addition to the module evaluations two VR and one flatpack evaluation will be conducted. The Virtual Reality (VR) evaluation will focus on a comparative study between traditional modes of training and modes that involve blended learning via the use of high-end immersive technology in a Virtual Reality setting. Results will be presented in future papers.

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Exploring the Current and Future States of Augmented Reality in the Construction Industry

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Abstract

In construction, adoption of advanced technologies has the potential to significantly improve the performance of projects. The construction industry has experienced a radical evolution as it entered the era of digital documentation and information exchange. Construction design began with drafting boards, then moved to Computer Aided Design, and finally to Building Information Modeling. At each stop along that journey, gains were made in information density and exchange. However, for all the progress made thus far, the paradox of designing the 3D in 2D space remains. As Industry 4.0 continues to evolve, it is imperative that construction firms seek, find, and adopt new technologies—both to remain competitive and to grow in the industry. Augmented reality (AR), a pillar of Industry 4.0, has the potential to transform the construction industry. This paper explores the current and potential future states of AR in construction. Might this technology gain momentum and take hold in construction, as it has done in other industries? To investigate this question, industry practitioners were surveyed. 128 responses were collected and analyzed to provide insight into the current and potential future states of AR in construction.

Keywords

Augmented reality • Construction industry • Current state • Future state

1 Introduction

Industrial interest in Augmented Reality (AR) has increased in the past decade, across sectors including automotive, aerospace, marketing, gaming, and others (Campbell et al. 2017). Construction has begun to follow suit in this area, and there has been a significant increase in research published on the subject. Researchers, however, have tended to issue their own definitions of AR. Therefore, in the interest of streamlining this paper, the authors describe AR both as an information aggregator and a data publishing platform that allows the user to (1) passively view displayed information, (2) actively engage and interact with published content, and (3) collaborate with others in real time from remote locations. Numerous research efforts have been undertaken to explore AR use-cases and develop applications to integrate the technology in the construction industry. The majority of this research explored AR from the academic perspective and developed prototypes and proof of concepts to study and prove the potential impact of AR on construction. While these research endeavors are the cornerstone for investigating the potential of the technology, it is equally important to investigate the state of practice of AR from the perspective of the construction industry itself. For instance, (Heinzel et al. 2017), interviewed two general contractors and one software company and investigated the application of available construction AR technologies during the construction phase of a building project with a specific focus on as-built, quality assurance, and safety. Extant research such as the work of (Heinzel et al. 2017), does not, however, provide a comprehensive investigation of the current state of AR in construction from the perspective of different construction stakeholders. Therefore, using industry-driven data collected from 128 practitioners, this research will assess the current state of the practice of AR in the construction industry. This study will also provide insights into the potential future of AR in construction.

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2 Literature Review

Ever since humanity started building structures, there have been accompanying methods for drawing, sketching, and planning these buildings. The two-dimensional (2D) drawings for architectural purposes have been traced back to Ancient Egypt, and have evolved over the course of history to keep pace with the advancing complexity and ambition of the built environment (Babič and Rebolj 2016). However, the use of 2D drawings and instructions in a 3D world requires multiple translations—from the initial concept in the designer's head, onto paper, and then into reality. As such, numerous efforts have been made to improve the quality of design drawings. These efforts are motivated by the need to reconcile planned solutions with practical implementations, poor communication between project parties, and inefficient scheduling of construction activities (Chi et al. 2013). Ref. (Ahmad et al. 1995), postulated that the need for teamwork, flexibility, coordination, and communication in construction gave the industry a great potential to integrate Information Technology (IT). Froese has divided the innovations in IT into three eras (Froese 2005; Froese 2010). The first era is comprised of stand-alone tools that improve specific work tasks—Computer Aided Design (CAD), Structural Analysis, Estimating, Scheduling—which are all individual programs that each work on a single facet of the construction process. During the early 1980s, CAD became commonplace in architectural work and soon supplanted the drafting board as the most common method of producing drawings. Eventually CAD also supported 3D design, making it a more attractive and efficient option than hand-drafting (Cunz and Larson 2006; Cohn). The second era includes computer-supported communications (i.e., email, web-based messaging), and document management systems. The third era is where construction currently sits—reconciling the first two eras into a unified platform wherein project teams can collaborate to produce a virtual model of all aspects of the construction project. One of the limitations with the early iterations of CAD was that, while it could represent geometric objects and show the relationship between them in space, it was lacking a precise understanding of how the relationship functioned. For example, it could be communicated that a beam is connected to a column, but the number, size, and placement of the bolts to connect it would not be communicated (Howell 2005). More modern iterations of CAD have included this process, commonly known as Building Information Modeling (BIM). BIM has been widely hailed as a successful innovation in the construction industry (Yeutter 2012), with numerous competing products available on the market today. However, even these types of advanced software still do not solve the problem that the project stakeholders faced—designing that which is 3D in a 2D environment. Thus, the industry must move beyond Froese's third era into a fourth era—the era of enhanced, or augmented reality. Introducing Augmented Reality (AR) into existing BIM applications has immense transformative potential. It allows users to work on their 3D design in a 3D space that they can interact with as they would interact with the final product.

Augmented Reality (AR) originated in 1962, when Morton Heilig, a cinematographer, created a Sensorama, motorcycle simulator with visuals, sound, vibration, and smell. In 1966, Harvard Professor Ivan Sutherland, invented the first Head-Mounted-Display (HMD), a device that allows the user to experience computer-fed graphics (Candy 2017). The term "Augmented Reality" was first coined by Caudell in 1990, and was defined as the technology that is used to "augment" the visual field of the user with information necessary to perform a task (Caudell and Mizell 1992; Ramos et al. 2018). Unlike Virtual Reality (VR), AR amplified the real world with virtual (computer-generated) information instead of substituting it (Wang 2009). There are two definitions of AR commonly referred to in the body of literature. One definition was proposed by (Milgram and Colquhoun 1999), who described AR from the perspective of the mixture between real and virtual environments. Ref. (Milgram and Kishino 1994), created the "Reality-Virtuality (RV) Continuum" in which the "real" and "virtual" environments are the two ends of the continuum. The second well-known definition of AR was put forward by Azuma who defined AR as any system that has the following three characteristics: (1) combines real and virtual objects, (2) is interactive in real time, and (3) is registered in 3D (Azuma 1997). Azuma later modified the third characteristic to only require the real and virtual objects to be registered with each other. Paragraph is not indented.

3 Methodology

To better understand the current and potential future states of AR in the construction industry, a survey was developed and distributed to industry practitioners. The survey included qualitative and open-ended questions to allow respondents to elaborate on their AR experience and current practcies in the construction industry. The perspectives of the entire construction industry was needed for a holistic and comprehensive investigatin of AR in construtcion, and therefore, different stakeholderswere targeted.

As the final stage of development, the survey was pilot tested by industry experts to allow for a comprehensive industry-driven assessment of AR in the construction industry. A total of 128 responses were collected from industry practitioners. Since the population dataset, i.e., the dataset that contains all stakeholders working within the construction industry, is not available, true values are not known and the variability in the sample dataset needs to be accounted for. Therefore, standard errors were used to represent variability in estimates of a parameter and to compute a 95% Confidence Interval (CI) that defines a range of values that contains the population parameter.

4 Analysis

4.1 Data Characteristics

A total of 128 responses were collected from industry practitioners, with the bulk of responses obtained from the United States. The survey included a question concerning the role performed by their firm: 36% of respondents reported that they work for General Contractors/ Construtcion Managers (GC/CM), 27% work in the Mechanical/Electrical/Plumbing Trades (MEP Trades), 16% work for Owners, 12% work for Architect/Engineer firms (A/E), and the remaining 9% work for Owner's Representatives (OR).

To assess their level of expertise with AR on a professional level, respondents were asked to select their level of familiarity with the technology and their level of usage of the technology in the construction industry. The breakdown of the responses shows that the majority of respondents (84%) have some level of familiarity with AR in construction with 17% being extremly familiar with the concept of the technology, 27% moderately familiar, 16% somehow familiar, and 24% slightly familiar. The remaining 15% indicated that they are not familiar with AR. On the other hand, only 47% of respondents (i.e., 60 respondents) have had some level of experience interacting with the technology in construction—15% have used AR on at least one construction project, 13% have tested or are testing AR applications for future use, and 19% have explored or are exploring potential AR applications.

In order to understand and investigate the current state of AR in construction, the 60 respondents who indicated that they have experience with the technology were asked to eleborate on their experience through a series of questions that we will be discussed in the following sections.

4.2 Current State of Augmented Reality in Construction

4.2.1 Augmented Reality Platforms

Out of the 47% of respondents (i.e., 60 respondents) who specified that they have had experience using AR in the construction industry (Explored/Exploring applications, Tested/Testing applications, and Used on at least one project), 65% indicated that they have used wearable technology to interact with AR and 62% specified that they have used mobile phones and tablets to interact with AR.

4.2.2 Augmented Reality Wearables

The 60 respondents who indicated that they have experience with AR in the construction industry were asked to select the AR wearable(s) that they have tried or used. The results showed that the HoloLens headset by Microsoft is the device that is most commonly used in construction with 68% of the "experienced" respondents reporting that they have used it for their AR application. Meta and Magic Leap were found to be the headsets that respondents are the least used in the construction industry.

4.2.3 Augmented Reality Wearables Concerns

Respondents who indicated that they have used AR warbles in construction were asked to identify any negative feedback they experienced from the use of the Head- Mounted-Display. Respondents reported that Safety Concerns (39%) was their most frequent deterrent from using AR wearable, followed by Discomfort (29%), Inaccuracy (29%), and Motion Sickness (27%). Headache was reported to be the least frequent concern (8%). In additions to these five concerns provided in the survey, some respondents specified other concerns including: narrow field of view and unclear vision when the device is used outside in the daylight.

4.2.4 Augmented Reality Phases

The potential of AR in the AEC industry has been explored by various researchers whose work has identified potential applications of AR throughout the life cycle of a construction project. The life cycle of a construction project consists of a series of phases and the literature review showed that there is no single definition for what the phases are (Shin and Dunston; Succar 2009). The stages of the life cycle adopted in this research are as follows: conceptual planning, design, pre-construction planning, construction, commissioning, operation and maintenance, and decommissioning. Respondents who had experience with AR in construction were asked to indicate the phase in which AR has been used. The 60 respondents reported that they have employed AR in 5 phases of the life cycle of a construction project. The majority specified that they have used AR during the construction phase (70%), design phase (67%), and pre-construction phase (60%). Few respondents have also used AR in the Operation and Maintenance (O&M) phase (12%), and commissioning phase (5%). None of the respondents reported any use of AR in either the planning or decommissioning phases. The breakdown of the respondents' experience with AR in each phase of the life cycle of a construction project.

4.2.5 Augmented Reality Hands-on Experience

Respondents who indicated that they had hands-on experience using Augmented Reality were asked to elaborate on their experience and use of the technology. This section summarizes the input of the respondents by company type.

Architects/Engineers

Respondents who work for A/E reported that they have used AR to leverage 3D visualization and enhance the client experience when exploring the design of the facility. Using the HoloLens, the 3D BIM model of the project was project in a conference room and clients were able to walk around, visualize the project in real time and discuss the design with the A/E. In addition, clients were able to interact with the project content and turn on and off layers such as structural steel, MEP, facade, and design options. Another use-cases of AR is the creation of coordination models in the HoloLens for complex mechanical spaces, so that the end users and facility managers can better understand the spaces that they will be expected to operate and raise their opinions about clearances and access requirements. Others reported the use of AR for planning purposes and engaging the client in the design process.

General Contractors/Construction Managers

The experience of GC/CM respondents were divided into in-house experience, and experience with other stakeholders such as designers, owners, and suppliers. Some respondents reported using Trimble Connect for HoloLens to improve Quality Control (QC) processes by allowing the user to compare the planned versus the installed systems. One particular case was the use of AR for quality control and inspection of pre- and post-concrete pours. Others used the HoloLens for filed layout and verification of the installation of the MEP systems on site and coordination with concrete penetrations. Another respondent reported that their company has used AR to visualize virtual mockup of a project. The use of AR to look at mockups provides a safe environment to review construction models, verify the design, and suggest and implement changes immediately. Another AR use-cases was the full-scale visualization of projects and overlays of planner systems onto the real structures. Respondents commented that AR fills in the gap between office (design work) and field (placing work) as it helps communicate the design and supports real time decisions that field personnel can make without having to go back to the office and look at a model. Another respondent described their use of the HoloLens to install in-wall blocking in the field while. A number of respondents indicated the use of AR for project proposal and presentations and pre-construction planning without expanding on the applications. Additionally, one respondent indicated that they have developed proof of concept applications for the HoloLens and have evaluated off the shelf applications for the last 3 years. However, the respondent did not provide further detail regarding their use of the technology. Moreover, GC/CM respondents reported using AR to review designs with A/E and walk the owner and users through their new space prior to building it. One respondent shared a story where AR allowed the client and A/E to notice that the doors were placed in the wrong spots. Finally, GC/CM have also worked with their suppliers and vendors to strategize how AR could be integrated into construction by listening to their needs. No details were provided regarding specific use-cases of AR.

MEP Trades

MEP respondents did not elaborate much on their use of the technology as the majority of their hands-on experience was at conference and during showcases, where they had the opportunity to demo the HoloLens and DAQRI for a few minutes. Although MEP respondents did not have any formal use of AR, they did indicate that the technology has a promising future in the construction industry.

Owners

Owners reported that they have mainly used AR to review designs and physically walk through their future projects, such as touring the planned expansion of a property.

Owner's Representatives

Owner's representatives indicated that they have used AR to gain owner buy in by allowing them to physically walk through the facility and to provide contractors with a better understanding of the projects.

4.3 Potential Future State of Augmented Reality

4.3.1 Use of Augmented Reality on Construction Projects

All 128 respondents were asked to select the types of projects on which they believe AR will be used in the future. The majority of respondents believe that AR will be used on Healthcare (92%), Industrial (88%), Institutions (72%), Commercial (72%), Renovation (67%), and Infrastructure (63%) projects and only 25% think that AR will be used in Residential.

4.3.2 Augmented Reality Adoption in Construction Companies Vs Industry

Respondents were asked to identify the timeline of the common use of AR within their company and the construction industry as well. The timeline was evaluated on an ordinal five-point scale from: [0–5 years] coded as 1, [5–10 years] coded as 2, [10–15 years] coded as 3, [More than 15 years] coded as 4, and [Never] coded as 5. The results show that employees believe that the industry is slower to adopt AR, while their organization is ahead of the curve than the construction industry as a whole. The Mann-Whitney-Wilcoxon (MWW) test was conducted to statistically verify the difference in the AR adoption timeline at the company and industry levels. The low p-value resulted from of MWW test (0.037) provides a statistical evidence at the 95% confidence level indicating that, on average, construction companies are ahead of the curve than the construction industry as a whole.

5 Conclusions

This study explored the current state of AR in the construction industry, with a dual aim of cataloging current trends in the industry and forecasting potential future applications. A total of 128 reponses were collected, 60 of which have indicated that they had interacted with the technology in the context of construtcion. Respondents who have had some experience exploring, testing, and using AR in the construction industry reported that they have predominantly used the HoloLens head-mounted display as their AR platform. The majority of those respondents have indicated that they have employed AR in the Construction, Design, Pre-Construction Planning, Operation and Maintenance, and Commissioning phases. Respondents also elaborated on their experience with the technology, showing that GC/CM had the most experience employing AR in most of the phases of a construction project life cycle. The majority of respondents reported that they see AR being used on Healthcare and Industrial projects. Finally, respondents were asked to specify the timeline of their companies, as well as the construction industry as a whole for using AR. The findings of this study contribute further knowledge to understand the current and future potential of using AR in the construction industry. This research serves a shared-knowledge platform to exchange AR practices and experiences among construction stakeholders. Further research could be conducted to expand the sample size, include other types of companies, such as Facility Managers, and perform a more detailed analysis for each stakeholder.

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Modelling Correlations in Highway Construction Projects

Alireza Moghayedi and Abimbola Windapo

Abstract

The study examines the different types of correlations between the construction costs, times and cost/time of highway construction projects and quantified their impacts on the total cost and total time of different structures of highway construction projects to determine whether repetitions of activities amplify the impact of correlation on construction cost and time. Highway construction projects are often plagued by cost and time underestimation due to ignorance of costs and times correlation between the activities in highway projects when deterministic estimation techniques are employed. Therefore, a probabilistic model is adopted in estimating the effect of correlations on the probability distributions of total cost and total time. This study identified various types of correlations between the costs, times and cost/time in the construction of highway projects and modelled them using Gaussian copula and analyzed the impact of such correlations in the construction of a highway project using Monte Carlo simulation. The results show that the standard deviation of the total cost and total time increases with the magnitude of the correlation and type of correlation matrix and, most importantly, it increases considerably with the number of costs and times that are correlated. Based on these findings, the study concludes that the deterministic estimation technique in use does not capture the wide range of the possible total cost and time of highway projects resulting in significant overruns.

Keywords

Correlation • Cost and time underestimation • Cost and time overruns • Deterministic estimation • Highway construction • Repeated activity

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1 Introduction

Transportation infrastructure projects, particularly highway construction projects, are often plagued by cost and time underestimations (Flyvbjerg et al. 2002). Various studies (Bakhshi and Touran 2012; Touran 1993; Moret and Einstein 2012; Purnus and Bodea 2014) proved that both construction costs and times are positively correlated. Positive correlations caused the standard deviation of the correlated costs and times to be larger than the standard deviation of uncorrelated costs and times, and the total construction cost and time of projects were underestimated if the costs, times and cost/time correlation were disregarded (Bakhshi and Touran 2012).

Correlation measures and describes the strength and direction of the relationship between two variables (Benjamin and Cornell 2014). The correlation varies between −1 (fully negatively correlated) and +1 (fully positively correlated), and, for a correlation equal to 0, the two variables are uncorrelated. If the value of one variable is above average, the value of the second variable tends to be above average when they are positively correlated, while it tends to be below average when they are negatively correlated (Ökmen and Öztaş 2010)

A positive correlation causes the standard deviation of the sum of the correlated variables to increase since cost and time correlations in construction are usually positive (Bakhshi and Touran 2012; Moret and Einstein 2012). Compared to deterministic estimated total cost and total time, the correlated cost and time are expected to increase the range of possible total costs and total times of the project, which generates the cloud of points in the total cost and total time directions. Differently from the deterministic cost and time estimate, which corresponds to one point, modelling the correlation of costs and times provides the range of the possible total cost and total time by a cloud of points. The cloud of points visually represents the range of possible

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correlated total costs and total times of the different structures of the project.

Correlation between the costs and times has been investigated in building construction (Touran 1993) and rail line construction (Moret and Einstein 2012), but there is a lack of studies on correlation in highway construction projects. Therefore, this study examines various types of correlation that occur in a highway construction project and analysed their impact on the distributions of the cost and time of three main structures of the highway construction project, namely: earthwork, bridge, and pavement, to determine whether repetitions of activities amplify the impact of correlations on such distributions.

2 Methodology

Correlations in the construction of a highway are analyzed based on the following methodology steps. First, various types of correlation in highway construction are identified. After that, the correlation coefficient of each type of correlation is determined from the analysis of historical data by a panel of experts (which, in the study, comprised five highway experts with experience of 30 years and more individually in the construction of highway projects in South Africa recommended by the South African national roads agency). Identified types of correlation are modeled and simulated in three structures of highway construction. Finally, the simulation results are analysed by comparing mean and standard deviation to the independent results; and findings and conclusions are discussed.

3 Correlations in the Construction of Highway Projects

Correlations in the construction of highway projects are investigated on the basis of a construction network model of a highway. In the network model, the construction of a highway project is modelled as the construction of a sequence of three main structures, namely, earthwork, bridge and pavement, each of which is modeled as a sequence of various construction activities characterized by cost and time.

The study identified the following five potential types of correlation in the construction of highway projects:

Correlation between the costs and times of a repeated activity in a structure (Type 1): The costs and times of a repeated activity are expected to be positively correlated because of the repetitiveness of the processes in a structure (Bakhshi and Touran 2012). To analyse the impact of repeated activities on the cost and time of activities of each highway structure, the intermediate correlation matrix including all positive correlations, ρ = (0, 1), is considered, which corresponds to the case where the cost and time are randomly selected for each unit, and if one cost or time per unit is above average, the next cost or time per unit will also tend to be above average.

$$\rho = \begin{bmatrix} 1 & 0.99 & \cdots & 0 \\ 0.99 & 1 & 0.99 & \vdots \\ \vdots & 0.99 & 1 & 0.99 \\ 0 & \cdots & 0.99 & 1 \end{bmatrix}$$

Correlation between the costs and times of the various activities in a structure (Type 2): To evaluate the correlation between the various activities in each of the three structures of the highway project, the expert panel of the study considered that the costs and times of the various activities in a structure were positively correlated because these activities were subjected to the same types of constraints. After analysis of the historical data of highway construction projects, the panel of experts recommended the correlation coefficients of ρ = 0.75, ρ = 0.65 and ρ = 0.8 for earthwork, bridge and pavement structures, respectively.

Correlation between the costs and times of activities in adjacent structures (Type 3): Although the pairs structures of earthwork-pavement and bridge-pavement are adjacent structures, they do not share any activities. Therefore, the expert panel recommended no correlation between the costs and times of these pairs. Earthwork and the bridge are excavated in the same geology so that a correlation between the costs and times of the cutting in earthwork and the cost and time of the bridge excavation is expected. However, due to the different excavation methods between the cutting and bridge excavation, the panel of experts recommended that the cost and time of earthwork and bridge should be independent.

Correlation between the costs and times of same activities in the same types of structures (Type 4): Positive correlations between the costs and times of the same types of structures (between bridge i and bridge j, between earthwork i and earthwork j, and between pavement i and pavement j) were expected if the geology (earthwork, bridge) and geometry (bridge) were similar. The cost and time distribution of bridge and earthwork structures were a function of the geology and the cost and time of a bridge were a function of the geometry so that similar geologies and geometry determined similar cost and time distributions.

Correlation between the cost and time of an activity (Type 5): Due to the difficulty of measuring the association between the cost and time of an activity, all members of the expert panel agreed to use ρ =+0.8 as correlation coefficient to model the correlation between the cost and time of activities.

$$\rho = \begin{bmatrix} 1 & 0.8 \\ 0.8 & 1 \end{bmatrix}$$

Therefore, the study focused on modelling correlation Type 1 (correlation between repeated activities), correlation Type 2 (correlation between different activities), and correlation Type 5 (correlation between cost and time of the activity), which was expected to have a significant effect on the standard deviation and the total cost and time of construction of highway projects.

4 Modelling Correlations

In this study, the correlation was measured with the non-parametric Spearman correlation coefficient and modelled with the Gaussian copula. A copula is a multivariate distribution function defined on the unit cube $[0, 1]^d$, with uniformly distributed marginals (Vrac et al. 2012). The choice of the Spearman correlation from amongst the available correlation measures and the Gaussian copula from amongst the available correlation models was because, differently from a random number generator, a copula first generates random numbers from a uniform distribution, then, through two transformations, it obtains random numbers correlated with the desired correlations and distributed with the desired probability distribution. Also, a copula generates the unit costs and production rates of the construction activities, which are correlated, then these are summed to obtain the total cost and total time of the activities. In other words, copulas allow the generation of correlated costs and times with the desired Spearman correlation matrix and with the desired marginal distribution, and, because of the availability of both marginal distributions and the correlation matrix for this study, the copula was employed.

The Gaussian copula generation and the summing of the unit costs and production rates of all activities were repeated for each simulation run. With the copula generation, the uncertainty in each unit of construction activities was modelled, as well as the correlation between the costs and times of the activities. At the end of each simulation run, the costs and the times (critical activities), were respectively summed up to calculate the correlated total cost and total time of activities for the particular simulation run. The correlation process was repeated for every simulation run by Monte Carlo until ithin $\pm$ 1% in 10 out of 10 simulations. A correlated probabilistic analysis was required to model the correlations on the construction cost and time of activities and evaluate the impact of the identified three correlations on the total cost and total time of the project. Essentially, the probabilistic distributions data of the cost and time variables were not available. Therefore, to model the correlation with copula, the following marginal distributions assumptions were constructed by the panel of experts based on the results of the variability of cost and time estimation sessions to generate a correlation probability distribution of costs and times:

- The underlying distributions of cost variables and time variables are lognormal and triangular, respectively (Touran 1993).
- The modes of the cost and time distribution are assumed equal to the deterministic cost and time.
- The minimum value of the cost and time distributions are 80% of the mode of each variable's distribution.
- There is a probability of 2% of exceeding the High Value (which is assumed to be 150% of the mode) of the cost distributions.
- The maximum of the time distributions is assumed to be 130% of the mode of the time distributions.

5 Results of the Study

The deterministic estimated cost and time, and resulting means, standard deviations and variation of standard deviations of each type of correlation to the uncorrelated case (base case) from modelling the three types of correlation on total cost and total time of the earthwork, bridge and pavement structures of the selected highway construction project are summarized in Table 1.

The selected case study was a 16.5-km section from a new highway infrastructure project with six lanes and controlled-access, which was constructed on both flat and hilly terrain in South Africa between 2014 and 2016. The deterministic estimated total construction cost of this section was ZAR 809,504,922.80 with a total duration of 340 days. The construction of the project comprised 2,973,692 cubic metres of earthworks in four different geological conditions, namely, fine, soft, hard and rock, precast concrete bridges and 1,015,340 cubic metres of asphalt pavements.

Furthermore, the cost and time of base case and correlation Type 1, 2 and 3 of earthwork, bridge and pavement structures from Monte Carlo simulations overlaid in scatterplots and are illustrated in Figs. 1, 2 and 3.

Cost correlations represent both threat and opportunity aspects. In fact, the correlations cause the range of the total cost and time on both sides of the mean, which is the threat of a total cost or time more substantial than the mean as well as the prospect of a total cost or time smaller than the mean total cost or time as illustrated in three overlaid scatterplots (Figs. 1, 2 and 3).

Based on the overlaying scatterplots of three types of correlation in the different structures of the highway project (Figs. 1, 2 and 3), and the results of means, standard

Table 1 Correlated means, standard deviations and standard deviation variations of three structures of the highway project

	Correlation	Cost (ZAR)				Time (Days)			
		Deterministic	Mean	Standard deviation	Δ Sd (%)	Deterministic	Mean	Standard deviation	Δ Sd (%)
Earthwork structure	Base case	244,292,292.83	268726606.90	1871424.00	0.00	215	222.19	2.61	0.00
	Type 1		268180187.90	22538485.66	1104.35		222.678	22.34	756.05
	Type 2		268608078.40	14106038.00	653.76		222.15	22.22	751.45
	Type 3		268784679.2	18319948.86	878.93		222.32	19.53	648.51
Bridge structure	Base case	70,952,700.00	78,030,393.34	1,920,505.95	0.00	340	351.35	5.04	0.00
	Type 1		78,113,067.80	6,014,085.33	213.15		351.36	30.15	498.24
	Type 2		77,890,401.00	6,425,163.00	234.56		351.46	32.81	551.42
	Type 3		78,072,569.32	6,191,307.31	222.38		351.57	22.61	348.55
Pavement structure	Base case	494,259,930.00	543,664,957.99	4,174,001.38	0.00	217	224.22	2.64	0.00
	Type 1		543,853,187.64	52,912,363.32	1167.67		224.27	13.23	401.14
	Type 2		543,899,815.54	33,572,597.99	704.33		224.41	11.13	321.59
	Type 3		542,662,510.48	41,474,779.05	893.65		223.93	11.59	339.02

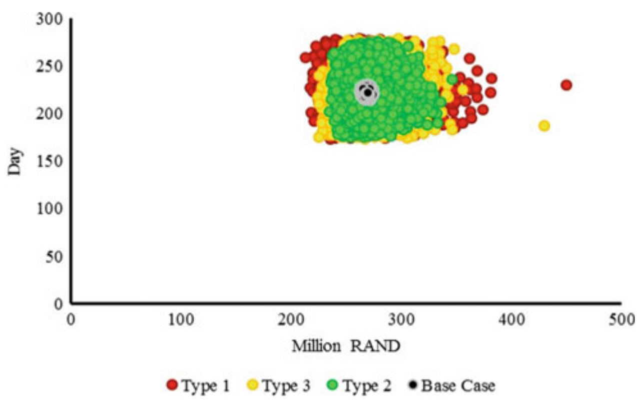

Fig. 1 Overlay scatterplot correlated cost and time of earthwork structure

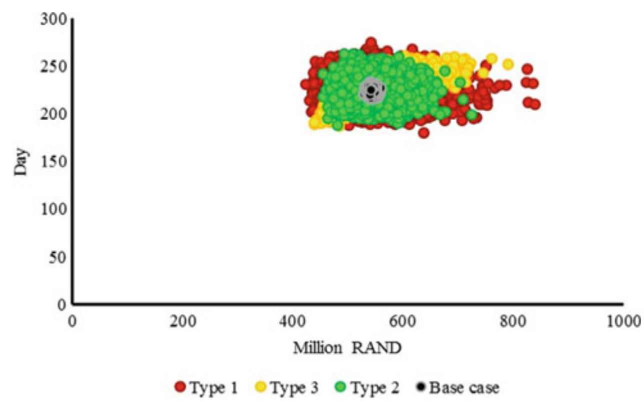

Fig. 3 Overlay scatterplot correlated cost and time of pavement structure

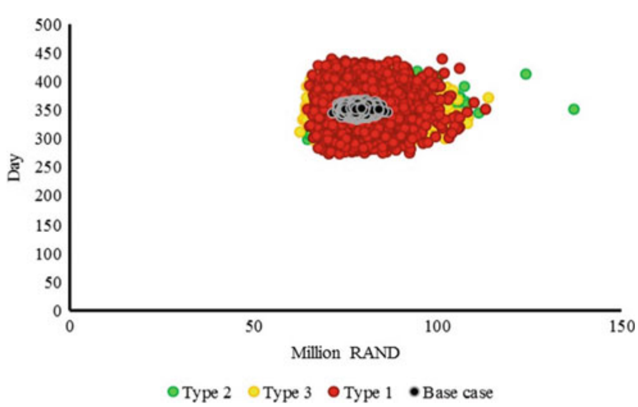

Fig. 2 Overlay scatterplot correlated cost and time of bridge structure

deviations and variation of standard deviations of correlated cost and total time of the three structures of the highway project the following observations were made:

- The mean of the correlated cost and time are constant across different types of correlations (Table 1), which is confirmed by a constant centre of gravity in the cost and time-frequency plots (Figs. 1, 2 and 3). This was expected because correlations affect the standard deviation and not the mean.
- The correlated means of total cost and total time are more significant than the deterministic estimated total cost and total time (Table 1) because the deterministic total cost and total time are the sums of the modes of costs and critical times of activities, but the correlated means of cost and total time are equal to the sum of the means of costs and critical times of activities; in other words, correlated cost and time are skewed to the right, (the mode is smaller than the mean) (Figs. 1, 2 and 3).
- The standard deviations of the cost and total time were increased considerably from base case (uncorrelated) to other correlation types, as shown in Table 1. The

increases in total cost standard deviation and total time standard deviation are visible in the overlaying distribution cost and time plots, as well as scatterplots.

- Correlation Type 1 (correlation between repeated activity) caused the most substantial increase in the cost and time of standard deviation of earthwork and pavement structure, which increased by 1,104.35% and 756.055 in cost and time standard deviation of earthwork structure, respectively, and 1167.67 and 401.14% in cost and time of standard deviation of pavement structure, respectively. On the other hand, correlation Type 2 (correlation between activities) caused the largest increase in the cost and time of standard deviation of bridge structure by 234.56 and 551.42%, respectively.

6 Discussion and Conclusions

This study examined the three types of correlation between the costs, times and cost/time of three main structures of highway projects and modelled their impacts on the distribution of the total cost and the total time of construction of highway structures. The effect of three types of correlations on the total cost and time standard deviation was modeled by Gaussian copula, a strong correlation model which allows correct generation of correlated variables, and the results were simulated by Monte Carlo simulation using actual data of 16.5 km of a new highway constructed in South Africa.

The three structures of the case study have been organized in an arrangement that allows analysis of the effect of the three correlation types in terms of the magnitude of the correlation coefficients, types of the correlation matrix, marginal distributions, and some correlated activity costs. The dominant type of correlation on cost and time of different structures of the highway project was determined by comparing the differences in total cost and time variation of standard deviations. In the earthwork and pavement, correlation Type 1 causes the most substantial increase in total cost and time standard deviation, whereas, in the bridge structure, correlation Type 2 causes the most significant increase in total cost and time standard deviation.

Concerning the magnitude of the correlation coefficients, the results have clearly shown that the more significant the correlation coefficients ($\rho = 0.8$ in the pavement), the larger the increase on the total cost standard deviations (1104.35%), which is aligned with the findings of Moret and Einstein (2012) study. However, in the time variable, the combination of the magnitude of the correlation coefficients and arrangement of critical activities on the network activity model of the structure determined the largest increase in the standard deviations of total time, which, in this study, is earthwork because $\rho = 0.8$ and all earthwork activities are located on a critical path (sequential network model without any dummy). The reason for this difference in type of correlation and considerable difference in the variation of standard deviation can be explained with the number of correlated costs and times: correlation Type 1 consists of the correlation between many activities' costs and times, while correlation Type 2 consists of the correlation between few activities' costs and times in bridge structure. The conclusion is that, as more costs and times are correlated with larger correlation coefficients, the effect on the total cost and time standard deviation becomes more substantial, which finding is supported by the studies of Bakhshi and Touran (2012), Moret and Einstein (2012). The results of modelling three types of correlations on the cost and time of a highway project proved that the range of the total cost and total time increase considerably due to correlations. This study has shown that, although estimating the effect of correlations on cost is more straightforward, estimating the effect of correlations on time is more complex. Furthermore, the study proved that the correlation impacts depend on the magnitude of the correlation coefficient, the correlation matrix, and the type of correlation. Also, the impact of the last is tightly connected to the number of activity costs and times that are correlated and the network model of the structure.

By considering the results of modelling correlation on the cost and time distribution of a highway project, it is now possible to determine the effect of such correlation in cost and time prediction models. Modelling correlation is an initial step towards a more comprehensive modelling of uncertainties of construction cost and time. The practical application of the proposed methodology can be extended to any construction project characterized by numerous repetitions of the same activities, particularly to the linear construction projects.

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Owners' Obligations Under FIDIC Construction Contracts

Omar Alhyari

Abstract

Proper delivery of construction projects entails collaboration between contracting parties and strict performance of contracting obligations. Each contracting party has rights that need to be fulfilled by the counterparty and responsibilities that need to be performed and respected. This paper presents an analysis of the obligations of the owner according to FIDIC construction contracts. Research on FIDIC contracts has focused on the responsibilities of either the engineer or the contractor with little or no attention to the obligations of the owner. The analysis revealed a number of obligations that include, but not limited to, the following groups: (1) pre-construction obligations; (2) obligations associated with contract documents; (3) obligations associated with the engineer and owner's personnel; (4) holding risks of events caused by external factors (third party actions); (5) obligations related to risks assumed by the owner; and (6) owner's obligations related to notification responsiblities. Proper understanding of the obligations of the owner can contribute to minimizing disputes and claims, and as such minimizing the considerable costs associated with the resolution and settlement of these disputes and claims.

Keywords

Employer • Owner • FIDIC • Obligations • Risk allocation

1 Introduction

Traditionally, the three major parties in a construction contract are: the owner (referred to as employer), the contractor, and the engineer. Contracts are drafted to assign rights and responsibilities to the contracting parties. Standard conditions of contract form a principal document in most contracts due to their balanced assignment of risk between parties, as well as wide coverage of issues that might be encountered during construction. Moreover, the standard nature of these conditions of contract and their wide usage enable the contracting parties to be familiar with their provisions and their established interpretations. Due to the above listed reasons, standard forms have significantly contributed to the reduction of construction disputes and the ease of settlement of disputes encountered.

Many countries have adopted international conditions of contract in their agreements which also helps owners and contractors in finding common grounds for the contract, especially with the globalization and wide movement of contracting companies to build projects internationally. FIDIC standard conditions are widely used worldwide (Ruxandra 2017; Battrick 2008).

While many publications studied the role of engineer in these contracts (Zoppis 2018; Saket 2019; Bunni 2019; Ndekugri et al. 2007; Lina 1997), and the responsibilities of the contractor (Robinson 2011; Seppälä 2005), few or no scholars investigated the responsibilities of the owner.

The owner is a major contracting party (first party) and has responsibilities that go beyond appointing the engineer and paying the contractor. The owner plays a central role in the delivery of a construction project and he is the only party who has contractual relationship with both the contractor and the engineering consultant as illustrated in Fig. 1. On the other hand, the contractor and the engineering consultant do not have a contractual relationship with each other. They are supposed to communicate and collaborate although their contractual relationship is with the owner.

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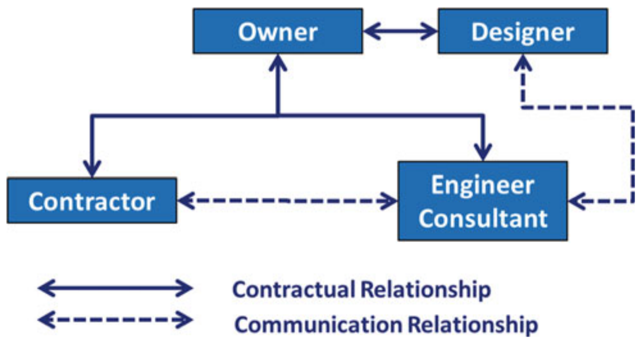

Fig. 1 Traditional delivery approach for construction projects

As such, this paper is intended to analyze the owner's responsibilities as stipulated in FIDIC construction contracts.

The understanding of the rights and responsibilities of each party can contribute to reducing conflicts that entail considerable resources for their settlements and can contribute to the speedy delivery of construction projects. The following section presents the obligations of the owner that are stated in FIDIC contracts for construction, or can be drawn from the provisions of FIDIC contracts.

2 Owner's Obligations

2.1 Pre-construction Obligations

Owner's obligations start early in the procurement stage before selecting the contractor, and continue throughout the procurement phase before the actual start up of the construction phase. These obligations include drafting clear contract, readiness of the site for construction without obstructions, financial arrangements for paying the contractor, etc.

2.1.1 Drafting Clear and Correct Contract

The owner is responsible for drafting contract documents that convey clear requirements. The established legal principle "ambiguous terms are interpreted against the party who drafted the contract" is intended to support this responsibility. Drafting contract documents that deliver the same message to all bidders is a prerequisite for healthy competitive bidding and reduces misunderstanding of contract requirements which leads to construction disputes. The owner is responsible for setting appropriate value for liquidated damages. An excessive value may be challenged at courts as a penalty and may not be enforceable. Excessive values may deter good contractors from bidding on a project due to risks involved in excessive damages. The owner must respect the law of the country, and therefore, should ensure that its drafted contract does not contradict mandatory provisions of the applicable law.

2.1.2 Site Access

The owner is responsible for giving the contractor access to the site at the time stated in the contract or in the approved schedule of work. The owner will be required to compensate the contractor for damages associated with delay in providing access. Compensation includes extension of time for completion and/or cost plus reasonable profit.

2.1.3 Supporting Contractor's Application for Permits, Licences or Approvals

The owner is required to provide reasonable assistance to the contractor in obtaining a copy of the relevant country's legislation, and in obtaining permits, licences or approvals required for the works. These obligations are stated in Sub-clause 2.2 (Assistance).

2.1.4 Disclosing Financial Arrangements

FIDIC contracts require the contractor to perform the work according to specifications and other contract documents, and at the same time require the owner to provide details in the contract documents regarding the financial arrangements made to pay the contractor during the construction phase of the project. This requirement is introduced in the new FIDIC contracts (International Federation of Consulting Engineers 2017) as a modification to the requirement stipulated in the previous edition (International Federation of Consulting Engineers 1999) which requires the owner to provide the contractor upon his request with reasonable evidence about the financial arrangements taken in order to allow the owner to pay the contractor. This request can be made anytime during construction. The new edition requires disclosing financial arrangements in the bidding documents. The owner is also required to inform the contractor of any significant changes to financial arrangements during construction. Failing to do so entitles the contractor to suspend the work and seek compensation for damages incurred. This requirement intends to reduce contractor's risk. The contractor in any contract is under the risk of performing work, incurring costs and not getting paid by owners. Construction contracts and the prevailing profit rates in the construction industry are based on the timely payment of contractors during construction. The contractor is not supposed to provide financing to the project beyond the limited amounts agreed upon at the time of the contracting.

2.2 Obligations Associated with Contract Documents

The owner is responsible for providing the contractor with the contract documents and as such will be responsible for errors or omissions in theses documents. The contractor has the right to study these documents and submit his bid on the premise that any error in the documents submitted by the owner will be compensated by the owner.

2.2.1 Compensating the Contractor for Errors in Setting Out Points of Reference

The owner is responsible for errors in points of reference (location and/or levels) given to the contractor, and therefore, is responsible for compensating the contractor for the consequences of finding an error in these points of reference. Compensation includes extension of time for incurred delay, and/or costs plus profit for incurred costs. FIDIC protects the owner by requiring the contractor to verify the accuracy of these points of reference, and stipulating that the contractor's entitlement for compensation will take place only if an experienced contractor could not reasonably discover these errors and avoid their consequences (i.e. time and cost consequences).

2.2.2 Responsibility for Adjusting Unit Prices for Quantity Variation

The contractor prepares his bidding offer based on the quantities provided by the owner in the bidding documents (bill of quantities). The owner will be required to make equitable adjustment to contract unit rates to compensate the contractor for variations in quantities of work from estimated quantities in the bill of quantities. This obligation is stated in Sub-clause 12.3 (Evaluation).

2.2.3 Responsibility for Compensating the Contractor for Omissions

The bidding price for individual work item includes the direct cost of the item in addition to a fair allocation of indirect costs and overhead. The owner will be responsible for compensating the contractor for unrecovered costs due to omitting items of work by a variation order. Compensation here includes only unrecovered costs (no profit or time). This obligation is stated in Sub-clause 12.4 (Omissions).

2.3 Obligations Associated with the Engineer and Owner's Personnel

The engineer plays a major role in FIDIC contracts, and is generally deemed to act for the owner. The following paragraphs include owner's obligations associated with the engineer, and other owner's personnel.

2.3.1 Appointing the Engineer

Appointing the engineer is the owner's responsibility. The owner must appoint an engineer and grant him the authority necessary to perform the role and duties assigned to the engineer under the FIDIC contracts. The appointed engineer should be competent to perform such role and duties.

2.3.2 Putting into Effect All "Determinations" of the Engineer

Although the FIDIC conditions state clearly that "the engineer shall be deemed to act for the Employer", they also provide that as to "determinations", the engineer shall be neutral between the parties, and shall not be considered as acting for the Employer. The owner is required to put into effect all determinations issued by the engineer. The enforceability of determinations applies to both the owner and the contractor, and is intended to avoid interruptions to the works in the project which can lead to more damages to both the parties. This balanced perspective takes into account that determinations are temporary decisions that will be enforceable until revised through dispute resolution mechanisms. This obligation is stated in Sub-clause 3.7 (Determinations).

2.3.3 Holding Responsibility Regarding Performance of the Engineer

Examples of such performance include: delayed drawings or instructions and suspension of works. According to Sub-clause 1.9 (Delayed Drawings or Instructions), the owner will be responsible for compensating the contractor for delays or disruptions caused by the engineer's delay in issuing necessary drawings or instructions. Drawings or instructions should be issued within a reasonable time. The compensation includes extension of time and/or cost plus reasonable profit. Also, by virtue of Sub-clause 8.9, the engineer can instruct the contractor to suspend part or all of the work in the project. However, if the cause of suspension is not the contractor's responsibility (e.g. faulty workmanship or materials, or failure to protect work), the owner will be responsible for compensating the contractor for the consequences of the suspension (extension of time and/or costs incurred plus profit).

2.3.4 Responsibility for Owner's Personnel's Cooperation and Compliance

The owner is responsible for ensuring the cooperation of his personnel with the contractor's efforts and their compliance with safety procedures and environmental protection practices. The responsibility of the owner includes also other contractors working with the owner in the project. This obligation is stated in Sub-clause 2.3 (Employer's Personnel and Other Contractors).

2.3.5 Responsibility for Compensating the Contractor for Damages Caused by Delayed Tests

According to Sub-clause 7.4 (Testing), the owner will be responsible for compensating the contractor if tests are delayed by the owner or on his behalf (owner's personnel). The compensation includes extension of time and/or cost plus reasonable profit. This requirement applies to all specified tests throughout the project. The owner carries similar responsibility for delayed tests on completion subject to Sub-clause 10.3 (Interference with Tests on Completion). Compensation in this case also includes extension of time and/or cost plus reasonable profit.

2.4 Holding Risks of Events Caused by External Factors (Third Party Actions)

In an attempt to protect the contractor, the owner is required to compensate the contractor for unforeseeable actions taken by third parties that affect the performance of the construction project.

2.4.1 Changes in Legislation

The owner will be responsible for compensating the contractor for any increase in cost or delay caused by changes in the laws of the country or in the official or judicial interpretation of these laws. The changes include introducing new laws or modifying or repealing any of the existing ones. Such changes need to occur after the base date (Sub-clause 13.6 Adjustments for Changes in Laws). It should be noted that Sub-Clause 13.6 also protects the owners since they will be compensated for changes that lead to reduction in construction cost. Compensation may include cost and/or time but with no profit.

2.4.2 Delays Caused by Public Authorities or Private Utility Entities

Subject to Sub-clause 20.2, and provided that the contractor has carefully followed the proceedings of the concerned public authorities or private utility entities in the country of the project, the owner should extend the duration of work to account for unforeseeable delays or disruptions caused by such authorities or entities. The owner's obligation is limited to extension of time without financial compensation.

2.5 Obligations Related to Risks Assumed by the Owner

FIDIC contracts are intended to provide a fair share of risks between the contracting parties. As such, the owner is obligated to compensate the contractor for risk events that may emerge if such risks are allocated to the owner in the contract.

2.5.1 Holding Risks of Unforeseeable Physical Conditions

Construction projects are subject to physical conditions that affect the performance of work. FIDIC contracts assign such risks to the owner as long as such conditions are unforeseeable (Sub-clause 4.12 Unforeseeable Physical Conditions). The criterion for determining whether such conditions are unforeseeable or conditions that should be accounted for by the contractor is stated in Sub-clause 1.1.85, that defines unforeseeable as "not reasonably foreseeable by an experienced contractor by the Base Date". The contractor is under duty to investigate the site and learn about any condition that might affect the performance of work, and subsequently the cost. However, if the contractor was required to hold the risk of unforeseeable physical conditions, this could lead to incorporating high contingencies in the bid price and increasing significantly the inherited uncertainty in estimating construction costs. The owner's obligation in the case of unforeseen physical conditions includes granting additional time and/or compensating the contractor for additional costs with no profit.

2.5.2 Compensating the Contractor for Archaeological Finding

Sub-clause 4.23 includes provisions that the owner will bear the consequences of finding archaeological finding in the construction site. Often times, such findings lead to a delay in performance, and as such the contractor can claim for damages incurred. Contractor's compensation in this case includes costs and/or time, but with no profit.

2.5.3 Compensating the Contractor for Specified Owner's Risks

According to Sub-clause 17.4 (Consequences of Employer's Risks), the owner will be responsible for compensating the contractor for damages that relate to any of the employer's risks specified in Sub-clause 17.3 (Employer's Risks). The compensation is extension of time plus incurred costs, and in some cases adding reasonable profit to the costs (only when the cause of damage is attributable directly to the owner such as utilizing permanent works or design carried by the owner or his personnel).

2.6 Owner's Obligations Related to Notification Responsibilities

FIDIC contracts include requirements on the contractor to notify the engineer in some occasions. Such a notification is considered in some cases a condition precedent where failing to notify within the stipulated period will deprive the contractor of his compensation entitlement. The owner is also required to provide notifications to the engineer or the contractor in some occasions. It is noteworthy that the owner's duty to notify is less restricted, relative to the contractor's notification duty. This difference can be attributed to the fact that the contractor's knowledge and involvement in the work is more than the owner, and therefore, the contractor is in a better position to know about any matter that requires notification. The owner's involvement is less, and therefore, notification periods are less restrictive. Examples of the owner's notification responsibilities include: (1) The owner is required to notify the contractor of his intention to replace the engineer at least six weeks before the intended date of replacement and (2) The owner is required to notify the engineer of his intention to claim as soon as practicable after becoming aware of the matter giving rise to his claim.

2.7 Other Owner's Obligations

2.7.1 Compensating the Contractor for Delayed Payments

The owner is required to make payments to the contractor in a timely manner. For delayed payments, the owner is required to compensate the contractor by paying financing charges compounded monthly on the due amount (Sub-clause 14.8).

2.7.2 Compensating the Contractor for Utilizing Parts of the Works During Construction

According to Sub-clause 10.2 (Taking Over Parts of the Works), the engineer may issue a taking over certificate for parts of the permanent works during the construction period. The owner may be required to compensate the contractor for any additional costs incurred by the latter due to the owner's utilization of works during the execution of the construction project. This is in addition to a reasonable profit.

2.7.3 Compensating the Contractor for Searching for Causes of Defects

If the contractor is instructed to search for the causes of defects which are not his responsibility, the owner will be required to compensate the contractor for extra costs incurred plus reasonable profit (compensation may also include time extension). The entitlement for compensation occurs when the cost of remedying the defect shall not be paid by the contractor according to Sub-clause 11.8 (Contractor to Search).

2.7.4 Insurance

If the owner is listed in the contract as the party who should effect and maintain any insurance, the owner should do so and will be responsible for compensating the contractor for consequences of failing to insure.

3 Conclusions

FIDIC construction contracts are widely used all over the world for reasons that include, *inter alia*, their fair allocation of risks between the contracting parties. Each contracting party has rights and obligations. This paper presented an analysis of the owner's obligations under FIDIC construction contracts.

The paper showed that the owner has obligations that go beyond appointing the engineer and paying the contractor. The owner, as well as the engineer and the contractor should be aware of these obligations and how they should be performed. The owner's failure to perform one or more of his obligations may lead to costly claims and disputes that require substantial resources to be resolved, and may erode the much needed trust and collaboration between the contracting parties.

The analysis revealed a number of risks allocated to the owner as examples of the fair allocation of risks between the contracting parties under the FIDIC contracts. This includes unforeseeable physical conditions; responsibility regarding the proper performance of the engineer (proper inspection and testing; site instructions; approvals…etc.); collaboration of the owner's personnel; errors in points of reference; errors in design and omissions in contract documents; delays and disruptions caused by third party; risks associated with changes in legislation; and archaeological findings.

The owner's proper performance of his contractual obligations helps in reducing disputes and contributes to the proper delivery of the construction project.

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Predicting the Impact Size of Uncertainty Events on Construction Cost and Time of Highway Projects Using ANFIS Technique

Alireza Moghayedi and Abimbola Windapo

Abstract

This study examines the ability and performance of Adaptive Neuro-Fuzzy Inference System (ANFIS) as an intelligent machine learning technique in the prediction of the impact size of uncertainty events on construction cost and time of highway projects. The rationale for the study stems from widespread reports of cost and time overruns on highway construction projects and the knowledge that the cost and time of projects are affected significantly by uncertainty events. Thus, the prediction of the impact size of uncertainty events during the design phase will enable project managers in preparing a proper plan with sufficient contingencies to deal with these uncertainty events. The success or failure of prediction depends on the credibility of the prediction method. In this study, the impact size of 76 uncertain events on the construction cost and time of highway projects were predicted using ANFIS technique, and the accuracy and reliability of ANFIS prediction were assessed. The results of R-Squared and four error tests proved that ANFIS is an accurate and reliable technique for predicting the impact size of uncertainty events on the cost and time of construction projects. Based on these findings, the study concludes that the use of intelligent machine learning methods such as ANFIS will minimise the potential inconsistency of correlations in construction cost and time prediction, improved accuracy in estimated project cost and time and reduced overruns.

Keywords

Accuracy • ANFIS • Construction cost and time • Impact size • Reliability • Uncertainty events

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1 Introduction

Construction of transportation infrastructure and particularly highway construction projects are one of the most unreliable projects in terms of estimating construction cost and time (Flyvbjerg et al. 2002). According to Abdullah et al. (2010) 90% of the People's Trust Council highway construction projects experienced cost and time underestimation. Providing accurate estimates of cost and time on the construction of highway projects is a difficult task because construction projects are subject to risks and uncertainties, especially in the planning phase of the project when insufficient data and information about the project is available (Ökmen and Öztaş 2010). Typically, in the estimation of construction project resources, several variables are not known since uncertainties populate construction projects.

There are many common uncertainty events (also known as risk events) that influence the cost and time of construction activities of construction projects that affect construction performance differently (El Khalek et al. 2016). According to Flyvbjerg (2007), the occurrence of uncertainty events in the construction of infrastructure projects, particularly in highway projects, is higher than other construction projects, due to unique features of highway projects, which include complexity between major construction activities, long duration of construction, dynamic processes, repetitive linear projects, and mobile construction sites. The project is regarded as successful if adequate allowance is made for uncertainty events and a proper response is provided for their impacts on cost and time of project which may or may not occur (Chan and Chan 2004).

Estimating construction cost and time at the early stage of project development represents a prediction provided by the estimator based on available information and data. Estimating in construction is defined as that area of construction practice where the estimator's experience and judgment are utilised in the application of scientific principles and techniques to the problem of predicting and controlling cost and

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time of projects (Ng and Zhang 2008). The ability to accurately predict the impact size of uncertainty events on construction time has always been one of the most critical challenges of estimators (Antunes and Gonzalez 2015). The success or failure of prediction depends on the credibility of the prediction technique.

The impacts of risk and uncertainty events on cost and time of construction projects have been approached in two major ways: qualitative techniques and quantitative techniques. A qualitative technique such as contingency application and fault tree analysis are more basic techniques, and the subjective judgment could not determine the exact impacts of events (El Khalek et al. 2016). Quantitative techniques such as regression modelling, neural networks and Monte Carlo simulation are more common and preferable than the qualitative techniques because of the capability of quantifying the impacts of such events (Moret and Einstein 2016). However, quantification techniques are complex and hard and furthermore require exact data, and such data either do not exist at all or are hard to obtain in the realisation of construction projects (Ebrat and Ghodsi 2014). Furthermore, the applicability of these techniques in predicting the impact size of uncertainty events in real construction projects is limited due to the unpredictable nature of construction projects and their dependence on the estimator's thinking prototype in the process of uncertainty analysis (Ebrat and Ghodsi 2014).

On the other hand, hybrid intelligence machine learning methods based on Fuzzy Inference System (FIS) is used in modelling the qualitative aspects without employing precise quantitative analyses, it provides standard practical methods for transformation into rule-based as well as effective methods for turning Membership Functions (MF) for better performance index (Chai et al. 2009). The Adaptive Neuro-Fuzzy Inference System (ANFIS) combines the strengths of Artificial Neural Network (ANN) with Fuzzy Inference Systems (FIS) to create an efficient method for analysing the complex problems. Also, neural network fuzzy systems interpret human knowledge and deduce it into a mathematical model. These two tools were combined to achieve readability and learning ability at the same time. ANFIS, trained to develop fuzzy rules and determine Membership Functions (MF) for input and output variables of the system is an intelligent system which can estimate the variables and fuzzy rules intelligently and does not require a systematic method for design of fuzzy systems. ANFIS can handle nonlinearity, uncertainty, and complex problems which are involved in predicting the impact size of uncertainty events on construction cost and time (Jin 2010). Generally, Neuro-Fuzzy has two major categories namely: fuzzy linguistic modelling which is focused on interpretability (Mamdani), and precise fuzzy modelling which is focused on accuracy (Takagi-Sugeno) (Lughofer 2011).

ANFIS has been used in various fields of engineering. For instance, Ugur (Ugur 2017) has developed ANFIS to estimate the costs of the residential building. While Fragiadakis et al. (2014) assessed the occupational risk in the shipbuilding industry; Ebrat and Ghodsi (2014) applied ANFIS to evaluate the risk in construction projects; Li et al. (2011) forecasted building energy consumption using hybrid ANFIS; GüNeri et al. (2011) used ANFIS to overcome supplier selection problem in construction projects; Shahhosseini and Sebt (2011) used ANFIS to establish a fuzzy adaptive decision-making model for selection and assignment of human resources to construction projects based on competency; and Wang and Elhag (2008) developed an ANFIS based risk assessment model for bridge maintenance projects.

However, there are limited researches undertaken using ANFIS in the field of construction management and limited studies have evaluated the performance of ANFIS as a technique for predicting the impact size of uncertainty events on construction cost and time of highway projects. Therefore, this study examines the predicted impact size of uncertainty events on the construction cost and time of highway projects using ANFIS as an intelligence method, and after that assessed the ability and accuracy of prediction of ANFIS.

2 Uncertainty Events on Highway Projects

An uncertainty event (also known as risk or unforeseen event) is an event with a substantial impact on the construction activities and process and occurs with some probability of occurrence, and severely disrupt the construction process if it occurs (Goodwin and Wright 2010). Uncertainty events are associated with the project characteristics and location and has no root causes that can be generalised (Ramanathan et al. 2012). Therefore, there is an obvious need to effectively anticipate, identify and classify the uncertainty events on different locations and projects to assess their influence on the objectives of construction projects. Moghayedi and Windapo (2018) identified 76 uncertainty events as affecting the construction of South African highway projects under seven major groups namely Economic, Environmental, Financial, Legal, Political, Social and Technical as presented in Fig. 1. The 76 uncertainty events identified by Moghayedi and Windapo (2018) was used in the current study to evaluate the performance of proposed techniques for predicting the uncertainty events.

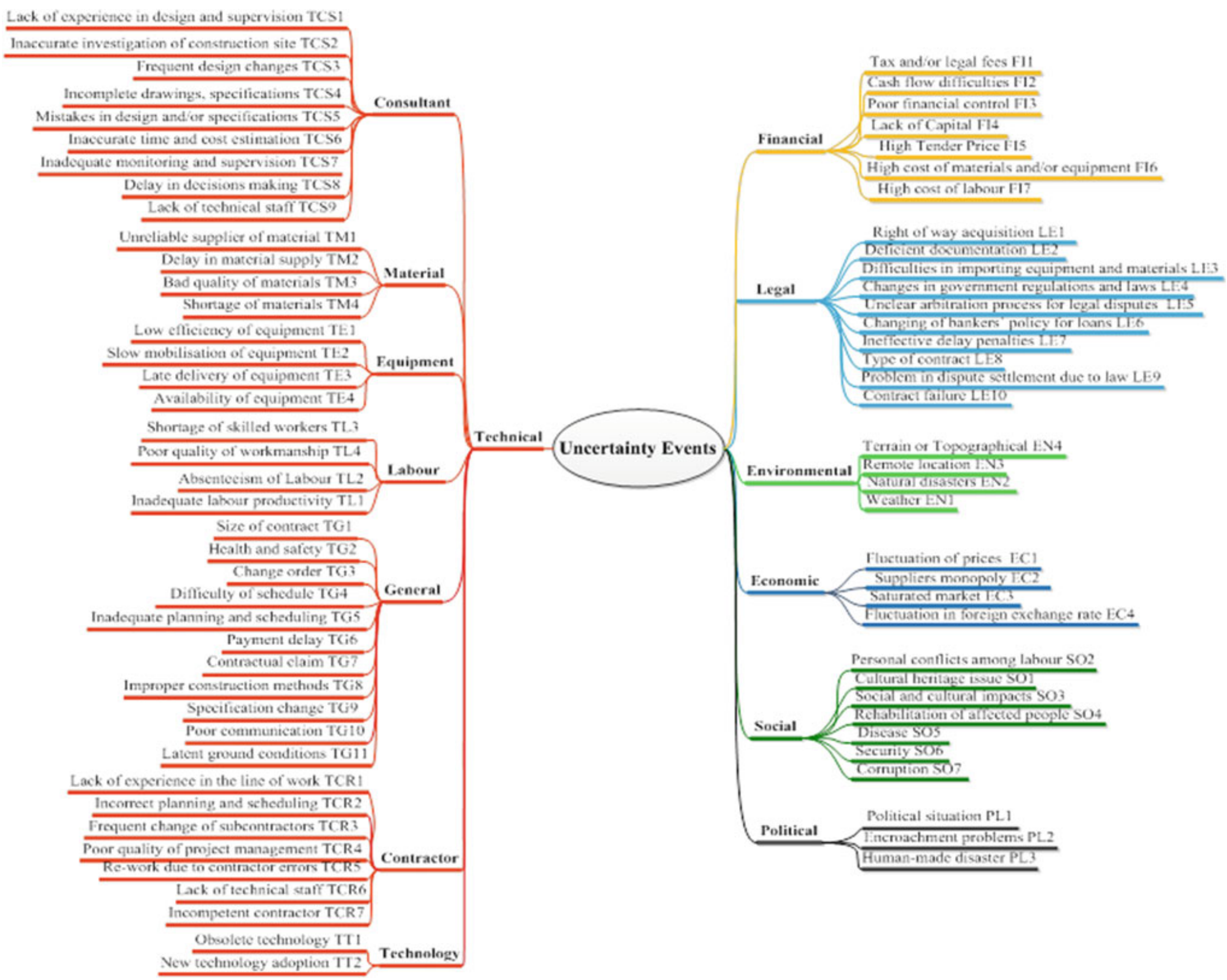

Fig. 1 Uncertainty events on South African highway construction projects distributed according to causative factors

3 Methodology

This paper developed An ANFIS model and evaluated its performance in predicting the impact size of uncertainty events on construction cost and time of highway projects. The hierarchy structure of the model developed for predicting the impact size of uncertainty events consists of four main steps; determination of uncertainty event attributes, data collection, developing the predicting models, evaluating the performance of the developed model and recommendations.

The process begins with a determination of criteria for uncertainty assessment. The impact size of uncertainty is assessed by two parameters, probability of occurrence and severity (ISO 1000). To model, the impact of uncertainty events on construction time, the ISO 31000 (International Standard Organization) impact matrix was used (ISO 1000). Figure 2 shows the probability of occurrence and severity as two input variables and relevant impact size as the output of the predicting model.

In the second step, the uncertainty event attributes (probability of occurrence and severity) were obtained from 32 project managers with a minimum of 20 years of work experience in South African highway construction projects recommended by The South African National Roads Agency SOC Ltd. (SANRAL) using the five-point linguistic Likert scale questionnaires.

In the third step, an ANFIS model is developed in MATLAB based on the impact matrix to predict the impact size of uncertainty events on construction cost and time of highway projects to assess the impact size of uncertainty events in construction cost and time of highway projects. In the last step, the fitness of predicted impact sizes to the real data are evaluated by R-Square, and the reliability of ANFIS on predicting impact size are evaluated using Root Mean Square Error (RMSE) and Mean Absolute Percentage Error

Fig. 2 Uncertainty impact matrix

		Severity				
		Insignificant (1)	Minor (3)	Moderate (5)	Major (7)	Catastrophic (9)
Probability of Occurrence	Rare (.1)	Minimal (1)	Minimal (1)	Low (2)	Low (2)	Moderate (3)
	Unlikely (.3)	Minimal (1)	Low (2)	Moderate (3)	Moderate (3)	High (4)
	Possible (.5)	Low (2)	Moderate (3)	Moderate (3)	High (4)	High (4)
	Likely (.7)	Low (2)	Moderate (3)	High (4)	High (4)	Extreme (5)
	Almost Certain (.9)	Moderate (3)	High (4)	High (4)	Extreme (5)	Extreme (5)

(MAPE). The predicted impact size and the performance values of ANFIS on construction cost and time of highway projects are presented in the next section.

The RMSE, MAPE and of predicted impact size of uncertainty events are calculated to evaluate the performance of ANFIS. The result of the selected 20 events is presented in Table 1.

4 Results

The study developed a first-order Takagi-Sugeno fuzzy inference system to accurately assess the impact size of uncertainty events on construction cost and time of highway projects. In this inference system, the output of each rule is a linear combination of two input variables added by a linear term of "AND" logic. The final output is the weighted average of each rule's output (Buragohain and Mahanta 2008). Figure 3 illustrates the Takagi-Sugeno ANFIS structure which was developed for this study. To model this ANFIS following 25 fuzzy rules "If-Then" are considered.

Eighty percent (80%) of the data collected from the research participants was used for training of the FIS, while the twenty per cent (20%) was used for checking and testing the neural network which set the system parameters. The RMSE, MAPE and R-Square value of predicted impact size of uncertainty events are calculated to evaluate the ANFIS performance and the result for the selected 20 events are presented in Table 1.

5 Discussion of Findings

This study employs ANFIS as intelligent machine learning technique in modelling the impact size of uncertainty events on construction cost and time of highway projects and evaluates the prediction performance of the ANFIS technique. The success or failure of prediction depends on the credibility and performance of the prediction technique. The examination of the calculated R-Squared value of cost and time reveals that the R-Squared value of intelligent machine learning method is significantly close to 1, which means the predicted impact size of uncertainty events by ANFIS has a very high fitness to the real data. Furthermore, the comparison of the R-Squared value of cost and time revealed that the predicted impact size of events on the cost of highway projects are more fitted to the real impact size on cost (15 impact size on cost predicted accurately) compared to the predicted impact size on time of highway construction projects. Also, the examination of the calculated RMSE and MAPE revealed that the error values of ANFIS on predicted impact size in both cost and time of highway projects are significantly close to 0, which means the reliability of prediction of intelligent machine learning technique in both cost and time of highway projects are very high.

The minimal error scores of RMSE ($e < 0.3$) and MAPE ($e < 0.1$) proved the high reliability of ANFIS models (Veerasamy et al. 2011). Furthermore, the extreme closeness of R-Square values to 1 verified the excellent fitness

Table 1 ANFIS models predicted impact size and performance evaluation for selected 20 events

Event	Probability of occurrence	Severity	Impact size	RMSE	MAPE	R-value	Severity	Impact size	RMSE	MAPE	R-value
TG11	0.84375	8.5625	4.97	1.13E-08	1.78E-09	1.000000000000000	8.3125	4.95	7.64E-07	9.70E-08	0.999999999999976
TCS6	0.79375	7.375	4.59	4.79E-08	7.51E-09	1.000000000000000	8.3125	4.85	8.71E-07	1.24E-07	0.999999999999967
PL3	0.8125	5.75	4.27	3.09E-08	5.91E-09	1.000000000000000	7.4375	4.69	1.10E-06	1.70E-07	0.999999999999945
EN3	0.75	6.0625	4.21	3.36E-08	7.08E-09	1.000000000000000	3.9375	3.68	8.36E-07	1.80E-07	0.999999999999948
SO7	0.79375	5.5	4.17	7.54E-08	7.99E-09	1.000000000000000	3.8125	3.79	6.32E-07	1.48E-07	0.999999999999971
SO5	0.70625	6.3125	4.11	3.59E-08	7.38E-09	1.000000000000000	6.8125	4.06	9.67E-07	1.85E-07	0.999999999999948
EC2	0.7	5.5625	4.08	1.07E-07	1.73E-08	0.999999999999999	3.5625	3.32	7.76E-07	1.88E-07	0.999999999999947
EC1	0.66875	6.5625	4.02	6.05E-08	1.35E-08	1.000000000000000	4.5625	3.7	8.74E-07	2.07E-07	0.999999999999936
EC4	0.65625	5.4375	3.88	1.27E-07	2.06E-08	0.999999999999999	2	2.48	7.22E-07	2.38E-07	0.999999999999924
TG9	0.73125	4.5625	3.86	2.50E-07	3.44E-08	0.999999999999995	6.4375	4.18	1.23E-06	2.16E-07	0.999999999999915
EN2	0.4125	8.125	3.84	1.39E-08	2.94E-09	1.000000000000000	7.9375	3.8	9.73E-07	1.83E-07	0.999999999999941
SO6	0.76875	4.1875	3.82	5.06E-08	1.26E-08	1.000000000000000	4.0625	3.78	8.05E-07	1.49E-07	0.999999999999952
FI6	0.55625	6.375	3.8	2.41E-08	5.99E-09	1.000000000000000	2.375	2.68	7.64E-07	1.98E-07	0.999999999999913
PL1	0.64375	5.1875	3.77	8.27E-08	1.33E-08	0.999999999999999	5.6875	3.88	7.76E-07	1.73E-07	0.999999999999956
TCR5	0.64375	5.1875	3.77	8.73E-08	1.33E-08	0.999999999999999	5.5625	3.86	8.86E-07	1.73E-07	0.999999999999947
FI5	0.55	6.25	3.75	2.65E-08	6.07E-09	1.000000000000000	2.0625	2.53	6.24E-07	1.63E-07	0.999999999999927
SO3	0.76875	3.875	3.72	5.31E-08	1.40E-08	1.000000000000000	4.375	3.88	8.96E-07	1.80E-07	0.999999999999945
TCS3	0.60625	5.625	3.72	6.65E-08	9.68E-09	1.000000000000000	5.8125	3.77	9.08E-07	1.82E-07	0.999999999999939
TCR4	0.66875	4.5625	3.7	7.50E-08	1.70E-08	1.000000000000000	5.5	3.95	8.83E-07	2.04E-07	0.999999999999945
TG3	0.74375	3.9375	3.66	7.51E-08	1.55E-08	1.000000000000000	4.0625	3.71	1.20E-06	2.51E-07	0.999999999999896

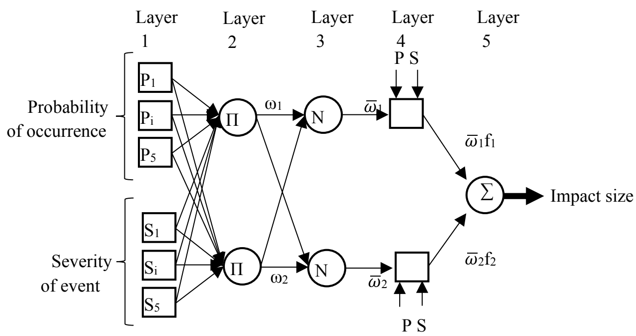

Fig. 3 Developed Takagi-Sugeno ANFIS structure

($r > 0.9$) of predicted impact sizes of all 20 models to the real data (Moore and Kirkland 2007).

6 Conclusions

This study examines the capabilities and credibility of ANFIS as an intelligence machine learning method for predicting the impact size of uncertainty events on construction cost and time of highway projects. The results show that an intelligent machine learning method (ANFIS) has a very high performance in both fitness and reliability of the prediction model. Also, the research results suggest that intelligence machine learning methods such as ANFIS could be used as a superior technique for predicting the impact of uncertainty in construction projects mainly when the input data are ambiguous or subject to relatively high uncertainty. The hybrid intelligent learning ability of Fuzzy Inference System (FIS) empower the ANFIS in learning, modelling and analysing the qualitative aspects of data such as human knowledge. The strength of the hybrid intelligent learning methodology provides a simple and efficient approach that helps project estimators and project managers to predict the impact size of uncertainty events of construction projects more systematically and efficiently compared to the existing construction project risk assessment techniques which require a large number of subjective judgments from construction project experts.

The developed hybrid intelligent machine learning technique also helps project managers to perform sensitivity analysis for uncertainty events, identify sensitive and critical events, and implement appropriate strategies. The developed ANFIS also has a high level of accuracy and reliability in prediction. Therefore, estimators will be able to save a significant amount of cost and time by using the developed approach. Besides accurate prediction and evaluation of uncertainty impacts, the ANFIS also reduce the potential inconsistency of correlations. The study advances that the use of ANFIS technique could be extended to the management of uncertainties in various sectors of the construction industry. Also that managing the uncertainties on projects could be executed more systematically using the advantages of the designed FIS and higher performance of predicted size by ANFIS. The use of a similar approach in evaluating the performance of intelligent machine learning methods as a predictor of various variables in the construction industry such as project complexity and project performance is recommended as the focus of further studies.

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Construction-Related Waivers to the Small Unmanned Aircraft Systems Rule in the United States

Michele Herrmann

Abstract

With the Unmanned Aerial Vehicle (UAV) industry poised to become a five billion dollar industry within the next year, UAVs have tremendous potential within the construction industry. From aerial surveys, jobsite photographs, and monitoring productivity and safety, UAV use could result in increased efficiency and reduced waste in the construction industry—which is notorious for having a high percentage of waste. Regulations enacted in August 2016, made the implementation of UAVs more straightforward for construction companies than had been the case in prior years. Conventional legal research methods were utilized, including a search of relevant statutes and a comprehensive review of Federal Aviation Administration (FAA), waivers granted since the implementation of the Small Unmanned Aircraft Systems (UAS) Rule. This, paper will discuss regulations applicable to UAV use in the construction industry, the parts of the regulations for which waivers can be requested, and the number and type of waivers sought since the current regulations were enacted.

Keywords

Drone • Federal Aviation Administration • Unmanned aerial vehicle • Unmanned aircraft system • Waiver

1 Introduction

Construction spending in the United States was approximately $1.13 trillion in 2016, yet with anywhere from 25 to 40% typically being attributed to waste, that results in approximately $160 billion in waste per year (Dillow 2017).

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While collaborative project delivery methods such as Design-Build and Integrated Project Delivery seek to reduce waste and inefficiency in the construction industry, advancements in technology also offer opportunities to maximize efficiency and reduce waste. Unmanned aerial vehicles (UAVs), often called drones and identified as Unmanned Aircraft Systems (UAS) by the Federal Aviation Administration (FAA), are one example of technology that is expected to improve efficiency in construction.

Expected to be a five billion dollar industry by 2020, UAVs offer many opportunities to the construction industry (Dillow 2017). From aerial surveys (Anderson 2015), to jobsite photographs and beyond, UAVs have the potential to increase efficiency, ultimately saving construction companies time and money (Knight 2015). Data collected from UAVs can be used to develop topographical maps, three-dimensional building models, measurements of stockpiles, and allow companies to manage productivity and allocate resources more efficiently. Software companies such as Autodesk are working to develop software that allows users to effectively and efficiently gather and manipulate data collected by UAVs. Autodesk, which already offers software that is widely used for building information modeling, has within recent years been expanding its usefulness to the construction industry by purchasing Skycatch, a company that makes hardware and software for the construction industry, and investing in 3D Robotics to develop cloud-based data collection from specialized UAV equipment (Dillow 2017).

2 Literature Review and Methodology

Unmanned aerial vehicle regulations were in a period of temporary uncertainty from the passage of the Federal Aviation Administration's Modernization and Reform Act of 2012 (the Act), until enactment of the current UAV regulations in August, 2016. The Act required the FAA to

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develop regulations that would allow UAVs to be safely implemented into domestic airspace by September 30, 2015 (Federal Aviation Administration Modernization and Reform Act 2012). When the Act was passed, commercial UAV use required prior FAA approval, which was typically obtained by applying for a Section 333 Grant of Exemption or Certificate of Waiver or Authorization (Herrmann 2017). In the interim period between the passage of the Act in 2012 and the adoption of the Small UAS Rule in 2016, there was a period of uncertainty about the viability of future UAV use, while operators waited to determine if the new regulations would foster their potential UAV use or be so restrictive as to make UAV use unviable. A 2017 survey of 113 construction companies found that 61% of respondents surveyed reported having used UAVs on their construction sites. UAV uses identified by respondents generally fell into the categories of (1) photography/videography, (2) surveying, (3) inspections, and (4) safety/security monitoring—with photography/videography being the most prevalent use (Tatum and Liu 2017). Additionally, a review of Section 333 Exemptions grated as of October 31, 2015, revealed a total of 2137 exemptions granted however, only 190 of those, or approximately 8%, were related to the construction industry (Definitions: Small Unmanned Aircraft System 2016). When granted, FAA Section 333 Exemptions were generally valid for a period of two years. Section 333 Exemptions granted prior to passage of the Small UAS Rule were still valid for a two-year period however, once those exemptions expire UAV operators will need to request Part 107 Waivers, discussed below.

Conventional legal research methodologies were used to compile information on the current regulations applicable to UAV use. A comprehensive review of the Certificates of Waiver or Authorization on the FAA's website was used to compile information about waivers from the current FAA regulations issued since the passage of the Small UAS Rule.

3 Results

3.1 Part 107—Small Unmanned Aircraft Systems

Enacted in August, 2016, the current regulations pertaining to the use of UAVs are contained in Title 14 of the Code of Federal Regulations, Part 107. Known as the Small UAS Rule, or Part 107, the regulations are applicable to small UAVs, defined to be those weighing less than 55 lb at takeoff, inclusive of any onboard attachments (Small Unmanned Aircraft Systems 2016). Part 107, Subpart B contains the following requirements for UAV operation: the operator must be at least 16 years of age, pass an Aeronautical Knowledge Test, have a Remote Pilot Certificate, and the UAV must be registered with the FAA. Operation must occur during daylight hours within the visual line of sight of the operator, groundspeed shall not exceed 100 miles per hour, and altitude shall not exceed 400 ft above ground level. Additional restrictions include prohibiting the UAV from being (1) flown over people (2) operated from a moving vehicle, and (3) operated near airports and other prohibited or restricted areas (Small Unmanned Aircraft Systems 2016).

While some construction companies may be tempted to characterize their UAV use as non-commercial on the premise that the UAV use is conducted by a company employee rather than for hire and the data is for internal use only, the FAA has been explicit in its interpretation of what constitutes commercial UAV use. Once the use is in furtherance of a person's business, the use is categorized as commercial, even if no compensation is received. Just as a realtor taking aerial photographs of a property can be considered commercial use, so too can taking aerial photographs of a jobsite. Regardless of whether the photographs are only used internally, the aerial jobsite photographs are presumably being used to further the business interests of the construction company, and the UAV use is, therefore, considered to be commercial (Federal Aviation Administration 2014).

3.2 Part 107 Waivers

Part 107, Subpart D allows the FAA Administrator to grant waivers to some of the regulations listed above, provided operation of the UAV can still be safely conducted. Applicants can request a certificate of waiver for the following regulations: operation from a moving vehicle, daylight operation, visual line of sight operation, visual observer, operation of multiple UAVs, yielding the right of way, operation over people, and operation in restricted airspace (List of Regulations Subject to Waiver 2016). Although these waivers are granted on a case-by-case basis, at this time the FAA has explicitly stated it will not grant waivers for package delivery by aircraft for compensation or hire.

To request a waiver, applicants must complete the application process via the FAA website and provide a description of the proposed use, as well as an explanation of how the UAV operation can be safely conducted with the waiver requested. The FAA has issued guidelines specific to each type of waiver to assist applicants in establishing how operations will be safely conducted. For example, if an applicant seeks a waiver to allow UAV operation over people—such as using the UAV on a construction site to take photographs or to monitor safety or productivity, the FAA guidelines require the applicant to (1) provide data demonstrating the UAV will not cause serious injury if it makes impact with a person for any reason, (2) provide data addressing blunt trauma and laceration injuries, as well as any other type of injury inherent to the UAV, (3) include any operating conditions or limitations to be followed to ensure safety, and (4) any special knowledge, qualifications or skills of the operator that ensure safety of the UAV operation over people (List of Regulations Subject to Waiver 2016). Similarly, if an applicant seeks a waiver to operate the UAV from a moving vehicle—such as using the UAV for survey purposes or stockpile management for linear construction, the FAA guidelines require the applicant to (1) provide a means of ensuring the area of operation is properly evaluated for potential hazards, which are constantly changing, (2) ensure the visual line of sight is maintained from the position of the moving vehicle, (3) ensure all persons involved in the operation of the UAV are free from distractions, and (4) ensure that in the event of a loss of data link, procedures are in place to account for the movement and positioning of a remote pilot and ground control station (Federal Aviation Administration 2017a).

Each waiver granted will specify the nature and extent of the waiver granted, as well as any additional conditions imposed on the UAV operation (Waiver Policy 2016). Processing time varies but can take approximately 90 days (Federal Aviation Administration 2017b).

3.3 Part 107 Waivers Granted

In the first year since implementation of the Small UAS Rule, the FAA granted 1298 waivers for various Part 107 regulations. As of the date of this paper, there are 2520 active waivers for various Part 107 regulations. As shown in Table 1, the majority of those waivers were issued to allow operation of the UAV at night, while very few have been issued to allow UAV operation above people.

Each waiver granted contains both standard and special provisions regarding the approved use. Standard provisions are applicable to all granted waivers and generally require the certificate of waiver to be presented upon request, require the holder of the certificate to comply with the terms of the certificate, and explicitly state the certificate is nontransferrable. Special provisions are then divided into common provisions and special provisions specifically related to the regulation being waived. Common provisions typically include but are not limited to statements authorizing the FAA to cancel or delay or all operations due to safety concerns or violations of the certificate and stipulate that UAV operations are to take place in Class G airspace unless a specific waiver is sought to operate in other airspace classifications. Special provisions specific to the regulation being waived are more specific. For example, some of the special provisions typically included in a waiver to operate over people include but are not limited to: (1) having designated launch and recovery areas where those not participating in the UAV operation are not allowed, (2) individuals directly participating in the operation of the UAV must be easy to visually identify, (3) while operating the UAV over people, ground speed must not exceed five miles per hour, (4) a UAV operated over people must not exceed an altitude of more than 21 ft, (5) operations must take place over private or controlled-access property and with appropriate permission, and (6) prior to conducting UAV operations over people, those people must be provided with notice of the UAV operation (Federal Aviation Administration 2017c).

If a construction company happens to have a project that is in close proximity to an airport, and the jobsite is located within airspace designated for an airport, UAV use may still be possible. For example, in May, 2017, Lane Construction was granted a Certificate of Waiver for Section 107.41 of the Small UAS Rule, allowing it to operate a UAV within a designated area in Class C airspace near the Bangor International Airport (BGR) for the purpose of aerial photographs. In addition to FAA jurisdiction, the waiver also gives the Bangor Air Traffic Control Tower (ATCT) jurisdiction over the UAV use and imposes additional coordination requirements on the UAV operator, such as requiring the operator to (1) provide the BGR ATCT 24 h advance notice of details of the planned operation, (2) contact BGR ATCT 15 min prior to the commencement of the operation to obtain real-time approval, and (3) notify BGR ATCT as soon as the operation is complete (Federal Aviation Administration 2017d).

4 Discussion

Although only a limited number of construction companies have sought Part 107 waivers in the first year since implementation of the current regulations, there are several possible explanations for this. First, a search of the FAA waivers granted using the search term "construction" reveals only five current waivers granted to construction companies. However, that does not necessarily mean only five construction companies sought waivers, it only shows that five companies include the word "construction" in the company name on their application. For example, a search of the waivers granted using the search term "survey" reveals seven surveying companies with active waivers, at least some of which may be related to the construction industry.

Second, the Part 107 waivers granted during the first two years since passage of the Small UAS Rule were only for companies seeking exemptions from the new regulations. Companies that were previously using UAVs and had previously obtained a Section 333 Exemption were able to continue operating their UAVs under their existing Section 333 Exemption until it expired. Now that slightly more

Table 1 Part 107 waivers active as of dates indicated

Section number	Regulation waived	Number of active waivers one year after implementation	Number of active waivers as of publication	Validity period of waiver (years)
107.25	Flying from a moving vehicle	4	4	4
107.29	Flying at night	1105	2390	4
107.31	Flying beyond pilot's visual line of sight	7	33	4
107.33B	Visual observer	2	22	4
107.33C	Visual observer	3	1	4
107.35	Flying multiple aircraft with only one pilot	19	43	4
107.39	Flying over a person or people	5	26	4 Years
107.41	Flying near airports/in controlled airspace	130	41	2 Years
107.51B	Flying above 400'	8	8	2 Years
107.51C	Minimum flight visibility	8	11	4 Years
107.51D	Minimum distance from clouds	7	10	4 Years

than two years have passed since passage of the Small UAS Rule, all Section 333 Exemptions will have expired and it is possible more companies will need to seek Part 107 waivers. For example, in the first year after the passage of the Small UAS Rule, 1298 were granted. As of the date of this paper there are 2520 active waivers, nearly twice the number that were active during the first year after passage of the Small UAS Rule.

Third, because the approval process takes approximately 90 days, there could be more waivers being considered that have not yet been granted. If a waiver is sought, it is important to note and comply with the restrictions of the waiver. For example, the default Part 107 regulations provide limitations of 100 miles per hour and 400 ft for the maximum groundspeed and altitude, respectively. However, as noted above, when a waiver is sought to fly over people, the default regulations may be modified by the waiver—such as further restricting maximum groundspeed and altitude to five miles per hour and 21 ft, respectively, to ensure the safety of the people below the UAV. As shown in Table 1, above, most waivers granted are valid for a period of four years. Examples include but are not limited to, flying at night, flying beyond the pilot's visual line-of-sight, and flying over a person or people. However, waivers granted for Section 107.41—flying near airports or in controlled airspace, and 107.51(B)—flying above 400 ft—are valid typically valid for a period of two years.

5 Conclusions

Based on the survey results from current UAV users, feedback is positive with regard to the viability and return on investment for construction companies that implement UAVs on their jobsites. Now that the period of uncertainty with regard to the FAA regulations is resolved, it is anticipated that UAV use will increase, as evidenced by the nearly two-fold increase in the number of active waivers. While the predominant use of UAVs in the construction industry at the time is jobsite photographs, as operators become more comfortable with UAV use, and as technology advances to make UAVs viable for expanded uses such as monitoring worker safety, it is possible that UAV use in the construction industry will increase.

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3D Scans—A New Teaching Tool in Construction Education

Pavan Meadati and Amin Akhnoukh

Abstract

Use of technological gadgets became an integral part of Construction Management (CM) students' life. Students have different learning styles and they want their academic learning experience to be engaging and interactive. Engaging these technology savvy students in the learning process with their preferred learning style is a challenging task. The differences in teaching and learning styles result in problems such as disengagement of students and loss of learning aptitude. This active student engagement challenge can be addressed by using 3D scan model learning environment. This learning environment has the potential to make a paradigm shift in teaching and learning process. This learning environment provides a new teaching style and helps the instructor to address some of the needs of the students' learning styles. This learning environment engages students in active learning processes and helps them to focus on their learning. It also encourages students to take more responsibility for their own learning process. This paper discusses about the frame work of the 3D scan model learning environment. This paper also discusses how this frame work was used for development of a 3D scan model learning environment for a residential house construction process.

Keywords

3D scan • Learning styles • Construction management • Framework • Students

1 Introduction

The Use of technology became an integral part of Construction Management (CM) students' life and they want their academic learning experience to be engaging and interactive. However, the traditional lecture format style is the one of the teaching styles which is widely used for teaching CM courses. Since this lecture style teaching provides very limited engagement and interaction, the CM students are unable to gain the required skills to solve the real world problems. The differences in teaching and learning styles also result in problems such as disengagement of students and loss of learning aptitude (Irizarry et al. 2012). Engaging these technology savvy students with their preferred learning style in the learning process is a challenging task (Wasim et al. 2011). This active student engagement challenge can be addressed through 3D scans which facilitate framework for the development of a 3D scan learning environment. Some of the characteristics of this learning environment such as easy access to the information, visualization, and simulation capabilities provide auditory, visual, and kinesthetic learning environments. This learning environment engages students in active learning processes and helps them to focus on their learning. It also encourages students to take more responsibility for their own learning process. This learning environment provides a new teaching style and helps the instructor to address some of the needs of the students' learning styles. Any time and interactive access to the repository through 3D scan model creates learning environment beyond time and space boundaries and facilitates students to learn at their own pace. This environment facilitates knowledge repository which also helps as an effective communication tool to transfer the knowledge. This paper discusses about the frame work of the 3D scan model learning environment. The paper also discusses how this frame work was used for the development of a 3D scan model learning environment for a residential house construction process. The following sections discuss about the

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3D scan learning environment followed by details of the pilot study conducted to engage the technology savvy CM students.

2 3D Scan Model Learning Environment

The two components included in the 3D scan model learning environment framework are shown in Fig. 1. They are (1) 3D scan model and (2) knowledge repository. The integration of these two components creates the 3D scan model learning environment. This learning environment serves as virtual instructor. It provides plethora of information. Depending upon the learning style, student can access the required information. This following section discusses the methodology adopted for the development of a 3D scan model learning environment.

2.1 3D Scan Model

The steps involved in the 3D scan model development are (1) data capture (2) Organization, cleanup, and analysis. Data capture step includes collection of data through 3D laser scan. 3D laser scanning is a process of collecting the spatial coordinates of points of an object by using lasers. The laser scan let you capture the real world in 3D representation (see Fig. 2). It is like a 3D photograph, but the typical representation is a point cloud (Autodesk: Creation Process 2019). These clouds are comprised of millions of colored points in a precise 3D space. The point clouds generated in this process are useful for measurement and visualization applications. The 3D laser scanners are made by Faro, Leica, Z + F, Riegl, Topcon, and Trimble (Autodesk: Creation Process 2019). Organization, cleanup, and analysis step includes processing of the scan data to provide a realistic 3D model which can be used for various applications. A number of methods are available to organize the indexed data to remove or hide portions of the point cloud.

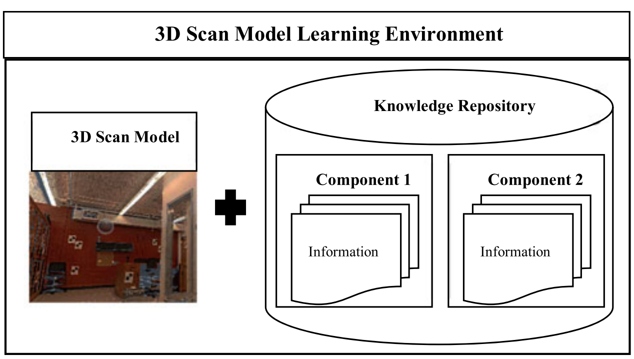


Fig. 1 3D scan model learning environment

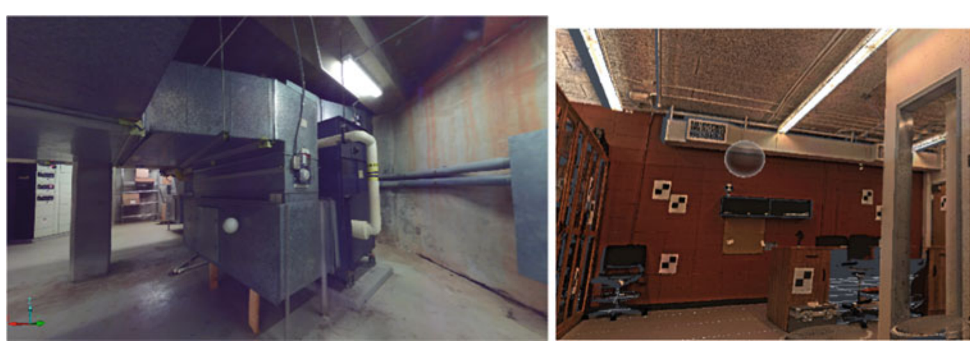
2.2 Knowledge Repository

This step includes the development of knowledge repository. This includes collection of the information and hosting it in the digital format on a web server. Information used to develop the knowledge repository can be classified as semi structured data files (HTML and XML files), unstructured data files (MS Word or plain text files), and unstructured multimedia files (photographs, audio, and video files) (Caldas and Soibelman 2005). To facilitate interaction with the repository through the 3D scan model, the information is to be integrated with the 3D scan model. This can be accomplished by hyperlinking the information with the 3D scan model through url.

3 Pilot Study

A pilot study has been conducted to demonstrate the feasibility of 3D scan model learning environment to address the challenge of actively engaging technology savvy CM students. The study includes three steps: (a) Students learning styles assessment (b) 3D scan learning environment development, and (c) Usability study. Overview of these steps are discussed below.

Fig. 2 3D scan samples



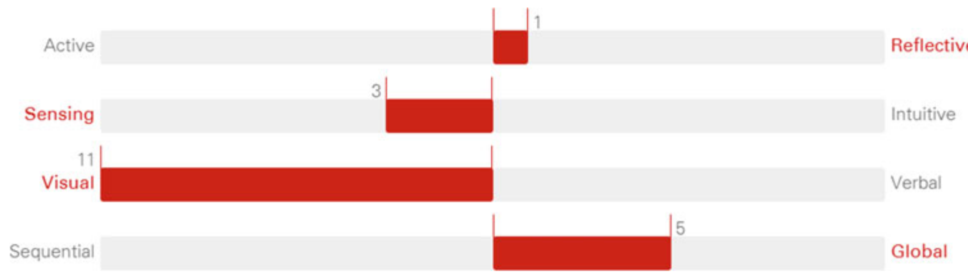


Fig. 3 Screen shot of the learning styles survey results

3.1 3D Students Learning Styles Assessment

The objective of this step is to assess the learning styles of the students. The assessment helps to assess the applicability of the 3D scan model learning environment to address visualization, engagement, and interaction challenges faced by CM students. Index of learning styles questionnaire proposed by Soloman and Felder of North Carolina State university (Felder and Soloman 2018), was used to assess the learning styles. It is an online instrument questionnaire and has 44 questions. Once the survey is submitted, the learning styles of the student are presented on a scale score ranging from 1 to 11 in increments of 2 for each learning style. Depending on the score, the students preference to particular learning can be classified as "fairly well balanced" (score on scale 1–3), "moderate" (score on scale 5–7), and "very strong" (score on scale 9–11) (Felder and Soloman 2018). Fairly well balanced indicate that the student is flexible in adopting either learning style. Moderate indicates student's moderate preference to particular learning style. Very strong indicates student's strong preference to particular style (Felder and Soloman 2018). A screen shot of the submitted survey results is shown in Fig. 3. For this study, visual and verbal category was only considered. Each student of the course was asked to complete the survey. The results of the survey were then analyzed to assess the different learning styles of the students in the course. The survey results indicated that all students are visual learners. As shown in Fig. 4, based on the scores 0, 17, and 83% were considered as fairly well balanced, moderate, and very strong visual learners, respectively. The following sections discuss how 3D scan model learning environment was used for engaging students and their usability experience of 3D scan model learning environment.

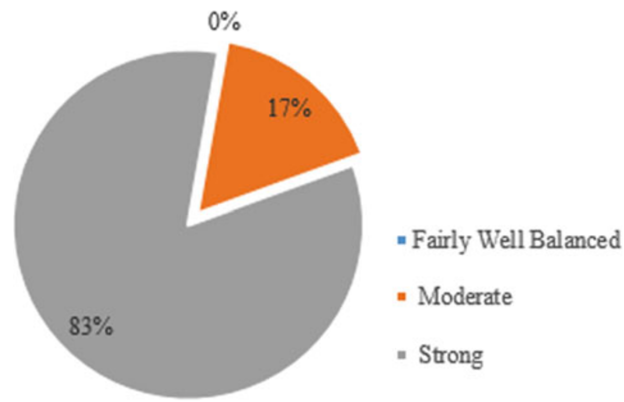


Fig. 4 Visual learners and their preferences

3.2 3D Scan Model Learning Environment Development

In this pilot study, a 3D scan model learning environment for a residential house construction process is developed. The steps involved in the development process include 3D scan model development and integration of information to the 3D scan model components. The point cloud data was captured using FARO focus 3D and Leica Scan Station P30 (see Fig. 5), laser scanners. FARO Focus 3D laser scanner is small and lightweight scanner. It is a high accuracy, high resolution scanner. It scans at the rate of 976,000 points per second. It has range resolution up to 70 megapixel color. It has ranging error of ±2 mm at 10 m and 25 m. It has 305° and 360° field of view in vertical and horizontal directions, respectively (FARO Laser Scanner Focus 3D user's manual 2019). Leica ScanStation P30 is designed to deliver highest quality 3D data and HDR imaging at an extremely fast scan rate of one million points per second at ranges of up to 270 m. It has range accuracy of 1.2 mm + 10 ppm over full range. It has 290° and 360° field of view in vertical and horizontal directions, respectively (Leica Geosystems 2017).

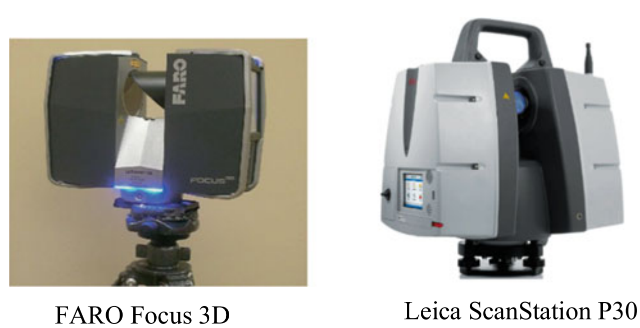


Fig. 5 3D laser scanners

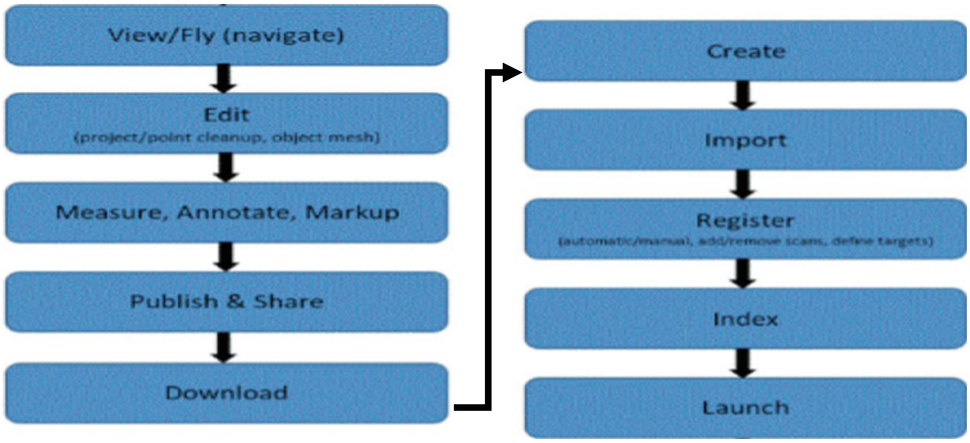


Fig. 6 Processing scan data work flow

Autodesk ReCap Pro software is used for organization, cleanup, and analysis of the point cloud data (ReCap Notes 10 2019). The steps involved in the work flow are given in Fig. 6.

Any measurements, regions, markups, and selections created within ReCap, along with any general points within the project, can have notes assigned directly to them, allowing for a richer form of communication. Title and description text, along with image attachments, can be added to annotations at any point by selecting the "Note" tool either on the in-canvas object or through its Project Explorer representation (ReCap Notes 2019) (see Fig. 7). A 3D scan model learning environment of residential house construction process developed by using the above framework is shown in the Fig. 8.

3.3 Usability Study

CM Students were asked to use 3D scan model learning environment to learn about the residential house construction process. After usage, the students were asked to express their satisfaction on usefulness, ease of use and ease of learning of 3D scan model learning environment with 5-point Likert-type scale (1 = Strongly Agree, 2 = Agree, 3 = neutral, 4 = Disagree, and 5 = Strongly Disagree). The analyses of the results are shown in Fig. 9. Most of the students were satisfied with the usefulness of 3D scan model learning environment and expressed their agreement with the statement "Overall, I am satisfied with usefulness of the 3D scan

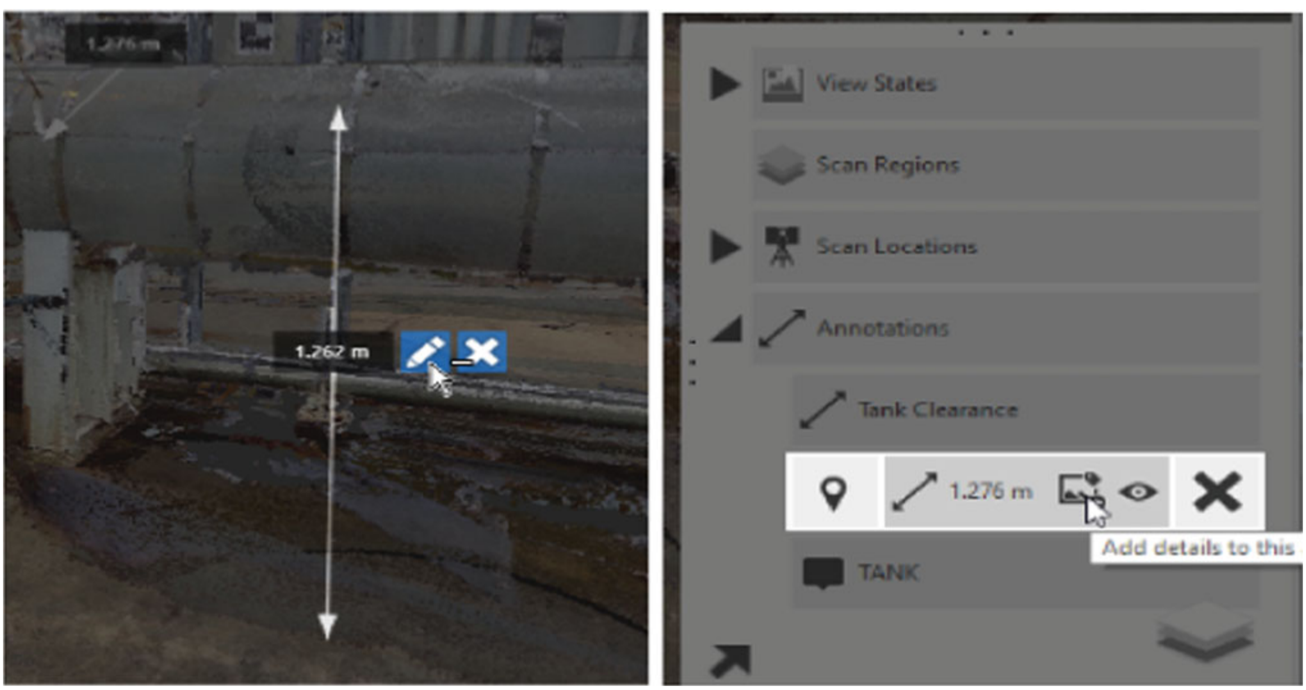


Fig. 7 Note tool options in ReCap

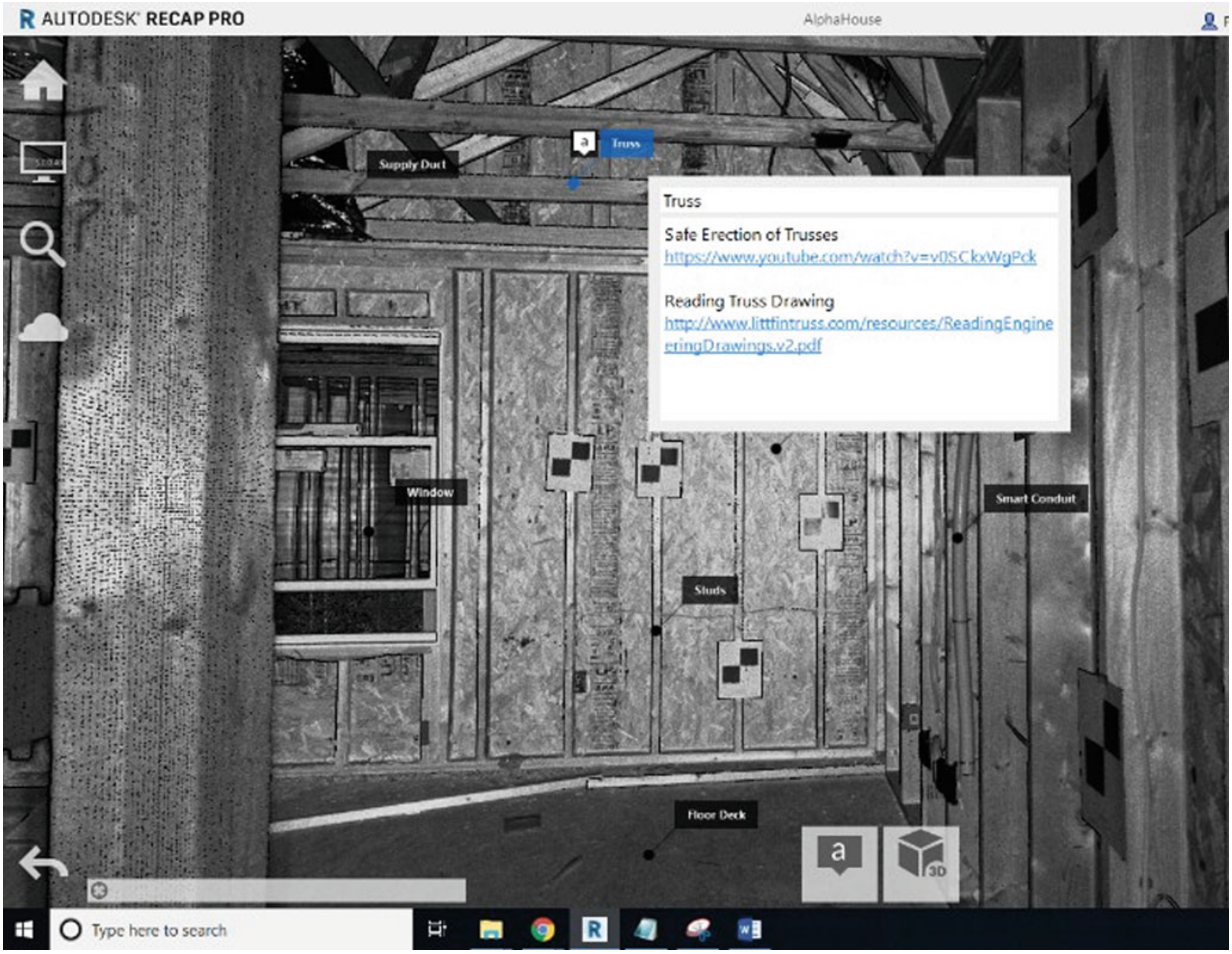


Fig. 8 3D residential house construction process scan model learning environment

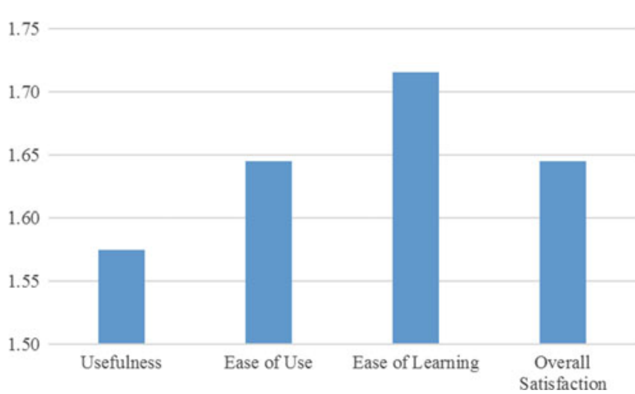


Fig. 9 3D scan model learning environment usability results

model learning environment" (65% strongly agreed and 22% agreed). Most of the students were satisfied with the ease of the use of the 3D scan model learning environment and expressed their agreement with the statement "Overall, I am satisfied with the ease of use of the 3D scan model learning environment" (51% strongly agreed and 43% agreed). Most of the students were satisfied with ease of learning through 3D scan model learning environment and expressed their agreement with the statement "Overall, I am satisfied with ease of learning through 3D scan model learning environment" (51% strongly agreed and 43% agreed). Most of the students enjoyed learning through 3D scan model learning environment and expressed their agreement with the statement "Overall, I am satisfied with 3D scan model learning environment" (51% strongly agreed and 43% agreed).

4 Conclusion

3D scan model learning environment serves as a new teaching tool and helps the instructors to be more effective in communicating the information to the students. This learning environment provide 3D visualization and helps students to be actively engaged in the learning process. 3D laser scanner is required for developing this learning environment. However, these scanners are not used widely because of this high cost and more computing hardware requirements for post processing the data. The continuous evolution of technology and computing hardware will make these scanners affordable. The 3D scan model learning environment has the potential to make a paradigm shift in teaching and learning process. The pilot study discussed in this paper serves as an initial step to extend the 3D scan model learning environment to various CM courses.

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Impediments of the Fourth Industrial Revolution in the South African Construction Industry

Douglas Aghimien, Clinton Aigbavboa, and Kefilwe Matabane

Abstract

The fourth industrial revolution (4IR) is upon us with evidence of its usage in the manufacturing industry of most developed and some developing countries around the world. Evidence of the concept of 4IR is equally evolving within the construction industry of developed countries and immense benefits are promised. However, the story is not the same for most developing countries as their construction industries face diverse challenges that impede the adoption of new concepts. Based on this notion, this study assessed the impediments of 4IR within the South African construction industry (SACI) with a view to positioning the industry in the 4IR. The study revealed the key impediments of the adoption of the 4IR concepts within the SACI. In the end, conclusions were drawn and possible directions that will help the construction industry in delivering better services to its clients using 4IR concepts were proposed.

Keywords

Construction 4.0 • Digital technologies • Digitalisation • Fourth industrial revolution • Industry 4.0

1 Introduction

Technological advancements are advancing at an alarming rate, thus constantly altering the way in which the society lives and functions. One such advancement is the fourth industrial revolution (4IR). Although several features of the 4IR have been adopted by different industries, its complete adoption has been met with resistance due to the level of uncertainty it breeds in relation to the type of changes that the phenomenon will provide. Particularly, the construction industry is known to be reluctant in the adoption of various technological innovations, while other industries such as banking, manufacturing and retailing have been open to adopt advanced technologies to boost their competitive advantage (Castagnino et al. 2016; Osunsanmi et al. 2018).

The phrase "fourth industrial revolution" inclines that chronologically there have been three other revolutions preceding it (de Andrade Régio et al. 2016). According to Lu (2016), the late eighteenth century marked the beginning of the first industrial revolution, represented by mechanical production plants propelled by water and steam power. It was followed by the second revolution that was initiated in the early years of the twentieth century. Its production was symbolised by mass labour fuelled by electrical energy. Thirdly, the development of computer technology gave rise to the third industrial revolution which massively affected all functions of society. Thus, the 4IR is viewed as a natural extension from the technological advances of the third revolution that have progressively evolved throughout the past years (Ozlu 2017).

Some key features of the 4IR phenomenon which initiated the digital transformation process within most industries are the Internet of Things (IoT) which implies an overall system of networks which are linked to each other, and uniformly addressed objects that are conveyed by means of standard conventions. Furthermore, it is mentioned that IoT can also be seen as Internet of Everything (IoE) which consists of Internet of Service (IoS), Internet of Manufacturing Services (IoMs), Internet of People (IoP), an embedded system and Integration of Information and Communication Technology (IICT) (Vaidya et al. 2018). Building Information Modelling (BIM) which according to Ashcraft (2007), "utilises cutting-edge digital technology to establish a computable representation of all the physical and functional characteristics of a facility and its related

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project/life cycle information, and it is intended to be a repository of information for the facility owner/operator to use and maintain throughout the life cycle of a facility". Augmented reality, which is an innovation with which one can be able to have an amplified view of objects (Celaschi 2017). Big data which is viewed as the most vital technology in relation to the large collection, preparation and investigation of unorganised and organised information with savvy algorithms (Petrillo et al. 2018). Autonomous Robots used in performing autonomous production methods, cloud computing, 3D printing and many more.

Despite the availability of these technologies and the mouth-watering benefits they propose, 4IR implementation as far as the SACI is concerned is still in its early stages. Thus far, only a few concepts of the revolution have been adopted by the industry (Aghimien et al. 2018a). It is based on the above knowledge that this study assessed the impediments of the 4IR within the SACI with a view to positioning the industry in the 4IR. Subsequent parts of this paper include the review of related literature, the methodology adopted for the study, the findings and discussion as well as the conclusion drawn from the findings and the recommendations made thereof.

2 Literature Review

The construction industry plays a crucial role in the economy of South Africa by providing more than one million jobs and generating revenue of approximately R267bn annually (Celaschi 2017). However, it has been observed that construction activities cause an impact on the environment through the process of construction and life cycle of development. These impacts start from the initial work on site, through the actual construction, operational or usage period and to the final demolition or re-use (Ozlu 2017; Petrillo et al. 2018). According to Li and Zhang (2018), the construction industry is responsible for the use of a very high volume of natural resources and the generation of a great amount of pollution. This is as a result of energy consumption during extraction, preparation, transportation and usage of raw materials. The adoption of 4IT concepts offers possible solutions to some of these problems. However, its adoption is faced with several barriers that need to be addressed.

According to Vaduva-Sahhanoglu et al. (2016), the main barriers to the adoption of 4IR technologies include high cost of research and development (R&D) innovation, technology cost updates to the latest state of the art, cost of training employees, incompatibilities with current practices and operations, challenges in finding the technologies needed, and psychological barriers referring the acceptance of the new technologies. Oke et al. (2018) also noted that the lack of training for professionals and skilled labour in using the digital tools at the institutional level, as well as its high cost affects the construction industry in adapting 4IR concepts. Moreover, according to Deloitte (2016), one of the challenges of the 4IR is the right talent required. It was stated that numerous South African manufacturers will face a significant challenge in talent when restructuring their organisation for the digital change in the adoption of the 4IR. Diversity in IT skill sets as improved skills blend and the changeover of skills are required. A huge challenge for South Africa is not only with the shortage of talent in the country, but there is also a shortage worldwide in professionals with the talent for the 4IR. There is a need to train professionals, that will, in turn, train workers within construction organisations to be able to understand and work with the new and smart technological innovations. Furthermore, Oke et al. (Oke et al. 2018), mentioned that the adoption of standards also affects the application of 4IR concepts in the SACI. According to the Deloitte (Deloitte 2016), another challenge of the 4IR is the availability of IT infrastructure needed. It was observed that the costs needed for the implementation of the 4IR are key factors in determining the upgrade of current IT infrastructure system or getting new ones. Also, electricity limitations contribute to being a hindrance for the digital change towards the 4IR. Overall, new investments in infrastructure and new technological innovations are required for more prominent improvement and adoption of 4IR applications. PwC (PricewaterhouseCoopers (Pwc) Industry 4.0 2016) share similar views as it was reported that there is a lack of digital culture with construction organisations. It stated that companies have to ensure that employees understand dynamic changes in the company and participate in these changes. These identified challenges and others were assessed in this study in a bid to determine the key impediments of 4IR in the SACI.

3 Research Methodology

This study assessed the impediments of 4IR within the SACI using a survey approach with quantitative data harnessed from construction professionals in Gauteng province. The choice of conducting the study in the selected study area is based on the premise that Gauteng houses the majority of construction organisations in the country with a high number of construction professionals available within the province. The instrument for data analysis was a questionnaire which was adopted based on its ease of use and ability to cover a large range of respondents within a short period of time (Tan 2011). The questionnaire used was designed in two sections with the first designed to harness information on the background of the respondents. The second section sought answers with regards to the impediments of 4IR within the study area using a 5 point Likert scale. A total of 60 construction professionals participated in the survey. In analysing the data gathered, information on the respondent's background was analysed using percentage. Mean item score was used to rank in descending order, the identified impediments based on their level of significance. Based on the different professional background of the respondents, Kruskal-Wallis h-test was further employed in testing the significant difference in the view of the different professionals. Kruskal-Wallis h-test was adopted based on its suitability in ascertaining the significant difference in the view of three or more group of respondents. The reliability of the questionnaire was also tested using Cronbach's alpha test. Cronbach alpha gives a range of value of between 0 and 1, and the higher the value, the higher the degree of internal consistency. The Cronbach's alpha value of 0.835 was derived which shows a high degree of reliability since the degree of reliability of an instrument is more perfect as the value tends towards 1 (Moser and Kalton 1999)

4 Findings and Discussions

4.1 Background Information

Findings on the background information of the respondents revealed that 55% of the construction professionals involved in the study were male, while 45% were female. Also, 50% of the respondents were Quantity surveyors, 18% were Construction managers, 24% were Engineers and 8% were Architects. In terms of their academic qualification, 42% had a National Diploma, 33% had a Bachelor degree, 20% had an Honours' degree, 3% had a Master's degree and 2% had a Doctorate. Majority of the respondents (55%) have up to 5 years of working experience within the construction industry, while the remaining 45% have above 5 years of working experience. Most of them (52%) work within a contracting firm, while 42% works for consulting firms and 7% were government employees.

4.2 Impediments of 4IR in the South African Construction Industry

The result in Table 1, shows the construction professionals rating of the identified impediments of 4IR within the SACI based on their level of significance. The table also shows the chi-square value and the significant p-value derived from Kruskal-Wallis h-test conducted. A cursory look at the last column on the table shows that all the assessed impediments have a significant *p*-value of above 0.05. This implies that at 95% confidence level, there is no difference in the view of the various construction professionals as regards the significance of the assessed impediments of the adoption of 4IR concepts in the SACI. A look at the table also shows that all the assessed impediments have a mean value of above average of 3.0 aside electricity limitations that gave a mean value of 2.93. This shows that to a significant level, all these 14 identified impediments affect the adoption of 4IR concept within the SACI. Chief of these impediments are lack of training for professionals (mean = 3.90, sig. = 0.291), high costs of training employees (mean = 3.82, sig. = 0.256), high costs of acquiring innovations (mean = 3.72, sig. = 0.443), lack of digital culture within the industry (mean = 3.68, sig. = 0.646), psychological barriers referring the acceptance of the new technologies (mean = 3.58, sig. = 0.222), and companies internal issues such as organisational culture and leadership style (mean = 3.50, sig. = 0.179).

It is no gainsaying that with innovations/new invention comes the need for trained professionals to handle same. Aghimien et al. (2018b) have earlier noted that a major challenge most construction organisations are likely to face with the adoption of new technologies is the issue of technical expertise. Embracing 4IR concepts and technologies comes with the training of personnel to handle these technologies. Oke et al. (2018) while assessing the challenges facing digital collaboration within the SACI made a similar observation. This need for trained personnel is not without its associated cost, which is coupled with the high cost of acquiring or adopting the technologies/features. Considering the fact that the SACI is saturated with small and medium enterprises that struggle with financial issues (Aghimien et al. 2018b), this associated cost of adopting 4IR concepts might prove to be a significant impediment to the adoption of these concepts and technologies. Dimick (2014), El-Mashaleh (2007) and Oladapo (2007) all made a similar observation regarding the huge influence of cost issue on the adoption of technologies and innovations in Canada, Jordan and Nigeria, respectively. Vaduva-Sahhanoglu et al. (2016) also submitted that high cost of R&D innovation, cost of acquiring technologies, the cost for training employees in using these technologies, as well as costs associated with modifying of the construction operations are key barriers to the adoption of 4IR concepts in most countries around the world.

Issues surrounding the construction industry's fear of adopting new ideas have been noted in the past (Aghimien et al. 2018b; Kissi et al. 2018). Due to the nature of construction industries in most developing countries regarding the poor adoption of technology, embracing 4IR concept might be a problem for most construction participants. This can be because of the fear of changing from the norm or even the fear of the unknown outcome these concepts and features might bring. Aghimien et al. (2018b) noted that there is some level of distrust in new technologies among

Table 1 Impediments of 4IR in SACI

Kruskal-Wallis				
Impediments	Mean	Rank	Chi-Sq.	Sig.
Lack of training for professionals	3.90	1	4.960	0.291
High costs of training employees	3.82	2	5.321	0.256
High costs of acquiring innovations	3.72	3	3.733	0.443
Lack of digital culture within the industry	3.68	4	2.491	0.646
Psychological barriers referring to the acceptance of the new technologies	3.58	5	5.704	0.222
Companies internal issues	3.50	6	6.281	0.179
Interoperability of systems	3.47	7	4.653	0.325
Incompatibilities with current practices and operations	3.45	8	6.588	0.159
Requires restructuring with organisations	3.42	9	4.017	0.404
Lack of standard in delivering the industry's products	3.40	10	2.371	0.668
Challenges in finding the technologies needed	3.33	11	1.873	0.759
Security issues	3.28	12	3.629	0.459
Lack of commitment from clients	3.17	13	5.895	0.207
Legal concerns	3.07	14	7.536	0.110
Electricity limitations	2.93	15	6.108	0.191

organisations. Change is challenging for humans, and in most cases, organisations tend to fall victim to this challenge. This resistance cuts across every level of these organisations, from workers to executive decision-makers. Thus, this tends to affect the culture within the organisation as regards the adoption of technologies and innovative concepts as noted in this study.

5 Conclusion and Recommendation

This study assessed the impediments of 4IR within the SACI with quantitative data gathered from construction professionals in Gauteng province. Based on the analyses of the data gathered, the study concludes that there is no significant difference in the view of construction professionals within the study area regarding the impediments of 4IR adoption within the construction industry. The major impediments observed are lack of training for professionals, high costs of training employees, high costs of acquiring innovations, lack of digital culture within the industry, psychological barriers referring the acceptance of the new technologies and companies' internal issues such as organisational culture and leadership style. Therefore, if the SACI is to enjoy the inherent benefits of the 4IR, then construction organisations must be ready to invest in technologies and innovations by acquiring these new technologies, as well as training their workers in the use of it. Also, the teaching of some of these technologies can be inculcated into curriculums of institutes of higher learning so as to equip construction graduates right from the institution level. Similarly, construction participants must be ready to jettison the old ways of providing construction services for a more innovative approach with 4IR concepts.

Although this study contributes to the body of knowledge by bringing to light some impediments of 4IR within the SACI, care must be taken in generalising the result of the study due to some identified limitations. The study was limited to a single province within the country, thus, there is a need for further studies within other provinces in the country, in order to compare results. There is also the need for further studies conducted with a much larger sample size than what is obtained in this current study.

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Environmental Sustainability: Impact of Construction Activities

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Abstract

As a result of pollution, deforestation and other environmental challenges, construction process and activities has contributed in no small measure to environmental degradation. One of the fundamental tripod of sustainability is keeping the environment safe for the inhabitants. This study, therefore, examines the impact of construction activities on the environment with a view to highlighting mitigation approaches and their enforcement strategies. A quantitative research methodology was adopted, and convenient sampling technique was employed to gather information from primary sources. Questionnaires were administered on construction professionals which include architects, quantity surveyors, engineers, safety officers, as well as construction and facility managers. Construction activities impact badly on the environment due to waste generation, resource consumption, noise pollution, air pollution due to dust from construction activities, as well as bad odours from large diesel-powered vehicles/construction machinery. Although, some of these impacts cannot be completely eradicated, there are a number of approaches that could be used to mitigate them, these include Environmental Impact Assessment (EIA), green building (sustainable construction), Quantitative Risk Assessment (QRA), Environmental Management System (EMS), and Environmental Protection Agency (EPA). Therefore, an effort should be made by government and construction stakeholders to efficiently incorporate and enforce the available approaches/initiatives through constant monitoring of construction process from start to completion and legislative laws that spell out punishment as response to violations. Awareness, learning, and trainings of construction stakeholders on the impacts of building construction activities on the environment is also recommended.

Keywords

Construction activities • Construction industry • Environment • Green building • Sustainable construction

1 Introduction

Construction activities involve the consumption of various forms of resources including raw and finished materials that are derived from various sector of the environment. The impact of these activities on the environment cannot be over-emphasised. In this regard, ways of controlling, managing, and reducing these environmental impacts have been developed and implemented from time to time. Construction project performance and success has traditionally been measured in terms of duration, cost, and quality. According to Gangolells et al. (2011), the environment has become the fourth variable. Fuertes et al. (2013) stated that while economic development of a country can lead to an improvement in the quality of life of her citizens, the resulting environmental damages may affect human health and ultimately undermine the economic development and growth. Therefore, it is imperative for the construction industry to always take into account the environmental impacts of construction activities as an important factor of project success. According to Tam et al. (2004), the construction industry plays an important role in meeting the needs of any society, as well as enhancing the quality of life of people. However, the responsibility for ensuring that activities of the industry and its products are consistent with environmental guidelines, standards, and policies is an aspect that still needs to be defined.

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One of the approaches that is widely used to reduce environmental impacts is the Environmental Impact Assessment (EIA). EIA is defined as a process that assesses and evaluate possible impacts of activities before the commencement of a project or development with a view to plan and mitigate the possible impacts (Murombo 2008). This help managers and concerned stakeholders to make decisions on whether the project or development should proceed, and the required condition for the project to proceed. Over the years, a number of other approaches have been adopted in various sectors of the economy including the construction industry (Fuertes et al. 2013; Ametepey and Ansah 2015; Dong and Ng 2015), these include; Environmental Protection Agency (EPA), Environmental Management Systems (EMS), and Life Cycle Assessment (LCA). All the approaches have different purpose, function, and procedure to implement them. However, one thing they all have in common is that they are all important tools for the conservation of the environment.

The Government plays an important role in this regard, in terms of commitment towards the different approaches through appropriate legislation. According to Murombo (2008), the South African government has put into practice environmental legislation for sustainable use of resources and conservation of natural resources, which addresses social, economic, and ecological issues. The implementation of laws and policies provided in this regard is of great importance, as it helps with the enforcement of the approaches. Wasserman (2011) stated that the full implementation of these approaches does not entirely lie with the Government, public participation is also necessary for the proper actualisation. In this study, the common environmental impacts of building construction activities were identified and assessed, current approaches to encourage the minimisation of the impacts were evaluated and different means to enforce the initiatives were also discussed.

2 Literature Review

2.1 Construction Activities

The construction industry plays a crucial role in the economy of South Africa by providing more than one million jobs and generating revenue of approximately R267bn annually (Gauteng Growth Development Agency 2015). However, it has been observed that construction activities impact on the environment through the process of construction and life cycle of development. These impacts start from the initial work on site, through the actual construction, operational or usage period and to the final demolition or re-use (Ametepey and Ansah 2015; Oke et al. 2018). According to Li et al. (2010), the construction industry is responsible for the use of high volume of natural resources and the generation of great amount of pollution. This is as a result of energy consumption during extraction, preparation, transportation, and usage of raw materials.

2.2 The Environment

According to Smull and Bourne (2012), every human being responds to the environment they find themselves in different ways depending on their level of satisfaction by what surrounds them. Certain things must be present in the environment and others must cease to exist for human beings to be satisfied or content in any environment. When an environment is harmful or extremely unpleasant, it is what the environment allows or accommodates that causes people to have complaints about the environment. The typical emotional response to a harmful or unpleasant environment is either anger or depression. By paying special attention to people's behaviour and their reaction to certain conditions, issues that are dissatisfying about that particular environment, and what needs to change can be identified. While there are some things existing within an environment that may prove to be toxic or dangerous, it does not necessarily mean that they will be toxic to everyone concerned, some things are toxic and dangerous to some people but not to others. Consequently, there are some factors that are toxic and injurious to all, and cannot be tolerated. When critical aspects of what is important to the public are absent, this will result in making the environment less healthy and less safe for the people.

2.3 Construction Activities and Environment

Most countries are faced with many environmental challenges due to the construction of different types of infrastructure. These include such things as soil alteration and excessive use of resources. Gangolells et al. (2011) stated that one of the critical issues that involve the greatest level of uncertainty is in the identification and assessment of environmental impacts. It is important, to identify and assess these impacts. Dong and Ng (2015) noted that due to the various challenges involved with the building of construction activities, including differences in locality, site, parties involved, as well as the tolerance levels, it is difficult to predict, manage, and address environmental impacts. There are a number of approaches/initiatives that aid sustainable use and protection of the environment. These include EIA, EMS, EPA, LCA, Environmental Management Framework (EMF), and Green Building (Sustainable Construction).

It has been observed that some effective approaches relating to the assessment of environmental impacts have been largely overlooked (Fuertes et al. 2013). In order for the approaches to be efficient and effective, Ametepey and Ansah (2015), concluded that it does not end with just the implementation of the approaches but enforcement has to be taken into account. The enforcement of these approaches contains factors such as monitoring, controlling, maintenance, as well as mitigation. Furthermore, participation in the approaches should not be undertaken as a once-off event, but a sustained and continuous iterative process. An iterative process that begins with the identification of the problem, through project conception/formulation, and final approval of the project (Murombo 2008).

Notable environmental issues include global warming, energy crisis, and ozone depletion. In order to control environmental pollution and sustain the development of infrastructure, sustainable development was proposed by the World Commission on Environment and Development (Fuertes et al. 2013). This was explained as the development that meets the needs of the current generation without compromising the ability of future generations to meet their own needs.

3 Research Methodology

A descriptive survey design was adopted for this study because it provides an adequate representation of the respondents' characteristics in term of behaviour, opinions, abilities, beliefs, and knowledge of a particular situation. This design was undertaken so as to meet the main objective of the study, which is to assess the environmental impacts of building construction activities. The study population include professionals in the South African construction industry. These include Quantity Surveyors, Construction Managers, Architects, Engineers, and Safety Officers who have the required experience and are currently involved in at least one construction projects in Gauteng region of the country.

Questionnaires were adopted as a research instrument for the study and were distributed using convenient sampling method. It was designed such that the respondents can answer the questions with no hassles. Straight forward, clear, and unambiguous language was used and close attention was paid to every question so as to make sure that bias questions would be avoided. A 5-point Likert scale was adopted for environmental impact of construction activities, as well as enforcement of measures to mitigate the challenge. The scale ranges from extreme negative, through neutral value, to extreme positive. Mean Item Score (MIS) and Standard Deviation (SD) were calculated using SPSS 21 and the resulting values were used to rank the variables in descending order. For measures to combat the impact, respondents were asked to select as many factors as relevant and percentile was used to analyse this aspect and rank the factors accordingly.

4 Findings and Discussions

4.1 Background Information

A total of 65 questionnaires were administered but due to non-responsiveness of some of the respondents and time constraints, 54 were retrieved. However, 50 of the completed instruments were adequately completed and certified fit for further analysis. Findings from the analysis of the research instrument indicate that 66% of the respondents are male and 34% are female with an average year of experience of about 7 years. Regarding the respondents profession, 18% are Architects, 32% are Quantity Surveyors, 12% are Engineers, 8% are Construction Managers, 4% are Facilities Managers, and the remaining 4% are site agents.

4.2 Environmental Impacts of Construction Activities

The basic environmental impacts of construction activities as indicated in Table 1, are resource consumption (such as water, electricity, and fuel consumption during the construction process) and waste generation. Others are air pollution due to dust from construction activities, noise pollution, destruction of the ecosystem, and air pollution due to bad odour from large diesel-powered vehicles/ construction machinery. The least impact is related to effects on biodiversity, soil alteration, and generation of volatile organic compounds (VOCs) as a result of vehicle movements and machinery used in construction. The SD values also indicate that there is an agreement among respondents in the assessment of the factors.

4.3 Combating Environmental Impact of Construction Activities

Construction experts were asked about the approaches that are in place to mitigate the environmental impacts of construction activities. Provision was also made for the respondents to write other approaches that were not listed. Using their frequency of selection and percentage calculated in Table 2, Environmental Impact Assessment (EIA) and Green Building (Sustainable Construction strategy) are the two important initiatives. Others are Environmental Management System (EMS), Life Cycle Assessment (LCA), Environmental Management Framework (EMF), and

Table 1 Environmental impacts due to construction activities

Environmental impacts	MIS	SD	Rank
Resource consumption (such as water, electricity and fuel consumption during the construction process)	4.02	0.829	1
Waste generation	3.92	0.709	2
Air pollution due to dust from construction activities	3.72	0.663	3
Noise pollution	3.60	0.551	4
Destruction of the ecosystem	3.46	0.289	5
Air pollution due to odour from large diesel-powered vehicles/construction machinery	3.44	0.755	6
Generation of greenhouse gas emissions as a result of vehicle movements and machinery used in construction	3.41	0.597	7
Vibrations due to heavy construction machinery	3.35	0.330	8
Generation of chlorofluorocarbon (CFC's) as a result of vehicle movements and machinery used in construction	3.26	0.608	9
Effects on biodiversity	3.10	0.618	10
Soil alteration	3.08	0.472	11
Generation of volatile organic compounds (VOC's) as a result of vehicle movements and machinery used in construction	2.96	0.995	12

Strategic Environmental Assessment. No other approach was specified by any of the respondents indicating that the selected list of initiatives is expansive.

Furthermore, steps to be taken to enforce the approaches/initiatives for the minimisation of environmental impacts of construction activities are indicated in Table 3. These include constant monitoring of construction process from start to completion, enforceability, and audit ability of the strategy, linking mitigation commitments to monitoring and legislative laws that spell out punishment as a response to violations. Others are transparency and accountability in contract administration, checking company profiles, and confirming qualifications, a delegation of tasks and continuous professional development. On the lower end are giving the public and government access to commitment documents and making follow up actions.

5 Discussion

In support of Zolfagharian et al. (2012), some impacts of construction activities on the environment are so minor that they may be considered as acceptable, whereas some are highly significant that they cannot be ignored. However, there are certain environmental impacts of construction activities that are significant, such as air pollution, noise pollution, resource consumption, destruction of the ecosystem, and waste generation. This is in agreement with Gangolells et al. (2011) and Ametepey and Ansah (2015). Previous studies from Ruckelshaus (1992), Rendell and McGinty (2004), Fischer (2009), Jay et al. (2007) and Murombo (2008) revealed that there are a number of approaches/initiatives that are available in combating

Table 2 Approaches to combat environmental impacts

Approaches/Initiatives	Percentage	Rank
Environmental Impact Assessment (EIA)	21.4	1
Green Building (Sustainable Construction)	20.9	2
Quantitative Risk Assessment (QRA)	12.3	3
Environmental Management System (EMS)	11.2	4
Environmental Protection Agency (EPA)	10.7	5
Life Cycle Assessment (LCA)	9.6	6
Environmental Management Framework (EMF)	7.5	7
Strategic Environmental Assessment (SEA)	6.4	8

Table 3 Enforcement strategies for environmental control measures

Mitigation method	MIS	SD	Rank
Constantly monitoring the construction process from start to completion	4.46	1.150	1
Enforceability and audit ability of the strategy	4.22	1.137	2
Linking mitigation commitments to monitoring	4.18	1.008	3
Legislative laws that spell out punishment as a response to violations	4.15	0.829	4
Strict disciplinary measures from professional bodies	4.12	0.957	5
Organisations to have programmes of awareness	3.98	0.656	6
Transparency and accountability in contract administration	3.94	1.026	7
Continuous professional development	3.84	1.025	8
Delegation of tasks	3.71	0.638	9
Appointment of highly experienced construction professionals	3.70	0.812	10
Devising contingency plans	3.70	1.139	11
Checking company profiles and confirming qualifications	3.44	0.718	12
Giving the public and government access to commitment documents	1.08	0.453	13
Making follow up actions	0.46	0.968	14

environmental impacts, both nationally and internationally. Some of these are regulations that should be adhered to so as to protect the environment. In agreement with these authors, the findings from this study indicate that EIA and Sustainable Construction are the most widely used approaches to combat environmental impacts.

6 Conclusion and Recommendation

Construction activities impact badly on the environment. Although some of these impacts cannot be completely extinguished, there are a number of approaches/initiatives that have been put in place in order to minimise and control these adverse environmental impacts. However, enforcing these approaches has been a major challenge. The impacts of construction activities include waste generation, resource consumption, noise pollution, air pollution destruction of the ecosystem, and generation of greenhouse gas emissions as a result of vehicle movements and machinery used in construction.

The approaches/initiatives currently used to mitigate these impacts are Environmental Impact Assessment (EIA) and Sustainable Construction. However, to ensure the enforcement of the mitigating approaches, construction process need to be monitored from start to completion, legislative laws that spell out punishment as response to violations must be put in place, strict disciplinary measures of members by various professional bodies, there should be transparency and accountability in contract administration, and continuous professional development should be encouraged. An effort should be made to efficiently incorporate the above-mentioned approaches/initiatives into construction projects right from the inception stage. Careful consideration should also be taken to ensure that these approaches are used efficiently and according to standard.

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Assessment of Embodied Carbon Footprint of an Educational Building in Pakistan Using Building Information Modeling (BIM)

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Abstract

The current study presents one of the few embodied carbon footprint assessments for an educational building in Pakistan. A four-story building with an area of 35,353 Sq. ft has been modeled in a 3D environment using Building Information Modeling (BIM). Life-Cycle Assessment (LCA) methodology with "cradle to gate" boundary limitation has been adopted. A total of 922,000 Kg–CO_{2E} have been calculated with a contribution of 26.09 Kg–CO_{2E}/Sq. ft. Among the materials brick, steel, concrete, brick mortar and ceramic tile were the top contributors in the environment. Load with a collective contribution of 92.86% from these five materials. The study suggested that a proper adoption of green materials at the design stage would help to lower down these environmental concerns to promote sustainable developments.

Keywords

Greenhouse Gases(GHGs) • Building Information Modeling (BIM) • Life-Cycle Assessment (LCA)

1 Introduction

Infrastructure of basic necessities is key element for human survival. To ensure the basic infrastructure, construction industry plays a prominent role. The efficiency and progress of this industry can be related with many other industries and their working. Construction industry revolutionizes the world providing vast opportunities in development of everyday needs. There is a general consensus that construction industry improves the Gross Domestic Product (GDP) and improves the living standards. However, improper functioning of construction industry would effectively contribute in impediments for growth as well in personal lives of a nation (Manu et al. 2018). Construction industry consumes about 60% of the raw material which enters into the global economy and produces 65% of atmospheric carbon dioxide during transformation of raw material to construction material (Asif et al. 2007) (Fig. 1).

Pakistan is a developing country and the construction is required for rapid development of the nation, environmental parameters must be kept in mind to keep the standards of healthy living. Construction process mainly depend on natural resources, which are depleting day by day and also a major cause of global warming (Yadav 2018). According to research, the global temperature is changing and the Earth is getting hotter as a result of activities undertaken by humans. Ozone layer is depleting and that is because of the increase in human activities (Gardezi et al. 2014). The construction industry plays a huge part in these activities. The global quest for development and increase in population growth has accelerated the construction activity. Greenhouse Gases (GHGs) are those gases, which trap heat in the atmosphere. The use of these natural reserves and fuels releases Greenhouse Gases (GHGs). Carbon dioxide is a naturally occurring gas, which is major component of such gases. A fair amount of carbon footprint, known as embodied carbon, is released during extraction for the utilization of material in construction activities (George and Jacob 2018). Embodied Carbon Footprint can be ascertained as the measure of the total amount of carbon dioxide emissions that is directly and indirectly caused by an activity. Evaluation of carbon footprint is a serious issue in construction business now because of the climate change and its after affects. Not only do they directly impact our current environment, but also indirectly affect the living standards and quality of life for our future generations. Therefore, the main focus in this evaluation is laid on embodied phase of carbon footprint emission (CO_{2E}).

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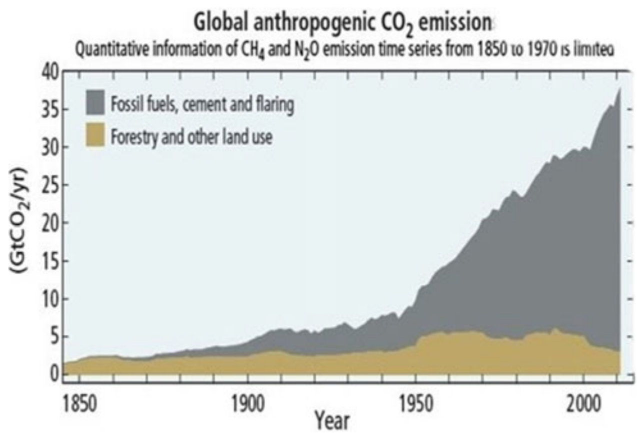

Fig. 1 Global CO_2 emissions over the years by IPCC 2014 (Bambrick 2018; Change 2014)

It largely depends upon the type of material, energy utilized in manufacturing, extraction, transportation, assembling of material and dismantling of material after useful life.

2 Literature Review

Intergovernmental Panel on Climate Change (IPCC) report 2014 reports that 40% utilization of materials globally is by construction industry and impact of over a half global CO_2 emanation was done by building sector, with an increasing at rate of 2.7% per year (2018). Among construction facilities, the buildings make the major chunk. The assessment of embodied carbon from educational buildings have been an interesting field for many researchers. The critical review of literature has highlighted that Building Information Modeling (BIM) is a new method being utilized to achieve such targets, Table 1. Life-cycle assessment with boundary condition "from cradle to gate" is a technique to assess environmental impacts associated with the stages of a product's life cycle.

3 Objective of Study

The main objective of current study is to assess the embodied carbon footprint potential of a conventionally constructed educational building by utilization of Building Information Modeling (BIM) and Life-Cycle Assessment (LCA).

4 Case Study

The building is located in capital city of Pakistan. It is four (04)-story framed structure with an approximate covered area of the building is 6,354 sq. ft for each floor. The external walls of the building are cladded with face bricks, whereas internally the floors are covered with porcelain tiles, it is sheathing with porcelain tiles till sill level, mostly wooden doors are used with some door with glass embedding. Figure 2 shows the conventional educational building selected as case study.

5 Methodology

The methodology adopted for current study is graphically represented in Fig. 3. LCA with boundary limitation of "cradle to gate" has been adopted in the study. Building Information Modelling (BIM) is utilized to foresee 3D development in a virtual environment. Data pertinent as to the materials for this case are extracted from these 3D systematic models using Microsoft Excel to achieve life-cycle inventory.

The Inventory Carbon and Energy (ICE) developed by Hammond and Jones 2008 was adhered to assess the embodied carbon footprint. The Architectural and structural model is shown in Fig. 4.

Table 1 Previous studies on carbon footprint assessment using BIM and LCA

Author	Country	Findings
Yang et al. (2018)	India (2018)	The building sector is responsible for 30% of total greenhouse gas emissions occurring throughout the world
Syngros et al. (2017)	China (2018)	The operation phase contributes to 69% of the total GHG emission, building material production contributes to 24%
Peng et al. (2016)	Greece (2017)	Concrete causes more emission because of its quantity
Lu et al. (2015)	China (2016)	Emission is more in usage, lesser emissions in demolishing then construction
Shafiq et al. (2015)	Taiwan (2015)	Reveals significant difference in the immediate carbon footprint computation
Biswas (2014)	Malaysia (2015)	Introduced smart integrated low-carbon infrastructure model
Hammond and Jones(2008)	Australia (2014)	Total embodied CO_2 emission is during usage stage

Fig. 2 Educational Building selected as case study

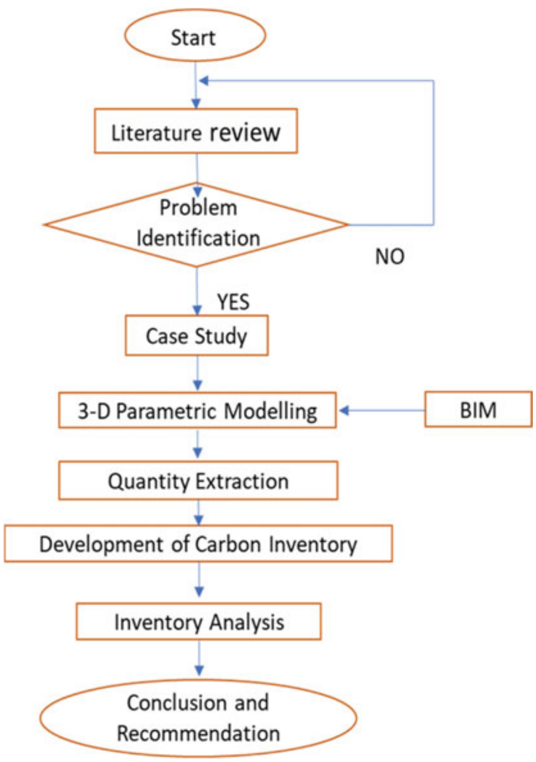

Fig. 3 Methodology for current study

6 Results and Discussion

Based upon 3D modelling, the quantities of materials were extracted to develop life cycle inventory, Table 2. This inventory was compared with the actual Bill of Quantities (B.O.Q). However, minor variations were observed. Table 3 details the carbon footprint contribution from these construction materials:

Based upon the carbon inventory developed by Hammond and Jones (2008), the extracted quantities were multiplied with the carbon equivalent factors to calculate the embodied carbon emission. A total of 922 tons of CO_{2E} has been emitted by the case study building. Figure 4 shows the percentage contribution of material in the research (Fig. 5).

In order to observe the contribution on individual basis, ranking was performed in Table 4. According to the results, brick (37.66%), steel (36.03%), reinforced concrete (14.05%), brick mortar (2.69%) and ceramic tile (2.46%) were the top five contributors in carbon emissions. The overall contributions from these materials was more than 90% of the total.

Fig. 4 Virtual 3D model of case study

Table 2 Quantity of material extracted from Revit (3D model) of case study

S.No.	Description of Materials	Unit	Quantity
1	Aluminum	Kg	1755.96
2	Brick	Cft	26,623.18
3	Brick Mortar	Cft	3,550.33
4	Ceramic Tile	Cft	821.02
5	False Ceiling	Sft	23,558
6	Glass	Cft	96.82
7	Paint	Sft	29,213
8	Paint	Sft	27,654.36
9	Plain Cement Concrete (1:4:8)	Cft	4,353.77
10	Plaster	Cft	2,002.54
11	RCC Concrete (1:2:4)	Cft	24,305.42
12	Stain less Steel	Kg	388.33
13	Steel	Kg	120,000
14	Wood (Play wood)	Cft	46.08

Table 3 Carbon Footprint emission—KgCO2E

S. No	Description of Items	$KgCO_{2E}$	$(KgC0_{2E})$
1	Plain Cement Concrete (1:4:8)	0.1	21698.13
2	RCC Concrete (1:2:4)	0.107	129611.60
3	Stain less Steel	3.27	1269.86
4	Wood (Play wood)	0.55	502.360
5	Ceramic Tile	0.7	22768.90
6	Steel	2.77	332400
7	Paint	0.87	2361.16
8	Aluminum	9.16	16084.59
9	Glass	0.91	6237.21
10	Brick	0.24	347389.40
11	Paint	0.87	2235.18
12	Brick Mortar	0.13	24831.90
13	Plaster	0.13	14006.26
14	False Ceiling	0.47	1028.65

Table 4 Material ranking which contributes more in carbon emissions

S.No.	Description of Items	Carbon Content ($Kg\text{-}C0_{2E}$)	Ranking
1	Brick	37.66	Rank-1
2	Steel	36.03	Rank-2
3	RCC Concrete (1:2:4)	14.05	Rank-4
4	Brick Mortar	2.69	Rank-3
5	Ceramic Tile	2.46	Rank-5

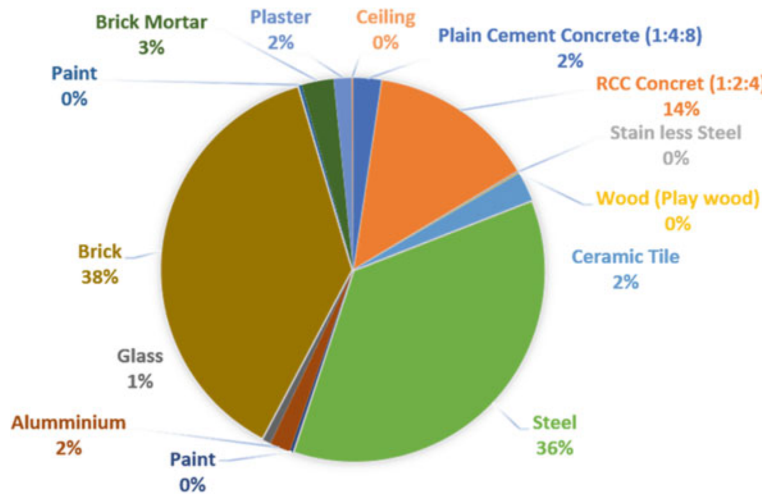

Fig. 5 Percentage contribution of respective construction materials

7 Conclusion

Embodied carbon footprint assessment of a conventional educational building has been performed. The 3D model was developed in BIM along with LCA methodology. It has been concluded that: Total emissions of almost 922,500 Kg–CO_{2E} was observed. Educational building selected as a case study with total area of 35,353 Sq. ft, the per unit area contribution is summed up to be 26.10 Kg–CO_{2E}/Sq. ft. The major contributing materials are brick (37.66%), steel (36.03%), concrete (14.05%), brick mortar (2.69%) and ceramic tile (2.46%). It is learnt that incorporation of Building Information Modeling (BIM) technology for further refinement of materials and their usage, further harm can be reduced and fruitful results for future construction can be obtained.

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A Strategic Approach to Emergency Preparedness in the UAE

Hamdan Rashid Alteneiji, Vian Ahmed, and Sara Saboor

Abstract

Disasters have a significant negative impact across the world, and this widespread impact helps to formulate policies, reviews, measures and approaches in managing them. Global efforts towards emergency management allow organizations to join hands and provide international support to developing countries in the form of assistance from international organizations or institutions such as the United Nations (UN) or the European Union (EU) in planning, responding or recovering from identified risks or disaster. Whereas, developed countries have progressed significantly in the field of EM. Therefore, this paper puts its focus on a developed country, i.e., United Arab Emirates, which has adopted its EM standards from other countries such as the UK, US, and Australia. In order to improve EM standards, the countries apply a framework for the implementation of preparedness phase which depends on eight key elements. However, the literature reveals that though UAE has emergency management standards, it lacks behind in terms of emergency preparedness framework or system. Therefore, the paper aims to investigate the state of emergency management standards in the UAE, to identify if any of the emergency preparedness elements are being practiced in any capacity, identify barriers to the preparedness phases and provide recommendations for the government to adopt the strategic approach for improving emergency preparedness in the UAE.

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Keywords

Emergency management (EM) • Emergency preparedness (EP) • Management standards • Preparedness barriers • United arab emirates (UAE)

1 Introduction

History is filled with a large number of tragedies that occur over a period (Haddow et al. 2011). Since the Second World War, the world has reacted, and governments have created acts to reduce and prevent disasters (O'Brien and Read 2005). To address the challenges and the harmful effect that such emergencies and disaster brought with them; organizations have joined hands under global efforts towards emergency management. The global effort regarding emergency and disaster management guides international support provided by one country to another during disaster situations; particularly in the case of developing countries. While it is the legislative duty of government to protect, guide and ensure the safety of the public, assets, and development from the impact of disasters, when this fails or is insufficient, international efforts are requested (Coppola 2011) such as the United Nations (UN) or the European Union (EU) in planning, responding or recovering from identified risks or disaster.

On the other hand, developed countries figure significantly in the field of EM, such as Japan, Singapore, Germany, and Sweden to mention a few. Similarly, the focus of this paper will be on a developed country, i.e., United Arab Emirates which has adopted its EM standards from other countries such as the UK, US, and Australia (NCEMA 2013). These countries have experienced hazards, threats, and emergencies/disasters of different scales which have influenced changes in their EM policies, standards, and frameworks and led to an emphasis on the preparedness phase depending upon eight key essential elements.

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However, the literature reveals the gap, that there is no documented emergency preparedness framework or system in the UAE.

Therefore, the rest of this paper will investigate the state of emergency management standards in the UAE, identify barriers to the preparedness phases and provide recommendations for the UAE government to adopt the strategic approach for improving emergency preparedness in the UAE.

2 Emergency Management

Emergency Management (EM) is an area,, which involves several actors and dimensions, thus making it a complex concept, as each actor defines EM in its way. The study, however, has accepted the definition of EM by the Michigan Department of State Police as: "a comprehensive system of policies, practices, and procedures designed to protect people and property from the effects of emergencies or disasters. It includes programs, resources, and capabilities to mitigate against, prepare for, respond to, and recover from effects of all hazards" (Michigan Department of State Police 1998).

This definition is adopted because it provides a comprehensive, clear and practical understanding of what EM is from a holistic perspective of practice and theory. Furthermore, it gives a general framework for all kind of hazards as well as the four phases of EM. Thus, it can be inferred that these phases of emergency management influence the management of disaster events and emergencies to facilitate the context of emergency management standards across the world including countries such as UK, US, Australia, and UAE, which is the focus of this study.

The rest of this section will, therefore, examine the EM standards, phases and their levels of responsibilities in developed countries to differentiate between the distinct aspects that characterize each country's approach to emergency management in the developed countries in general and the UAE in particular.

2.1 Emergency Management Standards in Developed Countries

The literature shows that some the developed countries such as the US, UK, and Australia are not necessarily consistent in their approaches and standards when dealing with EM.

Hence the levels of their centralization, responsibilities and the associated characteristics also vary. Such comparisons will help position the UAE's approaches and characteristics among these countries. This section will, therefore, attempt to draw on these comparisons.

A. Approach

By examining the various approaches and standards of EM, distinct similarities between the principles of emergency management used in the US, UK, and Australia emerge. All three follow, roughly:

- **The Comprehensive Approach:** includes overlapping and concurrently running phases such as Mitigation/Prevention Preparedness, Response and Recover. As reviewed, UAE emergency management is modeled after this comprehensive approach under the direction and management of the National Crisis and Emergency Management Authority (NCEMA).
- **The All Hazards Approach:** working on the basis that many risks cause similar outcomes requiring similar responses; this approach involves managing a wide range of possible crisis outcomes (FEMA 2007). Although NCEMA was only established less than a decade ago, the authority has been quick to learn that any risks cause significant impact on the public. Due to which it has offices in all the seven emirates to promptly identify new threats, hazards, and crises and suggests a structure that is progressive, which is one of the principles of EM.
- **The Integrated/All Agencies Approach:** includes the involvement of government agencies such as local councils, emergency services such as police, fire, ambulance, as well as NGOs such as local community groups and volunteer organizations (FEMA 2007). This is also evident from the operational procedures used by NCEMA and all emergency agencies in the UAE.

Reference to the preparedness phase in the US, UK, and Australia EM standards have helped this study to identify the possible gaps in the UAE system. However, there is no reference to the preparedness phase in the UAE being enhanced, improved, or changed based on the response to previous challenges or disasters.

B. Phases

Emergency management is often defined in terms of "phases", a concept used to help describe and comprehend disasters, and to help organize the practice of emergency management. The US process of emergency management involves four phases: prevention (or mitigation), preparedness, response, and recovery or rehabilitation (FEMA 2007; Green 2002; Waugh 2000). Similarly, Australia works on the US system and follows the "4 phases", although the UK, seeking to embrace a holistic approach, views the wider context of Integrated Emergency Management (IEM): the UK Cabinet Office specifies six stages in its emergency management concept: anticipation, assessment, prevention, preparation, response, and recovery (Godschalk 1991). Therefore, the phases of EM are a global concept used by many developed countries and which the UAE has been quick to adopt for usage. These phases and the relationship between them are well understood in the UAE and is coordinated by NCEMA in partnership with other emergency agencies such as police, civil defence, etc. However, it seems the problems are not with the four phases of EM, but the composition and application of each phase and how the activities of each phase link to the next, the link between the preparedness and response phases, which are very important for reducing the impacts of any emergency or disaster. The evaluation of the US, UK, and Australian EM standard and phases show that the UAE struggles to link the preparedness phase with the response phase by enhancing and applying the preparedness elements.

C. Levels of Responsibility

Literature reveals that levels of responsibility relating to emergency management in all three countries follow the lines of their national system of government, in the UK at the national, regional, and local level, and in the US at national, state, and local level. Australia deviates slightly from this (Cabinet Office 2014). Unlike the ever-present federal government approach in the US, the Australian approach to emergency management could be described as "bottom-up" (Commonwealth of Australia 2009). This approach puts leadership in the hands of the person on the ground. Perhaps this approach is what the UAE was also trying to incorporate into its standards when the NCEMA signed an MOU with Australia in June 2013. Since Australia is the only country with which the UAE has an MOU, it seems that the NCEMA wants the opportunity to learn from the EM concepts used in Australia to improve the UAE emergency management standard. However, in order to make the learning process effective, it is important to understand areas which require improvement, which is what makes this research important.

In conclusion, there are distinct aspects which characterize each country's approach to emergency management, as seen the Table 1.

As reviewed from the literature, the standards and frameworks used by the US, UK, and Australian preparedness is at all levels based on capabilities and risks that have been identified and assessed. The US, UK, and Australia have certainly experienced hazards, threats, and emergencies/disasters of different scales which have influenced changes in their EM policies, standards, and frameworks and led to emphasis on the preparedness phase. However, the literature reveals that there is no preparedness framework in the UAE emergency management standard.

Therefore, the next section will summarize the findings of frameworks/models of emergency preparedness as used in the US, UK, Australia and will try to investigate the state of preparedness in UAE.

2.2 Emergency Preparedness Models/Frameworks

Emergency Preparedness can be defined as the arrangement to ensure that all resources and services required for coping with any imminent emergency or actual emergency are identified, determined, mobilized, and deployed (Arklay 2012; Emergency Management Australia. 2004). In order to understand the application concept of emergency preparedness, preparedness models and frameworks used in the US, UK, and Australia were examined. These models/frameworks aid in identifying eight key elements, which influence the preparedness phase. The authors such as (Fagel 2011; Alexander 2002; Alexander 2006; Alexander 2009) and (Canton 2007) have repeatedly emphasized the significance of these elements which are: risk assessment, early warning system, information system, planning, training, exercise, organize and equip, and public education.

Since review and evaluation of emergency management standards in the previous section helped to identify that no emergency preparedness framework or model that exists in the UAE, it important to be able to identify if any of the emergency preparedness elements are being practiced in any capacity in the UAE. Therefore, the next section will focus on the methodological steps applied in order to achieve the aim of the study.

3 Methodological Steps

This section will help to address the aim of the study to investigate the state of emergency managements standards in the UAE, to confirm the findings of key elements of preparedness stage, and to explore barriers and deficiencies faced by emergency preparedness in UAE. A pure qualitative method of data collection was suitable; according to the objectives which can be achieved via the following methodological steps.

- **Literature Review**: It aids in understanding the emergency managements standards in the UAE and identified the eight key elements of preparedness stage.
- **Pilot study**: Apilot study using input from international experts in the field of emergency management; which further confirm and examine key elements affecting emergency preparedness identified from the literature review.

Table 1 Emergency management approach

Country	Approach	Cycle	Levels of responsibility	Main characteristics
US	All hazards, Comprehensive and Integrated Integrated	Four phases	Three levels: government, state, and local	Closely linked to prevention of terrorism
UK	Emergency Management (IEM)	Four phases with two guidelines	Three levels: government, area, and local	–Decentralized –Bottom-up
Australia	Comprehensive and Integrated	Four phases	Two levels: commonwealth (state) and local	–Decentralized –Volunteerism
UAE	All hazards, Comprehensive &Integrated	Four phases	Two levels: Federal and local	–Decentralized

- **Interviews at federal level (NCEMA)**: The primary data collection involves semi-structured interviews at federal level (NCEMA) to gain a deep understanding of the current situation of emergency preparedness in the UAE and barriers that effect its implementation: The findings suggested that the elements exist in the UAE's emergency management standard as an idea and not under a preparedness framework. Barriers faced in the implementation of these eight elements in the UAE's emergency management standard.
- **Interviews at local level (LTCEM)**: In order to confirm the validity of the responses from the federal level, it is triangulated at the local level. The results show that the interviewees from local level agree with the findings from federal level.
- Finally, recommendations addressing the barriers are presented for effective emergency preparedness strategy for the UAE.

The methodological steps have aided in addressing the aim of the study and to draw recommendation to overcome the barriers identified.

4 Recommendations

This section highlights the barriers identified and provides the solution for the barriers and outlines the recommendations for solving those barriers in Table 2. These recommendations are considered as the strategic approach for improving emergency preparedness in the UAE.

The solutions presented are based on principles, best practice and lessons learnt in emergency and disaster management. Solutions are also based on theoretical underpinnings for emergency preparedness as documented in several literature on emergency and disaster management as well as in the literature review of this research.

Table 2 Recommendations

B1: Lack of EM standards understanding	Promote a long term and sustainable strategy to educate all S/H on the fundamental stages of EM standards; Promote innovative ways of engaging S/H in the understanding of EM standards; Encourage innovative research to identify deficiencies in the current standards their effective implementation; Educate and train S/H in the understanding of the whole life cycle of EM standards; Raise employee awareness of the EP risk levels through dedicated training programmes; Promote training to enhance effective leadership and management skills and offer training to enhance employee IT skills and information management systems
B2: Lack of Limited & Focused on Government Employee Training	To promote specialized training for government employees; Support employees to obtain further specialized training in the field of EM; Change of culture and attitudes toward engaging employees in training and development and conduct training needs assessment to determine the level of training and knowledge required by each employee or government department
B3: Speed of submitting tasks i.e. delays and lack of committed staff	Increase the Human Resources to cope with the needs for specialized employees with specific roles; Assign specific staff to specific roles and offer training to enhance stakeholders understand EP requirements and speed up the communication process
B4: Lack of Coordination and transparency between government and S/Hs	Recognize the importance of the S/H role in EP; Seek strategies to build levels of trust with S/H in order to enhance collaboration and transparency; Develop clear policies for S/Hs roles and responsibilities during the EP process and develop strategic training programme to engage the S/H with government activities for EP
B5: Refusal and restriction to change of organizational culture and attitudes	Seek innovative ways of engaging experienced and older leaders in the sectors responsible for emergency preparedness; Develop policies which ensure that new technology is used by everyone; Built-in monitoring and evaluation process for everyone including “old school” leaders to ensure that everyone is progressing; Have policy which guides data sharing and data protection among stakeholders of emergency preparedness and develop policies to ensure that all feedback from exercise and training is adopted for mobilizing equipment and organize preparedness activities
B6: Lack of Coordination between the federal and local government	Adopt and implement all eight elements of EP in a combined way; Have policies which clarify roles and responsibilities of emergency organizations at local and federal levels; Develop strategy for enhancing EP education for EP elements; Put in place policies, conduct training and orientation to teach and state the relationship and coordination between federal and local levels
B7: Lack of policy to speed up initiatives leading to emergency preparedness with pending projects	To priorities the most essential tasks and complete them; Share some of the responsibilities with other emergency organizations such as the civil defense, police & Red Crescent to quicken the completion of projects and tasks and use comprehensive principle of EM to achieve EP elements and collaborative tasks
B8: Availability of public awareness strategies; Inefficient efforts and strategies to educate people	Work in partnership with other emergency organizations, private sector, media and NGOs to deliver public education; Adopt best practice as guidelines for delivering public education; Use public communication timeline as one of the strategies for implementing public education; Engage the public through creative ways and send information through businesses, organizations, religious and community groups; Use public communication timeline and best practice to teach about preparedness and risks of emergencies and reassure the public about safety and boost their confidence by using positive examples of how preparedness helped in other parts of the world

5 Conclusion

An overview of emergency management practices in the US, UK, Australia, and the UAE, which is the focus of this study was carried out. The rationale for this is to provide a good background into the research area and concept of emergency management and standards used to carry out operations within this field. In order to better understand the relevance of the EM standards for safety, the emergency preparedness phase was identified as of crucial importance in achieving effective emergency management. However, a critical examination and evaluation of the emergency preparedness elements shows that even though the UAE has an emergency management standard it uses, the emergency preparedness phase, in particular the elements, has not been given the attention it receives in the US, UK and Australia. In addition, unlike the other countries examined, the UAE does not have any emergency preparedness framework or cycle. While the reasons for this vary and might exceed the scope of this research, the research identified some barriers to implementation, although not for developing or instituting a preparedness framework. A set of recommendations were drawn to assist the UAE government to improve emergency management in general and emergency preparedness in particular.

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Embodied Carbon Footprint Assessment of a Conventional Commercial Building Using BIM

Daud Khan, Ehsan Ahmed Khan, Muhammad Sheharyar Tara, Syed Shujaa, and Safdar Gardezi

Abstract

Materials are one of the major sources of carbon emissions for the construction sector. The current research aimed to assess the environmental potential contribution of a ground plus three-story commercial building in Pakistan. Life-cycle assessment (LCA) along with BIM helped to develop the material inventory of conventional materials used and achieve their emissions. With a total contribution of 13 more than 80%, steel (33.51%), concrete (19.98%), brick (14.75%), aluminum (12.10%), and paint (3.22%) were the top contributing materials. A thorough embodied carbon emission assessment at the stage of planning and design would help to adopt a proper sustainable development strategy.

Keywords

Carbon emissions • Life-cycle assessment • BIM • Sustainable

1 Introduction

Construction is the major activity to fulfill the basic needs of development. Pakistan is a developing country presently striving for growth in construction activities. Although it has a good impact on economy, on the other hand it is directly affecting the environment. The increase in human population can cause an increase in the demand for building structures. With increase in construction activities, there will be a continuous pressure on natural resources to meet these demands. However, the construction activities are one of the major concerns for the generation of GHGs. Gases that entrap heat within the atmosphere are referred to as greenhouse gases. Carbon dioxide is a naturally occurring gas, which plays a basic role in the emission of GHG (Allen 2014). A large quantity of CO_2 is emitted due to construction. Construction completely depends upon natural resources. The consumption of those resources discharge a particular quantity of CO_2 into the atmosphere, which is the major source causing an increase in global warming. In the construction industry, buildings are one of the important parts for the fundamental residential, education, industrial, and health facilities requirements of human beings. Carbon dioxide is not only emitted while construction of building but also during its operation. Scientists are worried about the rapid change in climate and they are finding the way to stop the emission of GHG. Therefore, a concept of carbon footprint assessment came into being. Carbon footprint can be defined as the amount of carbon emission caused by the human activities like utilization and manufacturing of product in the form of equivalent factor of CO_2. Due to the lack of control environment, it is difficult to calculate the exact amount of $CO_{2,}$ and therefore the building construction is divided into various stages to calculate the approximate amount of CO2 emission. To study these effects and calculation of $CO_{2,}$ a method was introduced known as life-cycle assessment (Azzouz et al. 2017). Life- Cycle Assessment (LCA) is a tool to review the environmental impact of products throughout their entire life cycle—(from cradle to grave). In order to make this analysis, a suitable set of data is required. To estimate the CO_2 emission of material, the concept of embodied carbon came into being. It is the emission of CO_2 in the extraction of raw material, transportation manufacturing, and assembling of that material. In term of life-cycle, assessment of cradle to site stage of construction aims to support the sustainable development. This thing will help to develop a sustainable development.

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2 Literature Review

Climatic change and its social, environmental, monetary, and moral consequences are well known due to the fact the major set of interconnected issues facing human societies. Human activities are directly affecting the globe temperature. Due to this change, scientists started working in the early 1980s to control the built environment to fight the consequences of temperature variations on Earth. Building is one of the major sources of CO_2 emission. It contributes to both the construction and operational phase. According to IPCC (Allen 2014), the building consumes 40% of natural resources in construction which is 40–50% of GHGs emissions worldwide. Due to this rapid emission, scientists are predicting that building sector of construction industry emits about 50% of CO_2 all around the world by 2050. Different researchers have evaluated the environmental effects of building around the world. Table 1 shows the details of the same.

Sustainable development is a monetary development and performed without depletion of natural sources. The design directly affects the amount of CO_2 released and it can be controlled in this phase by efficient design and achieving sustainable development. To promote sustainable designs, a new process is introduced which is known as BIM (Building Information Modeling). BIM can also help in calculating the quantities of different materials to be used in building accurately, which increases the accuracy of environmental effect estimation.

Table 1 Environmental effect evaluation of different case studies

Author	Country	Findings
Shafiq et al. (2015)	Malaysia (2015)	Different classes of construction material can considerably reduce carbon amount
Syngros et al. (2017)	Greece (2017)	Concrete cause more emission because of its quantity and mass. Steel also plays its role in embodied carbon footprint
Abanda et al. (2017)	UK (2017)	Assessed environmental impacts using BIM
Lu et al. (2015)	Taiwan (2015)	Reveals significant difference in the immediate carbon footprint computation and the localized value-input while processing
Azzouz et al. (2017)	UK (2016)	Optimizing strategies can significantly save life-cycle of carbon and energy as well
Alwan and Jones (2014)	UK (2014)	Highlighted the impact of embodied energy of construction materials
Luo et al. (2016)	China (2015)	During construction materialization stage steel, concrete and walls as variables predicate CO_2 emissions
Dong and Ng (2015)	Hong Kong (2015)	An analytical tool EMOC has been developed to estimate the environmental performance of building construction
Wahidul and Biswas (2014)	Australia (2014)	Revision of cement formulations and recycled aluminum and steel can reduce emission

3 Objectives of Study

To assess the impact of construction activity on environment, estimation of CO_2 is necessary which will be generated from various materials used in building construction. The target of our study is to develop a 3D parametric model of a conventional commercial building using BIM (Building Informational Modeling) and its carbon footprint assessment. After the analysis, it is possible to see the contribution of each material in carbon emissions which have the potential to affect the climate of Pakistan.

4 Case Study

For the evaluation of the environmental effect of building on Pakistan's climate, a commercial building is selected as a case study. This building is located in DHA 2, Islamabad, Pakistan, Fig. 1. This study is only limited to the embodied part of CO_2 emission of material use in commercial building.

5 Methodology

This study includes the embodied carbon footprint assessment of commercial building. Building Information Modeling (BIM) process was adopted to develop a virtual model of building, Fig. 2. With the help of BIM, different materials were extracted and quantity database was formed. With the help of

Fig. 1 Commercial building on site

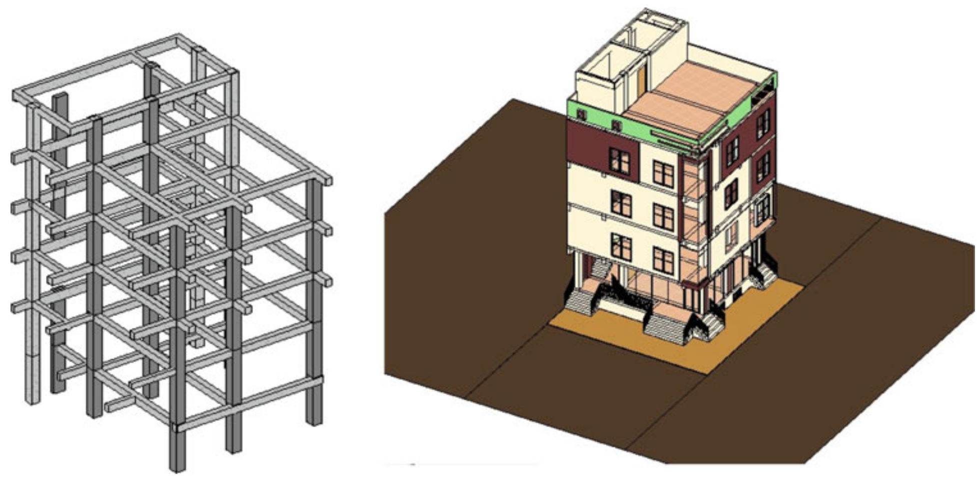

Fig. 2 Virtual 3D model of case study

this database, carbon footprint assessment was performed using ICE (Inventory of Carbon and Energy). LCA evaluation method is applied by restricting to 'cradle to site'. This methodology has been restricted to the carbon inventory assessment of construction materials. The characteristics of material chosen for the models was according to the site. Carbon emission of every material was calculated by opting CO_{2e} per kg coefficient given in ICE. The overall embodied carbon emissions for each material has been calculated in kg–CO_{2e}.

6 Result Analysis

Table 2 provides the details of materials quantities for the case study building. The quantities were cross-checked with the actual bill of quantities to observe any major difference.

The extracted quantities were multiplied with emission factor from Inventory of Carbon and Energy (ICE) to achieve the embodied carbon footprint contributions, Table 3. A total carbon footprint of 285189.87 kg- CO_{2e} has been extracted from the case study with a graphical percentage contribution detailed in Fig. 3.

In order to observe the contributions on an individual basis, material ranking was performed, Table 4. The major materials were steel, concrete, brick, aluminum, and paint with a contribution of 33.51%, 19.98%, 14.75%, 12.10%, and 3.22%, respectively. The study revealed that top five contributing material made a share of more than 80%.

7 Conclusions

The study explored the carbon footprint potential of a conventional commercial building in Pakistan. Building Information Modeling (BIM) along with ICE inventory has

Table 2 Quantities of materials extracted from virtual model

S. No	Description of Material	Unit	Quantities
1	Steel Rebar	Kgs	34496.20542
2	Concrete	Cft	6724.24
3	Brick	Cft	3093.25
4	Plaster	Sft	20644.29333
5	Aluminum	Kgs	3768.413025
6	Glass	Sft	3681.369863
7	Timber	Sft	591.12
8	Hygrip	Sft	900
9	False Ceiling	Sft	2838.6
10	Percaline Tile	Sft	5266.08
11	Paint	Sft	23272.5
12	Steel chrome	Kgs	486.938093
13	Motor	Sft	6346.08

Table 3 Embodied CO_2 emissions from materials

S. No	Materials	CO_{2e}/kg	CO_{2e} Emission (kg-CO_{2e})
1	Steel Rebar	2.77	95565
2	Concrete	0.124	56978.23911
3	Brick	0.24	42055.59829
4	Plaster	0.13	8836.980439
5	Aluminum	9.16	34518.66331
6	Glass	0.91	8658.671717
7	Wood	0.2	590.4386554
8	Hi grip	1.93	2460.012885
9	False Ceiling	0.47	1334.142
10	Percaline Tile	0.7	7395.894875
11	Paint	0.87	9186.513158
12	Steel chrome	2.87	8554.724479
13	Motor	0.13	9054.993862

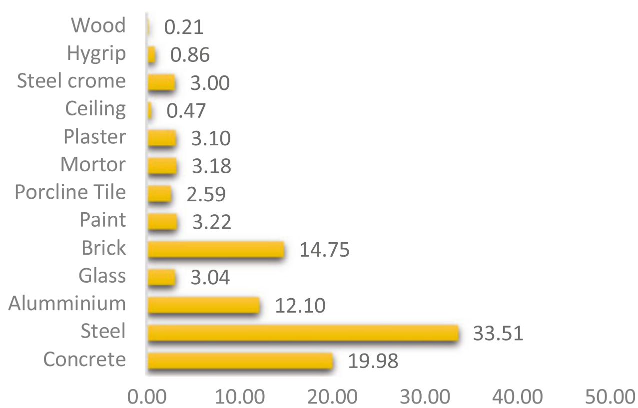

Fig. 3 Percentage contribution of material in carbon footprint content

assessed a total of CO_2 emissions equivalent to 285.189 tons-CO_2. Thus, per unit area contributions worked out to be 54.26. Thirteen (13) construction materials were taken into consideration. The top five (05) materials included steel, concrete, brick, 132 aluminum, and paint contributed to 33.51%, 19.98%, 14.75%, 12.10%, and 3.22%, respectively. The contribution from these five materials was more than 80% of the total embodied CO_2 in the study. From the research, it was observed that if the embodied carbon emissions from the five materials could be managed somehow, a noticeable reduction in such emissions is possible from conventional commercial buildings for the future.

Table 4 Material ranking which contributes more to carbon emissions

S. No	Material	Percentage contribution	Ranking
1	Steel	33.51	Rank 1
2	Concrete	19.98	Rank 2
3	Brick	14.75	Rank 3
4	Aluminum	12.10	Rank 4
5	Paint	3.22	Rank 5

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A Pilot of Student-Guided Virtual Reality Tours

Jeffrey Kim

Abstract

Construction management programs that contain technology courses often teach students how to create building information models (BIM). The problem is that creating these models for the first few times is a difficult process. This learning process pushes students' spatial abilities to the limit as they try to understand how buildings come together while trying to perfect their final product. However, when students can view their models at a 1:1 scale instead of on a flat computer screen, they start seeing things differently. Recently, nearly 60 students took part in completing their regularly assigned BIM project in a construction technology class. With the aid of an Oculus Go® virtual reality headset, students walked in their finished product and were able to critique their work from a different perspective. Furthermore, this pilot placed the student's in their model along with their classmates. This way, the author of the model could take their classmates on a virtual tour of their work, allowing multiple people to review and critique the finished product. This paper describes a pilot inquiry into the use of collaborative virtual reality in a 4-year construction management classroom to improve student's building information modeling skills. This paper presents the students' feedback about the experience and documents the researcher's observations in preparation for a plenary study on collaborative virtual reality in the classroom.

Keywords

Virtual reality • Construction education • Active learning • Collaborative learning • Spatial skills

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1 Introduction

This pilot inquiry was modeled as an action research study (Mertler 2016) and is being conducted to aid in the final design of a larger study on collaborative virtual reality (VR). In the context of this pilot inquiry, a series of assignments were used to comparatively evaluate the impact of using collaborative VR in the classroom. In particular, the VR was used to help the students score their classmate's assignments. The presumption from using VR in this manner is that the students would enhance their parametric modeling skills more than through the use of traditional scoring techniques. A limited amount of performance data was collected along with student perceptions of the new critiquing exercise. This pilot inquiry intends to establish a methodology that could be used to gather more detailed and statistical data in the use of this novel approach toward critiquing. Lastly, the instructor was motivated to introduce students to collaborative VR while in academia because it could prepare them for its use in industry (Kim and Leathem 2018).

2 Past Research

This pilot inquiry seeks to determine if an alternative method of critiquing students' parametric models provides the students with better feedback than through conventional methods of critiquing. Collaborative critiquing was selected as the alternative method for the classroom because of its similarity to the design industry practice of collaborative design. Collaborative design is used across many disciplines; however, in the building industry, it generally involves an iterative process where feedback is continually used to affect the final product (Kvan 2000). Student peer assessment or peer critiquing uses multiple feedback channels so that students can obtain a wide variety of suggestions to improve their learning (Topping 2009). Both processes are similar in that feedback is encouraged and can be used to improve the final outcome.

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This pilot inquiry was set up to mimic the design process because the industry is starting to make use of VR to enhance that process. Therefore, using VR-supported collaborative peer critiquing should improve the students' skills.

In the United States, construction management programs teach students how to interpret two-dimensional (2D) construction plans (American Council for Construction Education 2017). That interpretation involves the student reading lines on the construction plan and creating an abstract spatial image in their mind (Baartmans and Sorby 1996). Often it is necessary to reverse that order, and the student must be able to observe a three-dimensional (3D) rendering of a building and interpret its 2D representation. These back and forth translations are what faculty train in the construction management class. Unfortunately, many students, for various reasons, struggle with this spatial translation skill (McCuen 2014). The process of creating parametric models requires more advanced spatial skills from students (Kim and Irizarry 2017), and spatial skills can be improved (McCuen 2014). Unfortunately, due to the pace of learning within most construction management programs, students rarely have sufficient time to practice their newly acquired skills in plan reading, and subsequently, they have difficulties in properly creating parametric models. It would be beneficial to have more effective pedagogies available to students when it is clear that they continue to struggle.

Learning is achieved if students are not overloaded during their educational experience (Sweller 2011). There are many ways by which they can become overloaded or distracted during their learning experience and these amount to cognitive load. Cognitive load can be so overwhelming that it prohibits the student from properly storing newly acquired learning in their working memory (Sweller 2011). Technology is an infamous distraction (high cognitive load) to the modern classroom but, if the technology is applied properly, it can add positive value to the learning experience (Chen et al. 2015; Galanek et al. 2018). Therefore, considering the introduction of technology is necessary when a new pedagogy is introduced (Sweller 2011). However, in a classroom that is focused on teaching BIM, the need to introduce technology is expected.

The industry is moving toward increased use of BIM because of its many benefits (Taiebat and Ku 2009) so students that want to be future practitioner must be proficient in its use. Focusing on pedagogy that addresses this need is imperative, and through the use of properly applied collaborative technology, students will obtain enhanced feedback that improves their learning all while experiencing technology that the industry supports.

3 The Pilot

This section describes the process taken to obtain pilot data that would be used to develop a methodology and hypothesis for a future plenary study on collaborative VR. This pilot inquiry took place in the summer semester of 2018 with postsecondary students that were required to take a construction technology course. In this course, the students learn how to use 3D modeling software (Autodesk Revit® and Trimble SketchUp®). The instructor collected performance and perception data, while students completed a series of classroom assignments. The assignment selection involved modeling a 3D site logistics plan for a commercial building project.

3.1 Method 1: Modeling and Traditional Critique

The first assignment that was monitored involved the students creating a 3D site logistics model of a commercial building project. Once the students completed the assignment, they were asked to present the model to the class for traditional (anonymous) peer critiquing. All presentations required the students to display their model to the classroom on an overhead projector using the features of the modeling software to guide their classmates through their work. The workflow for this method is illustrated in Fig. 1.

3.2 Method 2: Modeling and Collaborative VR Critique

Later in the semester, with the same students, another similar assignment was completed. However, the students were asked to present their model by curating a tour through the model using a VR headset that would be worn by all students. The assignment's author was given the role of tour guide, and all other students were considered a tourist. Viewing the model in this manner was different for the students in that everything visible to them was at 1:1 scale as if they were in the model itself. The workflow for this method is available in Fig. 2, and an illustration of the students participating in a VR-guided tour is available in Fig. 3. The collaborative nature of this configuration allowed all students using the VR headset to see each other in the model as avatars (floating headsets). Upon completing the tour of the model, all students completed a peer (anonymous) critique scorecard and a perception survey.

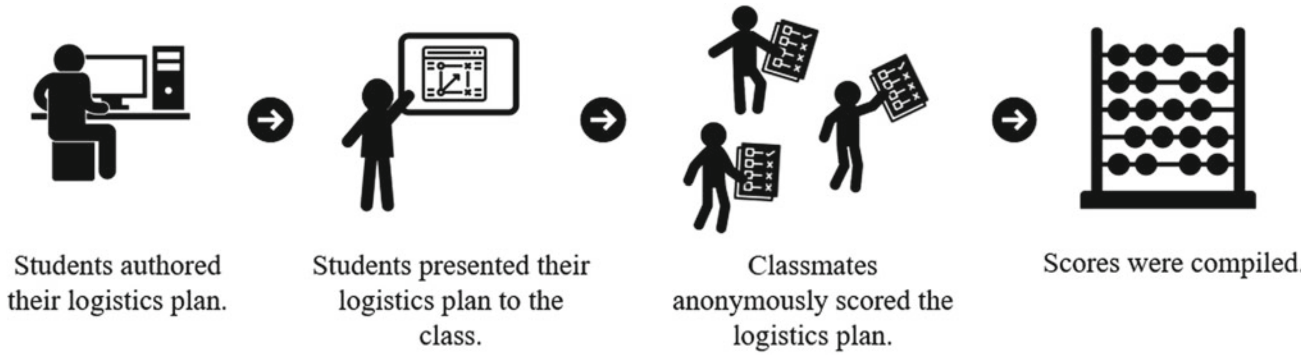

Fig. 1 Method 1: workflow with a traditional critique

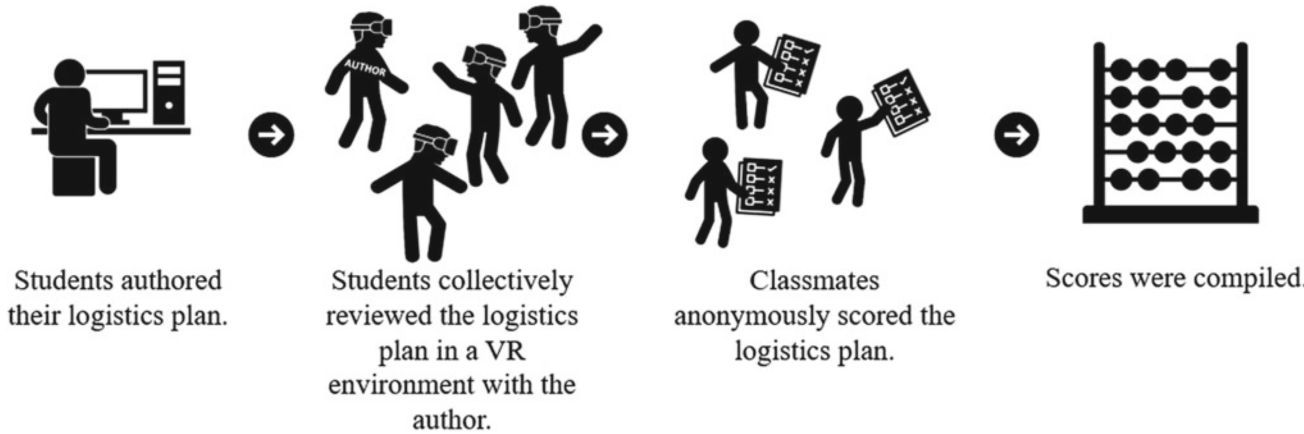

Fig. 2 Method 2: workflow with VR critique

Fig. 3 Students presenting their assignment using virtual reality

3.3 Scorecards and Perception Surveys

The anonymous assessment for the models was handled through a grading rubric designed by the instructor. Each student scored the models that they viewed in Method 1 (see Fig. 1) and scored again in Method 2 (see Fig. 2). The following three criteria were used in both methods.

1. Rate the quality of the logistics model.
2. Rate the effectiveness of using the model as a tool for communicating site logistics.
3. What is the overall ranking for quality that you would give to this student's work?

Lastly, the students also responded to a perception survey of their experience in the VR tour.

3.4 Virtual Reality Setup

The virtual reality setup consisted of two components. The cloud storage site for the student's parametric models (InsiteVR® accessed via https://app.insitevr.com/) and the VR headset (OculusGo®).

4 Results

4.1 Demographics

The students that participated in this pilot inquiry were selected because they were representative of students in a common 4-year post-secondary construction management program in the United States. A review of data from the American Council for Construction Education (American Council for Construction Education 2017) indicates that the demographics for these students are similar to those found across the United States. Additionally, since the 4-year program includes opportunities for students to obtain work experience in the way of internships and cooperative education programs, it is not surprising that most indicated that they had some experience in the construction industry. Lastly, the students were asked if they had used VR before, and most had indicated that they had some exposure to it in the classroom. Both of these demographic indicators were documented because they may have an impact on the results presented in this paper and should be evaluated further in an expanded research study.

The students that participated in this pilot did so as a tourist (students that were guided through a model by another student) or a tour guide (a student responsible for leading other students through their model). The following table summarizes the demographics of each of the groups of students (Table 1).

4.2 Comparison of Critiquing Methods

There were two methods for critiquing that the students engaged in during this pilot inquiry. The first method consisted of a traditional critique of a classmate's model by using a projector display that the authoring student would use to present their work to their classmates. The second method consisted of a VR-based approach, whereby the students critiqued their classmate's work in a collaborative VR environment. Following the student's presentation, their classmates provided anonymous feedback (critique) for three criteria.

4.3 Comparing Responses Between Tourists and Tour Guides in the VR Critiquing Method

The students, regardless of their role as *tourist* or *tour guide*, completed a perception survey. Figure 5 illustrates the differences in perception to nine criteria that were asked following a tour of a student's models. The nine criteria are as follows:

Q1: Rate the quality of the logistics model.
Q2: Rate the effectiveness of using the model as a tool for communicating site logistics.
Q3: What is the overall ranking for quality that you would give to this site logistics plan?
Q4: Upon completing this critiquing exercise, do you think your modeling skills have been enhanced?
Q5: Upon completing this critiquing exercise, do you think your construction management skills have been enhanced?
Q6: Rate the tourists or the tour guide.
Q7: Did the model represent the proper scale between all the elements in the model? Q8: Did the model make the best used of colors and textures?
Q9: Did the VR technology interfere with the learning experience during your critiquing?

5 Discussion

5.1 Comparison of the Critiquing Methods

As apparent in Fig. 4, the perception from the students when critiquing site logistics models between a conventional critique and a collaborative VR critique shows consistently higher scores overall for the VR approach. However, the scores are not significantly much higher (0.09 points difference at the greatest) which may indicate that the two approaches result in balanced scoring for the logistics models, regardless of the method of reviewing them. Moreover, since neither of the critiquing methods resulted in

Table 1 Student demographics

Characteristics	Tourists (n = 64)	Tour Guides (n = 17)
Experience Working in the Construction Industry Yes	44 (68.8%)	9 (52.9%)
No	20 (31.3%)	8 (47.1%)
Have You Used VR in the Classroom Before?		
Yes	44 (68.8%)	11 (64.7%)
No	20 (31.3%)	6 (35.3%)

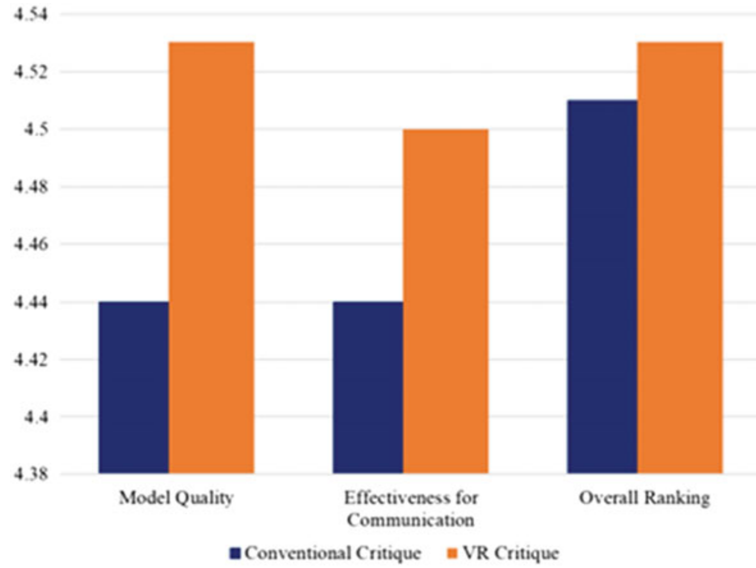

Fig. 4 Comparison of critiquing methods

significantly different scoring results, the introduction of the collaborative VR technology does not appear to cognitively overload students and impede their learning. Otherwise, we may expect to see collaborative VR critique scores in Fig. 4 lower than the conventional method of critique. Therefore, expanding this pilot to the plenary research study should seek to hypothesize that the critiquing method does not affect the student's cognitive ability to learn.

5.2 Comparing Responses Between Tourists and Tour Guides During VR Critique

This part of the pilot inquiry was staged to determine if there was a difference in the learning experience between the two roles in this critiquing method. In Fig. 5, the responses to questions Q1, Q2, Q3, Q4, Q5, Q6, Q7, and Q9 were similar with only an average difference of |0.2|. This data indicates that there was not much difference when one acted in the role of *tourist* or acted in the role of *tour guide*. However, Q8 requested that the students respond to the author's use of color and texture in their model. The difference was |0.7| with the *tour guide* indicating a more critical review of their model than the *tourists*. Again, not a significant difference between the roles and indicates that the critiquing was not unfairly biased. There is balance in the assessment regardless of the role that the student takes as well as an apparent balance in the learning experience as reported from the student's responses to questions Q4 and Q5. Much like the result from the comparison of the critiquing methods, there

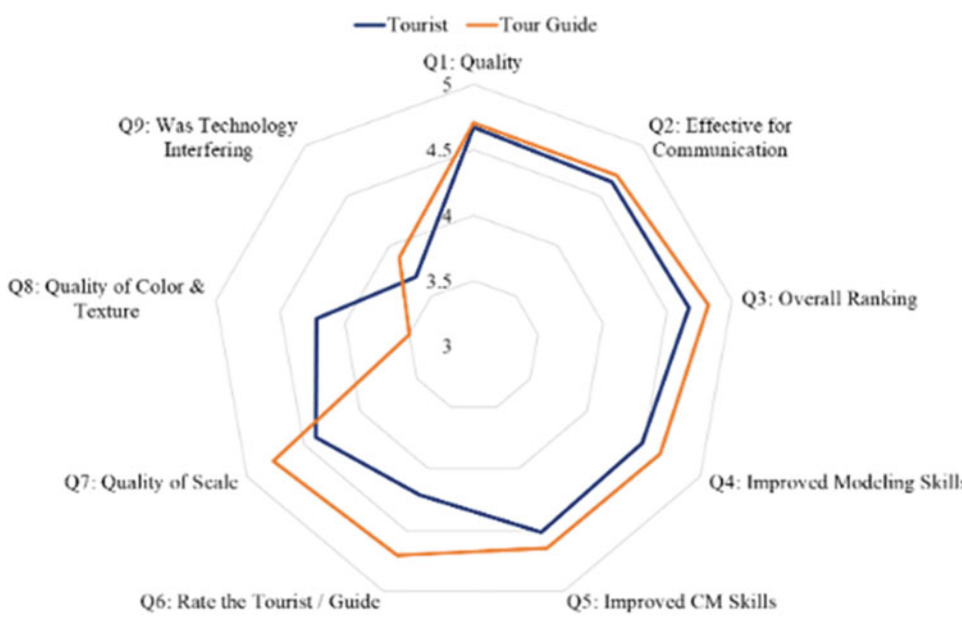

Fig. 5 Comparison between tourist and tour guides in the VR critique

is a balance between the perceptions of the different roles. What this should allow for in the plenary study is an unbiased analysis of analytical scores in a pre- and post-assessment data gathering experiment.

5.3 Future Work

As an aside, the individual scores for Q8 and Q9 were about |0.5| lower than the individual scores for Q1, Q2, Q3, Q4, Q5, Q6, and Q7. The students were less confident that these two questions contributed positively to their experience in the VR critiquing method. The data indicate that students can be more critical of the model in a way that was not available to them when critiquing them traditionally. This fact is supported regardless of whether they participated as a *tourist* or a *tour guide*. It is obvious that viewing the model in a 1:1 scaled immersive environment is different than viewing them on a flat 2D display. There is a possibility that critiquing using this method would allow the students to be more critical and in turn, learn more from the experience. More analytical research would be needed to support this notion.

Lastly, this pilot inquiry did not conduct a formal or analytical review of the student's pre- and post-scores. While it did appear that the students learned from the VR experience; their future models included more details, better coloring, and more informative annotations. Data collected in this pilot inquiry did not allow for isolation of all the variables; therefore, obtaining a truly accurate dataset that could speak to the student's learning performance was not a part of this pilot inquiry.

6 Conclusion

While the results are not based on a systematic pre- and post-test experimentation, this pilot inquiry provides a basis for developing the methodology and establishing hypotheses that could be used in an expanded research, resulting in more actionable and generalizable results. Concluding this pilot inquiry, the following points were determined:

1. **Impact on Critiquing**—Regardless of how a faculty allows the students to self-critique parametric models, the scores are unaffected. The data from this pilot inquiry did not appear to show significant bias for critiquing the models using a traditional approach (as detailed in Sect. 3.1) over using a collaborative VR approach (as detailed in Sect. 3.2).
2. **Roles in the VR Approach**—The VR approach requires at least one student to take on a different role than the remaining students, and this role did not appear to bias the scoring of the student that authored the model. The learning experience between the two roles shows to be balanced.
3. **Cognitive Load**—The introduction of the VR technology did not appear to be a distraction, and the data indicated no additional cognitive load, allowing for a balanced learning experience regardless of the method used to critique. However, a more analytical verification of this fact should be pursued in an expanded research study.

The results of this pilot inquiry found that using collaborative VR critique was not measurably better than using a traditional method of critique. However, qualitative data from the students suggested that they received better feedback on their work when collaborative VR was used. Consequently, the results from this pilot should encourage more detailed and analytical research in the use of collaborative VR for educational use in the construction management classroom.

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Factors Affecting Indoor Environmental Qualities of Social-Housing Projects in South Africa

Mpho Ndou, Clinton Aigbavboa, and Felicia Yaka

Abstract

The South African housing delivery plan faces various economic and social challenges, which include a high unemployment rate, low income, a huge housing backlog, and a lack of infrastructure, particularly in rural areas. Indoor environmental quality (IEQ) is the ability of a building to deliver adequate indoor environment beyond occupant's expectation. These expectations include the occupant's health, well-being, and productivity among others which are often not considered during the design stages of social-housing projects. This paper presents the results of IEQ of social-housing projects in South Africa. The study adopted a quantitative, where a questionnaire survey was constructed and distributed to occupants of social-housing in the Gauteng province of South Africa. Analysis of the primary data collected was conducted using descriptive statistics procedures. The findings revealed that the major factors affecting IEQ of social-housing occupants were indoor air quality parameters, level of privacy, acoustics sound between the units and level of visual comfort among other factors. Also, the occupants were not satisfied with the overall state of their IEQ which was driven by the above factors. Thus, creating a provision for IEQ aspects during the design and administration phases of social-housing projects will make social-housing more desirable in South Africa.

Keywords

Air quality • Occupant satisfaction • Thermal comfort • Social housing

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1 Introduction

Following the democratic freedom that South Africa endured in 1994, providing adequate housing for the nation has been a constant challenge faced by the government. The department of housing (Department of Human Settlement (DHS): South African Yearbook 2012) highlighted that challenge has been fueled by increased housing demands, amended housing scope and the social-housing policy shortfall absorbed from the pre-democratic government. The need for practical solutions arose as various strategic policies related to housing projects and programmes required major revisions. Ironically, major housing problems still exist despite government's initiatives which were formulated to provide affordable housing projects for all (Othman and Mia 2008).

The is a steady civil argument on the adverse impacts of inadequate indoor environmental quality (IEQ) on the well-being and occupant's satisfaction of their indoor environment. Ibem (2012) noted that the need to guarantee unwavering quality relating to social service delivery and housing provisions to the public had drawn the attention of the governing body together with the stakeholders of housing schemes in many developing economies. Also, contemporary literature has shown that across the globe, social-housing provision is regarded as an alternative to the privatised housing sector, which caters mostly for the middle to the high-class households. As a result, households of the lower class are found in an economic crisis that social-housing address (Santamouris et al. 2014). Santamouris et al. (2014) further added that the economic crisis brings about inadequate IEQ of the lower-class households which the current study seeks to identify.

For this reason, more research is required to investigate occupant's satisfaction level with their IEQ within social-housing projects. Recent studies demonstrated that living in a reasonably planned indoor environment promotes more individual comfort and well-being of mental and the physical (Akom et al. 2018; Patino and Siegel 2018). It is,

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therefore, important to study the elements influencing the IEQ of social-housing projects. The study seeks to identify the factors that will contribute to the overall assessment of the challenges faced by the social-housing project scheme, in a bid to increase the demand for social housing in South Africa. The structure of the paper includes a credible literature review followed by a comprehensive write up of the adopted research methodology and the collection of empirical data through research findings. Subsequently, conclusions and recommendations relating to improving social-housing satisfaction are drawn using the findings of the paper.

2 Indoor Environmental Quality: A Review of Literature

Indoor environmental quality (IEQ) is a term which covers the environmental qualities within a building and is commonly linked to the well-being and comfort levels of the building's occupants. The phenomenon addresses the three main indoor environmental factors which mainly are air quality (which is made up of humidity, temperature, pollutants and odours), light and acoustics quality. Aigbavboa and Thwala (2012) mentioned that these factors should be the basis of any design when constructing social-housing units. Similarly, Sakhare and Ralegaonkar (2014) emphasised that the most important function of a building or an enclosed structure is to provide ultimate user satisfaction through adequate IEQ. The following are known factors that influence the IEQ of occupants.

2.1 Indoor Air Quality

Indoor air quality (IAQ) is characterised as 'clean' air in an environment, where the presence of air contaminants in the indoor space is significantly low. Similarly, indoor air exposure is dominant for occupants who spent over fifty per cent of their time indoors (Al horr et al. 2016). Sanni-Anibire (Sanni-Anibire et al. 2016) further defined IAQ as a mean or suitable level of tolerance with the indoor ventilation, humidity and biological air contaminants. IAQ is a component of IEQ that addresses two main indoor environmental aspects of air flow and humidity. Inadequate IAQ is common in the following indoor environments. Mainly all major modes of transportation, institutional buildings, shopping outlets, workplaces, crèches, housing, hospitals and schools (Al horr 2016).

2.2 Thermal Comfort

Thermal quality (TC) is defined as a perceived feeling linked to the overall fulfilment with the thermal environment relating to the temperature (Frontczak et al. 2012). TC influences the level of IAQ in a building. Similarly, thermal comfort is affected by various mediation variables such as the season, age, gender, ethnicity, geographical climate and location (Quang et al. 2012).

2.3 Acoustic Comfort

Acoustic comfort (AC) can be characterised as a condition of happiness with acoustic conditions (Al horr 2016). The adoption of acoustic comfort is limited and providing for a decent acoustic environment can be a challenge for public spaces. The environmental element of the sound is naturally connected to various physical parameters. The physical properties of these parameters incorporate the sound source and the indoor environment. The sound weight level describes the sound recurrence and fleeting together with the duration period. The properties of an acoustic environment can influence the physical indoor space through the sound absorption and reflection, assimilation and resonation time, which bring about indoor discomfort to the occupants.

2.4 Visual Comfort

Visual comfort is described as the light level of an area relating to light uniformity, colour, glare control, luminance and illuminance together with the distribution of a light source (Hwang and Kim 2011). Also, it was documented in a separate study that human sleeping patterns were influenced by the visual quality experienced during the day (Katafygiotou and Serghides 2014). It is for this reason that visual comfort should be catered for in social-housing projects among other IEQ parameters.

Moreover, the Leadership in Energy and Environmental Design (LEED) included IEQ as part of the five classes which deals with fabricating evaluation framework, created by the Green Building Council of the United States of America (USGBC). Thus, IEQ is mentioned to influence the occupant's fulfilment, building usage and overall efficiency. This can be achieved by guaranteeing high IEQ requirements of lighting, acoustics, clamour control, ventilation and thermal regulations.

In addition, Afacan and Demirkan (2016) observed that constructing an acceptable and solid indoor environment is essential for tenants as it eliminates the need for reconstruction and renovation. According to Awabi (Awbi 2007), health, comfort and safety issues are particularly pronounced in the area of social housing, where the deterioration of the existing building creates a need for renovations to be prioritised. It is for this reason that a study aimed primarily on the factors that affected the qualities of social-housing projects in South Africa with emphases on the indoor environment.

3 Research Methodology

The research study adopted a quantitative approach using a structured questionnaire survey design that was distributed mainly to the occupants of social housing. The study setting was mainly in the Ekurhuleni Development Company (EDC) and JOSHCO (Johannesburg Social Housing Company) which is found in the Gauteng province. The occupants of these social-housing companies were the targeted respondents. The selection of the study area was prompted by the fact that most social-housing projects in South Africa are established in Gauteng due to the urbanisation of the working class. A convenience sampling method guided the selection of a sample size of 70 occupants who were selected due to the time and available respondents that were willing to participate in the study. A close-ended questionnaire survey was designed with four sections. The first section of the survey was designed to gather demographical data of the respondents like the period of occupancy, age and gender. The second section sought to gather the occupant's behavioural patterns or habits done in their units. The third section sought to understand the type of control occupants had over the facilities in their social-housing units. The last part dealt with the factors affecting IEQ. A 5-point Likert Scale was used to measure all factors associated with IEQ. Only 52 out of 70 distributed surveys were received back yielding a 71 per cent response rate which is deemed adequate for analyses. In analysing the data gathered, descriptive statistics was done of each factor using mean item scoring (MIS), standard deviation (SD) and ranking (R), respectively.

4 Results

4.1 Background Information

The data analysis gathered demographical information of the respondents which reflected that the occupant's gender was 34% of the respondents were male, while 66% were female. Also, the data showed the duration that the occupants have stayed in their current unit; which revealed that 8% of the respondents have stayed in their units for 0–6 months; 8% of the respondents have stayed in their current units for 7–12 years. Similarly, 44% of the respondents have stayed in their current unit for 1–5 years; 40% of the respondents have stayed in their current units for 6–10 years, 0% of the respondents have stayed in their current units for 11–15 years, and 0% have stayed in their current units for above 15 years. These demographical findings reveal a significant influence and relationship to the impact of the IEQ factors by gender and the duration of stay in their units similar to other studies (Lai et al. 2009; Choi et al. 2010; Kamaruzzaman et al. 2018). The statistical findings of the study are presented in Table 1 were: (MIS) is the Mean Item Score, (SD) is the Standard Deviation, and (R) is the factor Ranking. The SD seeks to measure the variability of the occupant's response to the mean data which reflected a higher margin.

5 Discussion

In assessing the factor affecting IEQ, a five-point level of significance relating to each factor would be recorded by the occupant, with five being strongly agreeing, four being agreeing, three being neutral, two being disagreeing and one being strongly disagreeing. Table 1 shows the ranking of these factors by the occupants. Findings show that 46% of the factors assessed were deemed significant by the occupants as they have an MIS value above the 3.0. The main leading factors are; the air quality of the unit, sound privacy between the units, temperature in the units, general cleanliness of the building and the level of privacy. These factors show an MIS value of 3.42, 3.17, 3.09, 3.08 and 3.01, respectively. Furthermore, 64% of the analysis informed us that the occupants were neither neutral or satisfied with their IEQ as an MIS value between 2.08 until 3.0 was recorded.

The findings of the study are analogous with the findings of three similar studies (Groth 2007; Wolfson and La Jeunesse 2016; Yousef et al. 2016) that revealed that most household owners in their study cited concerns on the air quality and general cleanliness of their homes as leading causes of inadequate IEQ in their homes. On the other hand, the findings from this study are in contract with the finding of Frontczak et al. (Frontczak et al. 2012) who mentioned that the least concerning factors affecting the IEQ of open plan units was sound privacy. Also, Kamaruzzaman et al. (Kamaruzzaman et al. 2018) observed that indoor glare and visual contrast related to visual comfort was the least important factor that affected the IEQ of indoor occupants

Table 1 Factors affecting IEQ of social-housing units

Factors	MIS	SD	R
The air quality of the unit (airflow, contaminates, stale air)	3.42	1.002	01
Sound privacy between the units (limit eavesdropping)	3.17	1.030	02
Temperature in the unit	3.09	0.961	03
Building sanitation and cleanliness	3.08	1.168	04
Level of privacy	3.01	0.898	05
Cardinal direction of the building	3.00	1.092	06
General maintenance of the building	2.58	1.216	07
The adjustability of unit furniture to personal preference	2.50	0.808	08
Amount of light in the unit	2.33	1.144	09
Properties of unit finishes (texture and colour of walls, furniture and floors)	2.25	1.165	10
Comfort of furnishings	2.17	1.136	11
Visual comfort of the lighting (glare, reflections and contrast)	2.09	1.380	12
Availability of unit space (recreational and storage space)	2.08	1.126	13

(Kamaruzzaman et al. 2018). The current findings of the study concurred with these results.

Further analysis of the results uncovered that the cardinal direction of the units that the respondents occupied influenced the extent of lighting, and temperature present in the unit. These findings were analogous with similar studies which identified that the clime elements of the indoor and surrounding environment affected the occupant's control and usage of sunlight and thermal satisfaction with their IEQ (Groth 2007; Frontczak and Wargocki 2011; Vardoulakis et al. 2015). Similarly, it has been observed that the occupant's level of satisfaction is further influenced by external factors such as the amount of time spent in the unit, the intensity of the activities conducted while in the unit and the ability to adjust or control facilities to suit the required temperature (Kamaruzzaman et al. 2018; Agha-Hossein et al. 2013). These findings also correlate with the perceptions of the current respondents of the study.

In addition, it was concluded that the absence of a mechanically driven IAQ system influenced the level of contaminants that were present in the indoor space (Yousef et al. 2016; Lai and Yik 2007; Norhidayah et al. 2013). The same is true with the current study as windows allowed for continuous airflow and ventilation in their units which invited outdoor pollutant that contaminated the indoor air in their units. These pollutants entered the building through exhaust air, infiltration through cracks and openings from doors and windows. From this observation, it can be noted that the age of the building together with routine maintenance plays a vital role in ensuring adequate IEQ in social-housing projects. Likewise, the observations from this study are evident in other recent researches (Fisk and Seppänen 2007; Jin et al. 2012). Moreover, the findings of Frontczak et al. (Frontczak et al. 2012) is in line with the beliefs of the study that maintaining adequate IEQ can be a profitable strategy for any public and private building investment.

6 Conclusions

The indoor environment is an outcome of the collaboration between the spatial matter, indoor clime and the occupants of the indoor space. The amount of complains relating to the building stiffness, the increase in the usage of raw materials that devour natural resources, and the increasing amount of energy that is consumed to attain indoor comfort, has increased over the years. Based on the literature and empirical data, the study investigated the factors affecting the IEQ of social-housing projects in South Africa. It was noted through the survey data collected that the level of awareness regarding the indoor environmental condition and their qualities linked to social-housing satisfaction was below expectation which raised concern among occupants. The study concludes that the main factors affecting IEQ of social-housing projects were linked to the primary IEQ constituents which mainly were: IAQ, TC and AC. Moreover, the findings of the study cannot be generalised due to the limitation of the research scope.

It is, therefore, recommended that during the initial or retrofitting stages of a building, the provision of IEQ elements ought to incorporate to the design through a mechanical system that creates indoor proficiency and comfort. Also, social-housing projects which are already established can create, implement and adopt an IEQ management system that seeks to maintain and improve the current qualities of social-housing projects. An extension of the study can be conducted in other provinces to create a wider view of the research topic. Also, further research can investigate the benefits of a central IEQ management system in social-housing units that can be adjusted to the occupant's preferred level of comfort.

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Construction Health and Safety (H&S) Practitioners' Developmental Needs

John Smallwood and Claire Deacon

Abstract

A South African industry H&S status report reported a deficiency in terms of effective management and supervision of H&S on construction sites, and referred to the lack of sufficiently skilled, experienced, and knowledgeable persons to manage H&S on construction sites. The study reported on, constitutes a further phase in terms of assessment of the status quo of construction H&S practitioners' performance and developmental needs. A self-administered survey was conducted among members of the Association of Construction Health and Safety Management (ACHASM), and ACHASM continuing professional development (CPD) events' delegates. The salient findings include: respondents' source of H&S knowledge is predominantly informal, and CPD would contribute to an improvement in respondents' knowledge and skills relative to nine SACPCMP knowledge areas, five SACPCMP scope of services' areas, eight composite knowledge areas, and seven composite skills areas. Conclusions include: there is a potential for construction H&S practitioners to enhance their knowledge and skills; CPD is necessary and should be provided relative to all the knowledge and skills areas, and undergraduate and honors level construction H&S qualifications are necessary to remedy the situation.

Keywords

Construction • Development • Health and safety • Practitioners

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1 Introduction

The Construction Industry Development Board (cidb) (2009), industry report 'Construction Health & Safety Status & Recommendations' attributes the lack of compliance with H&S legislative requirements to, inter alia, a deficiency of effective management and supervision of H&S on construction sites, and refers to the lack of sufficiently skilled, experienced, and knowledgeable persons to manage H&S on construction sites.

The Council for the Built Environment (CBE) mandated the South African Council for the Project and Construction Management Professions (SACPCMP) in terms of Act No.48 (Republic of South Africa 2000), to register construction H&S professionals following the cidb's report which highlighted the need for professional registration of construction H&S practitioners due to, inter alia, the finding that there was a lack of competencies, and no formal registration process. This, in turn, led to the identification of three such categories of registration, namely Professional Construction Health and Safety Agent (Pr CHSA), Construction Health and Safety Manager (CHSM), and Construction Health and Safety Officer (CHSO). Registration rules were then gazetted for these three categories for commencement 1 June 2013 in the case of Pr CHSA, and 1 August 2013 in the case of CHSM and CHSO.

The Construction Regulations make provision for the appointment of CHSAs, and also require the appointment of either part-time or full-time CHSOs (Republic of South Africa 2014).

Given the findings in the cidb report, and subsequent research findings, a study was conducted to determine, inter alia, the extent to which CPD would contribute to an enhancement of ACHASM members', and ACHASM CPD events' delegates' knowledge and skills relative to various knowledge and skills areas.

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2 Review of the Literature

The SACPCMP requires a report upon application to register as a CHSA, CHSM, and CHSO that addresses the following nine knowledge areas: Procurement Management; Cost Management; Hazard Identification Management; Risk Management; Accident or Incident Investigation Management; Legislation and Regulations; Health, Hygiene, and Environmental Management; Communication Management, and Emergency Preparedness Management (SACPCMP2013a).

The CHSA Scope of Services, in turn, states that CHSAs, CHSMs, and CHSOs are expected to be experienced and knowledgeable relative to the following areas: construction project H&S management systems; construction H&S management; construction H&S performance measurement and monitoring, and construction H&S continual improvement (SACPCMP 2000; 2000; 2000).

A study conducted among members of the Association of Construction Project Managers (ACPM) by Smallwood (2015) investigated, inter alia, the performance of CHSAs. A further related study was conducted among delegates attending a two-day construction H&S summit in Durban, South Africa, by Smallwood and Deacon (Smallwood and Deacon 2017), to investigate, inter alia, the performance of CHSOs. Table 1 indicates that in terms of composite knowledge areas, members of the ACPM rated CHSAs above average relative to only 3/8 (37.5%) areas. The summit delegates also rated CHSOs above average relative to only 3/8 (37.5%) areas. Table 2 indicates that in terms of composite skills areas, members of the ACPM rated CHSAs above average relative to only 3/7 (42.9%) areas. The summit delegates rated CHSOs above average relative to 5/7 69 (71.4%) areas.

3 Results

3.1 Research Method and Sample Strata

The survey entailed the administration of an eighteen-question questionnaire, which included seventeen closed questions and one open question. The first nine of the closed questions were demographic in nature, and the further seven were five-point Likert Scale type questions.

87 Responses were included in the analysis of the data: 21 ACHASM members responded to an electronic questionnaire survey; 32 delegates responded to a questionnaire survey administered at an ACHASM one-day Symposium, and 34 delegates responded to a questionnaire survey administered at an ACHASM two-day Summit.

The analysis of the data entailed the computation of frequencies and a measure of central tendency in the form of a mean score (MS) to enable ranking and comparisons.

3.2 Results

In terms of occupations, 32.1% of respondents were CHSMs, 16.0% were CHSOs, 13.6% were Safety, Health, Environment, and Quality (SHEQ) consultants, 8.6% were Site H&S Advisors and 29.3% constituted ‘other’. Only 1.2% were Candidate CHSAs, and 4.9% Pr CHSAs.

In terms of qualifications, 24.7% of respondents possessed a NDip, 17.3% a BTech, 11.1% M/MSc, 4.9% B/BSc, 2.5% B/BSc (Hon), 1.2% PhD, and 38.3% other.

Table 3 indicates that experience (81.6%) predominates in terms of respondents’ source of H&S knowledge, followed by workshops (62.1%), CPD seminars (58.6%), and tertiary education (55.2%). The percentage responses

Table 1 Rating of CHSAs and CHSOs in terms of composite knowledge areas

Composite knowledge area	CHSAs		CHSOs	
	MS	Rank	MS	Rank
Project administration	3.14	3	2.78	5
Financial management	2.43	7	2.35	7
Design	2.29	8	2.13	8
Law	3.14	2	3.09	3
Construction technology/Technology	2.93	4	2.77	6
Health & Safety	3.71	1	3.96	1
Planning	2.71	5	3.17	2
Management/Management of parameters	2.64	6	3.00	4

Table 2 Rating of CHSAs and CHSOs in terms of composite skills areas

Composite skills area	CHSAs		CHSOs	
	MS	Rank	MS	Rank
Interpersonal/Developmental	3.36	1	3.26	5
General management	3.21	2	3.26	4
Financial	2.29	7	2.78	6
Leadership	2.93	4	3.43	2
Negotiating	2.92	5	3.43	1
Planning	2.64	6	3.32	3
Technical	3.07	3	2.76	7
Interpersonal/Developmental	3.36	1	3.26	5

Table 3 Respondents' qualifications

Source	%
Experience	81.6
Workshops	62.1
CPD seminars	58.6
Tertiary education	55.2
Magazine articles	28.7
Post graduate qualifications	26.4
Conference papers	25.3
Practice notes	21.8
Journal papers	16.1
Other	13.8

relative to the other six sources are less than 50.0%. The percentage relative to tertiary education is notable.

Respondents have worked 13.30 years on average in construction, 9.90 years as a construction H&S practitioner, and 7.99 years for their current employer.

Table 4 indicates the extent to which CPD would contribute to an improvement in respondents' knowledge and skills relative to nine SACPCMP knowledge areas on a scale of 1 (minor) to 5 (major), and a MS ranging between 1.00 and 5.00. Given that all the MSs are > 3.00, it can be deemed that CPD would contribute to an improvement in such knowledge and skills to a major as opposed to a minor extent. There is a difference of 0.49 between first ranked legislation and regulations and ninth ranked communication management.

However, MS ranges provide more insight. It is notable that no MSs are > 4.20 $\leq$ 5.00-CPD would contribute to an improvement in such knowledge and skills between a near major to major/major extent. All nine MSs are > 3.40 4.20, which indicates CPD would contribute to an improvement in such knowledge and skills between some extent to a near major/near major extent-legislation and regulations (4.02) are ranked first, which is 0.01 higher than second ranked risk management, which is followed by hazard identification management (3.90), and health, hygiene, and environmental management (3.90).

Table 5 indicates the extent to which CPD would contribute to an improvement in respondents' knowledge and skills relative to five SACPCMP scope of services' areas on a scale of 1 (minor) to 5 (major), and a MS ranging between 1.00 and 5.00. Given that all the MSs are > 3.00, it can be deemed that CPD would contribute to an improvement in such knowledge and skills to a major as opposed to a minor extent.

It is notable that no MSs are > 4.20 $\leq$ 5.00-CPD would contribute to an improvement in such knowledge and skills between a near major to major/major extent. All five MSs are > 3.40 $\leq$ 4.20, which indicates CPD would contribute to an improvement in such knowledge and skills between some extent to a near major/near major extent. It is also notable that there is only a difference in MS of 0.10 between first ranked construction H&S continual improvement, and fifth ranked construction H&S performance measurement and monitoring.

Table 6 indicates the extent to which CPD would contribute to an enhancement of respondents' knowledge relative to eight composite knowledge areas on a scale of 1 (minor) to 5 (major), and a MS ranging between 1.00 and 5.00. Given that all the MSs are > 3.00, it can be deemed that CPD would contribute to an enhancement of such knowledge to a major as opposed to a minor extent. It is notable that there is a difference of 0.30 between first ranked OH&S and eighth ranked Construction technology/Technology.

All eight MSs are > 3.40 $\leq$ 4.20, which indicates CPD would contribute to an enhancement in such knowledge between some extent to a near major/near major extent. OH&S ranked first, is followed by law, management/management of parameters, design, financial management, planning, project administration, and construction technology/technology.

Table 7 indicates the extent to which CPD would contribute to an enhancement of respondents' skills relative to seven composite skills areas on a scale of 1 (minor) to 5

Table 4 Extent to which CPD would contribute to an enhancement of respondents' knowledge and skills relative to nine SACPCMP knowledge areas

SACPCMP knowledge area	Response (%)							
	Unsure	Minor				Major	MS	Rank
		1	2	3	4	5		
Legislation and Regulations	0.0	1.2	7.3	18.3	34.1	39.0	4.02	1
Risk Management	1.2	0.0	11.0	18.3	28.0	41.5	4.01	2
Hazard Identification Management	1.3	2.5	12.5	16.3	28.8	38.8	3.90	3
Health, Hygiene and Environmental	1.3	2.6	9.0	19.2	33.3	34.6	3.90	4
Cost Management	3.8	6.3	5.0	20.0	43.8	21.3	3.71	5
Emergency Preparedness	1.3	5.0	12.5	21.3	31.3	28.8	3.67	6
Procurement Management	4.9	3.7	11.0	26.8	30.5	23.2	3.62	7
Accident or Incident Investigation	1.2	2.4	17.1	22.0	32.9	24.4	3.60	8
Communication Management	2.5	7.6	12.7	24.1	26.6	26.6	3.53	9

Table 5 Extent to which CPD would contribute to an enhancement of respondents' knowledge and skills relative to five SACPCMP scope of services' areas

Scope of services' area	Response (%)							
	Unsure	Minor				Major	MS	Rank
		1	2	3	4	5		
Construction H&S continual improvement	0.0	3.7	4.9	21.0	38.3	32.1	3.90	1
Construction project H&S management system	3.7	3.7	6.1	17.1	40.2	29.3	3.89	2
Construction H&S management	2.4	1.2	12.2	20.7	30.5	32.9	3.89	3
Construction H&S	1.3	3.8	8.8	18.8	36.3	31.3	3.84	4
Construction H&S performance management and monitoring	1.2	3.7	8.5	20.7	36.6	29.3	3.80	5

Table 6 Extent to which CPD would contribute to an enhancement of respondents' knowledge relative to eight composite knowledge areas

Composite knowledge area	Response (%)							
	Unsure	Minor				Major	MS	Rank
		1	2	3	4	5		
OH&S	1.2	3.7	12.2	13.4	40.2	29.3	3.80	1
Law	2.4	6.1	7.3	24.4	31.7	28.0	3.70	2
Management/Management of parameters	11.0	3.7	12.2	20.7	31.7	20.7	3.60	3
Design	8.6	7.4	7.4	23.5	32.1	21.0	3.57	4
Financial management	8.5	6.1	6.1	26.8	36.6	15.9	3.55	5
Planning	3.8	6.3	10.1	29.1	25.3	25.3	3.55	6
Project adminstration	3.7	6.2	9.9	25.9	35.8	18.5	3.53	7
Construction technology/Technology	7.3	9.8	4.9	28.0	29.3	20.7	3.50	8

(major), and a MS ranging between 1.00 and 5.00. Given that all the MSs are > 3.00, it can be deemed that CPD would contribute to an enhancement of such skills to a major as opposed to a minor extent. It is notable that there is a difference of 0.33 between first ranked technical and seventh financial construction technology/technology. 5/7 (71.4%)

Table 7 Extent to which CPD would contribute to an enhancement of respondents' knowledge relative to seven composite skills areas

Composite skills area	Response (%)							
	Unsure	Minor				Major	MS	Rank
		1	2	3	4	5		
Technical	3.6	7.2	3.6	21.7	42.2	21.7	3.70	1
Leadership	2.4	3.6	15.7	24.1	26.5	27.7	3.60	2
Interpersonal/Developmental	4.9	4.9	14.6	22.0	29.3	24.4	3.56	3
Planning	1.2	6.0	10.7	26.2	36.9	19.0	3.53	4
Negotiating	2.4	2.4	19.0	22.6	33.3	20.2	3.51	5
General management	3.6	4.8	14.5	33.7	26.5	16.9	3.38	6
Financial	4.8	4.8	14.5	28.9	34.9	12.0	3.37	7

MSs are $> 3.40 \leq 4.20$, which indicates CPD would contribute to an enhancement of the skills between some extent to a near major/near major extent. Technical ranked first, is followed by leadership, interpersonal/developmental, planning, and negotiating. General management, and financial (28.6%) have MSs $> 2.60 \leq 3.40$, which indicates CPD would contribute to an enhancement of the skills between a hear minor to some extent/some extent.

4 Discussion

Respondents' source of H&S knowledge is predominantly informal, which aligns with the findings of previous studies.

The literature indicates that in terms of composite knowledge areas, both CHSAs and CHSOs are rated above average relative to only 3/8 (37.5%) areas. In terms of composite skills areas, CHSAs are rated above average relative to only 3/7 (42.9%) areas, and CHSOs above average relative to 5/7 (71.4%) areas. No prior studies have been conducted relative to CHSMs.

CPD would contribute to an improvement in respondents' knowledge and skills relative to nine SACPCMP knowledge areas and five SACPCMP scope of services' areas to a major, as opposed to a minor extent. CPD would also contribute to an enhancement of respondents' knowledge relative to eight composite knowledge areas and seven composite skills areas to a major, as opposed to a minor extent, which findings correlate with the findings of literature in that ratings relative thereto indicate potential for improvement.

5 Conclusions

There is a potential for construction H&S practitioners to enhance their knowledge and skills. The extent of the potential is likely to be attributable to the extent of tertiary education, and that the predominating source of H&S knowledge is informal.

CPD is necessary and should be provided by the SACPCMP and ACHASM relative to all the knowledge and skills areas, and especially the non-H&S knowledge and skills areas. Furthermore, contractors should provide in house courses relative to all the knowledge and skills areas, especially the non-H&S knowledge and skills areas such as planning and construction technology. Other necessary interventions include the development of practice notes and guidelines by the SACPCMP and ACHASM.

Finally, undergraduate and honors level construction H&S qualifications are necessary to remedy the situation in a sustainable manner. It should be noted that the re-curriculation of South African tertiary education has resulted in the development of such courses.

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Construction Contingency Determination: A Review of Processes and Techniques

Richard Emeka Adaurhere, Innocent Musonda, and Chioma Sylvia Okoro

Abstract

Contingency provision on a construction project is one of the risk management techniques embraced by project owners to deal with project unanticipated expense (spending) and time overruns. However, contingencies could be overestimated or underestimated. The current study, therefore, investigated how contingency is determined on construction projects and the benefits of contingency planning. A literature review was undertaken from various databases including Academic Search Complete, Google, Goole Scholar, Ebscohost and others. The materials used were selected based on their possession of the keywords related to the study. Thematic content analysis was used to identify themes on cost and time contingency planning process and techniques. The findings revealed that the process of cost contingency determination entails identifying different scenarios of events and risks, and developing the plans based on the potential responses to the identified risks. Further findings revealed that various techniques may be used in the process and practice of estimating cost and time contingencies. The findings are envisaged to be beneficial to construction stakeholders to assess and improve on contingency planning process on projects.

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Keywords

Construction • Contingency • Planning • Project management

1 Introduction

The construction industry contributes to the gross domestic product (GDP), employment and capital formation in an economy (Kraaz et al. 2014). The sector is the biggest industrial employer recording to around 7% in many nations and making up around 9% of the world's GDP (Horta et al. 2013). However, most often, construction projects overall make a nationwide headline for being a financial disaster as opposed to the accomplishment of the critical engineering contribution that it adds to the improvement of our built environment (Oppong 2013). Construction projects are faced with various risk and uncertainties, including conceptual cost estimation (Jackson 2012). The construction industry had thus gained a poor reputation for delivering project over the estimated budget and time plans. Due to the numerous risks associated with project deliveries, project owners tend to make provision for contingencies, as part of the costs at the planning stage, which are able to absorb monetary impact risk/uncertainty and variability. These contingencies can be in the form of (money, time, quality specification, man-hours, machine-hours and rawmaterials), which are put in place to ensure that the project objectives of time, quality and scope are not jeopardized due to any unforeseen risk that might arise during project execution. Contingencies are planned in order to hedge and absorb these risks (Ortiz-González et al. 2014). However, construction projects hardly live up to the plans because of the risks related and the general vulnerable and stochastic nature of construction projects (Dos Santos and Jungles 2016). These risks should be recognized and overseen in the planning stage. This is even more important given the complex nature of

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construction projects with hidden and apparent costs. Therefore, research on how contingency amounts are determined and the benefits of contingency planning in construction projects warrant attention.

Previous similar studies on contingency planning have dwelt on schedule delays and plan contingency (Dos Santos and Jungles 2016), or on the techniques and did not include the process of contingency planning (Baccarini 2004). Further, (Ortiz-González et al. 2014) investigated management of contingencies among Spanish contractors and found that about half of the site managers do not typically include time and cost buffers in their budgets and schedules and when contingencies are established, it is usually done in a subjective manner. However, the study did not reveal the processes undergone or the factors considered in contingency planning. Other studies which considered factors affecting contingency determination employed risk analysis and fuzzy logic system (incorporating subjective notions of contractors) (Panthi et al. 2009; Idrus et al. 2011). The objectives of the study were, therefore, to investigate the processes and strategies for contingency determination and the pros and cons of inadequate contingency planning. The findings of the study are significant because if projects are delivered without adequate determination and management of contingencies, they may not perform as planned. The succeeding sections of this paper present the findings from a literature review on the factors that should be considered in the contingency planning process, irrespective of the various stakeholder views.

2 Methods

The present paper presents a review of literature based on international context with the aim of identifying how contingencies are determined and the benefits of adequate contingency planning. To achieve this objective, a distillation of related literature from online databases including Google, Google Scholar, Ebscohost and Science Direct, was undertaken. Various sources including accredited journals, conference proceedings and organization websites were consulted. The materials used were selected based on their possession of the keywords related to the study, including contingency planning, risk management, construction contingencies and project management. Thematic content analysis was used to identify themes on contingency planning influencers and considerations. The succeeding sections present the review of related literature on the themes, summary of findings, conclusion and recommendations.

3 Construction Contingency Planning

3.1 An Overview

Construction projects are typically a once-off endeavour with numerous unique features, for example, different project members, long maturation periods (between origination-design construction), composite acquisition procedure, huge fiscal requests and dynamic organization configurations. All these have made the risk and vulnerabilities identified with construction projects more peculiar as compared to other sectors. Though literature revealed that construction risk can't be disposed of, it can be relieved and overseen successfully. Thus, if project risk and unprecedented attributes are recognized and measured at the beginning times of the project, this will ensure that all relevant project stakeholders (customers, experts and contractors) will strive to accomplish project goals of cost, time, quality and safety.

The success of construction projects, generally viewed as being completed on time, within the budget plan and the quality fulfilled by all, is charaterised as much preferred outcomes over the normal or ordinarily acquired. Nonetheless, the term project success is a foundation to manage and control the current project, in order to plan and orient the future project (Chovichien and Nguyen 2013). It assumes that things that cannot be estimated cannot be improved. This is the basis of adequate planning in construction project development. The planning and control of costs cannot be successful if the extenuations are not evaluated and planned for at the initial stage of the projects.

The term contingency, used in this document in a generic manner, is mainly employed by a number of authors to describe the amounts of money that budgets often include in order to prevent cost overruns related to unforeseen, unexpected or underestimated events (Ortiz-González et al. 2014). However, there are various other forms of contingencies including time (buffers) to accommodate project delays, material stock piles buffers, work in process buffers, capacity (manpower, tools and equipment), plan buffers, as well as scope and quality buffers (Ortiz-González et al. 2014). According to (Jackson 2012), contingency is viewed differently, but the various stakeholders in a project. To engineers, contingency is a savings account that can be drawn on to take care of the extra expenses of miscalculated or excluded project costs; to the construction division, it is an amount used to take care of extra expenses caused by longer schedules, construction issues and lower profitability; to the cost engineer, it is an amount that can be utilized to take care of higher expenses because of the absence of definition at the evaluating stage, including miscalculation of material, gear, labour and indirect expenses. The two main types of contingencies are further discussed hereunder.

3.1.1 Cost Contingency

Contingency cost is a reserve fund added to the total assessed project cost and often it is communicated in percentage terms (Bakhshi and Touran 2014). "Cost" is alluded to as the level of fulfilment of construction work within the assessed spending plan. A project's total cost is often broken down into two parts, namely: base cost and contingency cost. Base cost is the expense of the project which omits contingency. The total cost is not just bound to the tender sum, but incorporates any expenses that emerge from varieties, changes amid the construction time period, including impact of changes in the price of labour, material, plant, preliminary items and specialist subcontractors, as well as costs brought about by lawful cases, for instance, litigation and arbitration (CIDB 2017). This underlines the relevance of more accurate cost determination or estimation techniques at the planning stage of projects, to cater for project exigencies or unexpected occurrences from a reserve of funding termed "contingency".

3.1.2 Time Contingency

The term 'time contingency' is characterized as the measure of time added to the base assessed project time to accomplish a particular certainty level or to take into account changes where experience indicates commitment (Mohamed et al. 2009). It can likewise be characterized as the measure of time put aside to manage construction vulnerabilities, risk of overruns of project goals to a satisfactory level (PMI 2000). Time contingency is viewed as a stand out amongst the most basic instrument used in a construction project to foresee or to givea sensible time frame. Because of this reason, satisfactory estimation of time contingency will help towards minimization of overspending plan and help to prevent completion delays in projects (Mohamed et al. 2009).

Contingency is utilized to guarantee the fruition of time of a project and all things considered gives a level of certainty that the planned duration be accomplished. Most managers and engineers depend on their experience of deciding on schedule and cost contingency (Mohamed et al. 2009). On their part, (Park and Peña-Mora 2004), evaluated time contingency as 20% of the project period, while (El-Karim et al. 2015), presented an approach that joins network analysis incorporating flexible scheduling in risk strategy and plan analysis due to changes as a result of the complexity of construction projects. The study (El-Karim et al. 2015), examined the impact of different factors on time contingency utilizing a linear equation. Further, (Illsley 2006), expressed that in the industrial division, there are numerous project scheduling programming, for example, Primavera and Microsoft Project; in any case, the most prominent is Risk Expert. This is on the grounds that it gives quantitative and qualitative examinations of project data, which is utilized to give a clearer image of the genuine expense and time size of any project considering risk, punishments and complex scheduling factors.

These varying views, therefore, make it difficult to determine the amount to be set aside for contingency on a particular project. However, certain factors affect the determination or planning for contingency in order to deal with unanticipated expenses and spending overruns, which are not considered or satisfactorily took into account at the planning phase (Amade et al. 2014). This is the premise of the current study.

3.1.3 Material and Labour Contingencies

Related to the costs of construction are project resources such as material and labour required to successfully complete a given project (Enshassi and Ayyash 2014). Considerations made at the time of concept and planning of projects should include these which may constitute risks in building projects (Lam and Siwingwa 2017). Hence, in preparation of bids, estimates should include thorough assessment and planning for project resources.

3.2 Benefits of Contingency Planning

Contingency planning helps to ensure that response is composed in light of the fact that objectives, procedures, roles and duties are cleared up ahead of time (International Federation of Red Cross (IFRC) 2019). In addition, (Hobbs 2010), added that the benefits of contingency reserve in a projects are as follows:

- This reserve fund is important to guarantee smooth fulfilment of design and construction, with no risk to the project caused by an absence of accessible funds.
- The contingency amount put aside as a cost contingency in the project is a component of the cost risks related to the project at that time.
- The incorporation of contingency amount on a project spending plan mirrors the by and large budgetary plan that will be utilized to cover known and unknown components of the projects.
- The value and assessed risk of a project change over its life cycle. For example, the best pre-construction planning will greatly reduce contingency reserve.
- Contingency reserve for design will reduce from the concept design stage to contract document stage.

Undoubtedly, contingency planning guarantees accessibility of standby resource and provides an effective mechanism that can help reduce project disaster response (Waterberg District Municipality. 2014).

3.3 Contingency Planning Process

According to (Choularton 2007; Bridges 2014), the contingency determination process, as depicted in Fig. 1, entails an identification of scenarios of events, determination of imminent risks, developing responses to the identified risks and thereafter, developing a budget to cater for the risks identified.

The first step in the planning process is identifying scenarios of events and having records or rundown of conceivable courses of events that could happen, which forms the reasons behind planning presumption. Notably, scenarios are important scope of conceivable issues and its probabilities, for instance, what planners think could happen, how to work around such issues, what conditions individuals will confront, what effect will the risk will have and what limit individuals should adapt to in such an event, how well to be prepared ahead of time. Developing scenarios is a good way of thinking through the possible impacts, on which basis one can develop a plan that sets out the scale of the response and the resources needed (International Federation of Red Cross (IFRC) 2019). Therefore, scenarios being the foundation of the contingency plan, likewise contains the principle and assumptions used for the development of such a plan (Choularton 2007).

The second step is detecting the imminence of risk. This alludes to the probability of the recognized risk happening and assessing the level of potential harm (Bridges 2014).

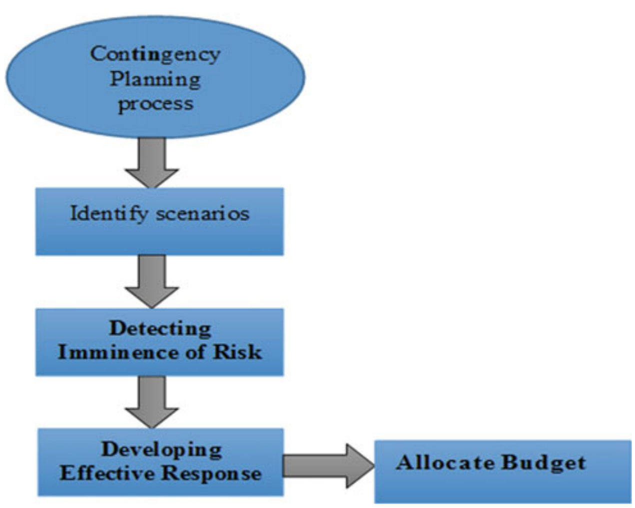

Fig. 1 Contingency planning process (*Source* Bridges, 2014)

Once the risk has been recognized, they ought to be recorded within contingency plan and monitored (Bridges 2014). The risk is categorized by the probability of their occurrence (Bridges 2014). In addition, the impact or severity and distribution of those risks are quantitifed (Panthi et al. 2009).

The third step is for the risk manager to develop effective responses to events in order to relieve possible misfortune should the distinguished risk happen (Bridges 2014). It is suggested that event managers conduct an experimental run of responses created to oversee recognized risk situations, in order to guarantee that they can deal with the management of contingency plan (Bridges 2014).

Lastly, a contingency budget and schedule plan is created and all required will be reliant on the size and unpredictability of the project. For example, most organizations usually add 10%–15% to the base cost for all contingency related expenditure. In addition, it ought to be noticed that while some contingency planning are broadly detailed, others are short and unreal (Bello and Odusami 2009). Nonetheless, planning for contingencies should incorporate all the factors that potentially affect the estimated costs, time and related uncertainties in order to ensure that a project is completed successfully.

In the view of the IFRC (2019), the contingency planning process is an iterative process that involves developing plans, reviewing and refining plans (Fig. 2). In addition, it should be a collaborative effort on the part of all stakeholders involved in the project.

3.4 Contingency Determination Techniques

According to Ayub et al. (2016), the methods used to estimate cost contingency in most construction industries are traditional, qualitative, semi-quantitative, probabilistic, deterministic and simulation-based techniques. The majority of contingency estimation methods available focuses on the initial estimate of time and cost contingency and the most methods used are the deterministic and probabilistic method.

Deterministic approaches are the most basic since they focus on estimating a general percentage of the base cost estimate to include in the budget or the schedule, while probabilistic methods focus on identifying risk and allocating them in an itemized way of time and money to cover the risk (Anderson et al. 2009). Further findings evinced the advantages and disadvantages of these cost contingency determination techniques (Baccarini 2004; Mohamed et al. 2009; Amade et al. 2014; Hamid and Kehinde 2017). These are summarized in Table 1. According to (Baccarini 2004), a variety of techniques are necessary, given the major shortcomings of the traditional judgemental and arbitrary approach to cost contingency estimation, which includes the following:

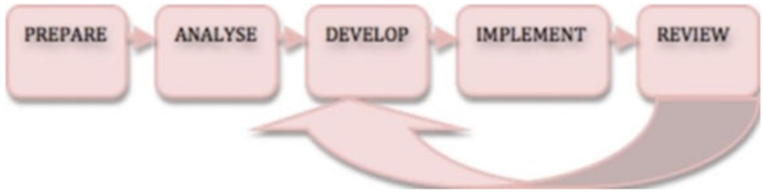

Fig. 2 Steps in contingency planning (*Source* IFRC, 2019)

Table 1 Contingency methods/techniques

Contingency methods/level or area of usage	Advantages	Disadvantages
1. Traditional Percentage Method / Used on all project types	• Convenience and consistency • Subjectivity is expelled from the procedure by the utilization of a consistent percentage	• Problematic for the estimator to legitimize the reason for the percentage utilized • Does not support creativity in evaluating in practice • The risk is either disregarded or managed in a discretionary way
2. Method of Moment/Infrequently used	• The individual cost in the project has its normal values and variance • The normal values and variance for all cost items are included in arriving for the overall project cost	• Because of its mathematical foundation, it is extremely hard to use • Not reasonable for complex and large infrastructure
3. Individual risk- expected value/Used in all project types	• It can model vulnerability as contingencies with particular probabilities can be examined for a better outcome	• Recognizing the fixed and variable components of the project is in respect to the type and nature of the project. Regardless, it receives a conventional approach
4. Monte Carlo Simulation/Used in substantial capital projects	• The model identifies the result of risk identification and effect assessment which can be used to estimate Contingency	• Monte Carlo evaluating method is frequently harder than the traditional strategy • It is once in a while used as a part of the business. It does not specifically give data about the change of the measurable dispersion of the acknowledged net benefits
5. Factor Rating/Used in substantial capital projects	• This technique can be utilized to check the measure of contingency dictated by different strategies for assessing contingency sum • Apart from the capacity to check the contingency sum created by different techniques, it is a strategy for foreseeing its own particular contingency	• Picking the four determinants of the accuracy of the estimate is Seriously deficient. It might prompt high contingency if the estimator is incorrect
6. Range Estimating/Construction road projects	It deals with hopeful and negative closures of estimation. It is more secure than the traditional strategy	• It additionally receives a deterministic approach which makes it less precise compared with regression models
7. Regression/All construction projects, mostly building	• These models depend on historical information of projects, they bring expert information to contingency setting without the requirement for a skilled expert on each project	• It depends on historical cost information which once in a while may not be accessible Tedious to assemble historical cost information
8. Artificial Neural Networks/Roads projects, Oil and gas projects	The forecast precision of this strategy for contingency estimation outperforms that of the traditional technique	Appropriate for non-linear modelling of information. It contradicts the direct approach of regression and different techniques like the Monte Carlo
9. Fuzzy Sets/Significantly on building projects; few highway projects	• It permits examination with small samples • It uncovers relationship between result and illustrative factors	• It is difficult to build up a model from a fuzzy system. For this strategy to be utilized for successful contingency estimation, it requires more fine tuning and simulation before it is operational

(continued)

Table 1 (continued)

Contingency methods/level or area of usage	Advantages	Disadvantages
10. Controlled Interval Memory/hardly used	• The model is accommodated with different perspectives of the project it speaks to	• The numerical structures make it hard to use since management and expert thinks that it's hard to understand
11. Influence Diagrams/Multifaceted construction projects	• It helps to lessen extensive volumes of information that is fundamental to the decision making process	• Like other probability Models
12. Theory of Constraints	• The utilization of this model yields an achievable and immunized plan centred on the Critical path of the work that rules the project through to its execution	• This strategy presumes cost Items are autonomous from each other • This is not correct in a real life application

- Being calculated as an across-the-board percentage addition on the base estimate, typically derived from intuition, past experience and historical data;
- It is usually illogically arrived at and thus may not be appropriate for the proposed project;
- Calculation is difficult for the estimator to justify or defend and the risk is either disregarded or handled in a discretionary way, and so percentage used is sometimes not justifiable; and
- It does not encourage creativity in estimating practice, promoting a routine and mundane administrative approach requiring little investigation and decision- making.

Therefore, other methods including Monte Carlo simulation, range estimating, regression, artificial neural networks and others may be more suitably applied in certain types of projects that others. In summary, if project risks and unprecedented attributes, which cause (envisaged) vulnerabilities in the project, are recognized and measured at the planning stage of projects, success in terms of cost and time control will be achievable.

4 Conclusion

The study sought to investigate the process and techniques for planning and determining contingencies on construction projects. It was found that the process of contingency determination involves identifying different scenarios of events and risks, and developing the budget and schedule plans based on the potential responses to the identified risks. Further findings revealed that various techniques may be used in the process and practice of estimating contingencies. The current study provides information, which is envisaged to be beneficial to construction stakeholders in adequately planning and allowing for contingencies on their projects. Since the current study was a literature review only, further studies are recommended to determine how contingencies are allowed for on construction projects and the level of usage of the identified techniques in practice, using alternative research approaches.

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Practical Application of Natural Pozzolans and Lime for Cost Optimisation in Low-Cost Housing

Dans Nshekanabo Naturinda

Abstract

Portland cement is considered one of the costly construction materials. It is sometimes used in applications where its strength levels are not necessary. This study optimized the use of OPC by considering its substitution with pozzolanic materials to reduce the construction cost. The pozzolanic material used was volcanic ash which is abundant in many parts of Uganda. The ash was mixed with lime and water. The study examined the pozzolan-lime system to determine its optimum performance for a given pozzolan with known mineral composition. The work was experimental involving testing trial mortar cubes of different pozzolan-lime blends and varying pozzolan particle sizes. The results yielded second order polynomial relationships between the achieved compressive strength and the pozzolan-lime content. The optimum blend was determined from the first derivative of the functions. The blends that would yield the highest possible compressive strength values were derived from the absolute critical points of the polynomials, which when substituted into the functions yielded the actual peak values. Using the best fitting polynomial models, the maximum possible compressive strength values were generated. The blends containing pozzolans of 125 µm particle size yielded consistently high peak values for all the experiments. The optimum blend was determined using the 125 µm function, and the pozzolan-lime content that yielded consistent results was between 54 and 60%. The achieved compressive strength was 0.9 MPa, which is expected to increase for pozzolans with finer particles. The values attained are adequate for a number of low-strength construction applications. The use of OPC can be restricted to only structurally-sensitive elements like beams and columns. This would serve to reduce the demand for OPC in housing construction and also reduce the cost of construction.

Keywords

Pozzolans • Volcanic ash • Low-strength construction applications

1 Introduction

Portland cements are the most widely used binders in construction. However, cement-based binders are costly mainly due to high energy requirements for Portland cement production (Day 1990). In spite of its cost, the high demand for Portland cement has been attributed to the little confidence the users have in alternative binders (Spence 1980). When used for small buildings and low-strength applications, Portland cement makes construction unnecessarily more expensive than it ought to be. Habitat (1985) estimates that up to 80% of the worldwide use of cement does not require strength levels of Portland cement. This can only change if the fitness of purpose of cheaper alternatives is explored to reduce the cost of construction. One such alternative is the use of natural pozzolans with lime.

A pozzolan is a material which when finely ground and mixed with lime in the presence of water, reacts to form a cement-like product (Kerali et al. 2007). Addition of natural pozzolans to lime was found to increase the density and reduce porosity of mortar, which increases its strength and durability (Malisa et al. 2014). Significant increases in compressive strength of concrete were also registered by various researchers (Osei and Jackson 2012; Rahmaa and Jomaa 2018).

There are vast deposits of natural pozzolans in Uganda, especially in the form of volcanic soils and other natural earth deposits of similar origin in rift valley areas (Department of Geological Surveys and Mines 1992). Their

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extensive use in construction has been hindered by the suspect quality of their products and lack of adequate information about their performance.

The use of lime binders in construction has become prominent due to its sustainability credentials (Warker and Pavira 2010). Pozzolans have over the years been used to enhance the properties of lime as a binder (Massaza 2002).

2 Objectives, Materials, and Methodology

This study was carried out to examine the pozzolan-lime system to determine its optimum performance for a given pozzolan with know mineral composition. The work was experimental involving trial mortar cubes of different pozzolan-lime blends and varying pozzolan particle size, and tested after 7 days, 28 days, and 90 days of curing.

A fixed effects model was used with 5 different blending levels selected over a uniform range from 10 to 90%. Each grade of the pozzolan defined by the dominant particle size was divided into five proportionate portions and treated to the lime blends of 10, 30, 50, 70, and 90%. Each treated portion was mixed thoroughly with a motorized mixer, and the same quantity of water added to each. All the cubes were subjected to the same curing environment, and tested for compressive strength. The procedure used ensured pre-treatment equality of the sample portions by random assignment. The compressive tests were guided by the test procedure prescribed in ASTM311 detailed under Test Method C109/C109M.

The experiments focussed on two parameters that were found to have significant influence on engineering performance and cost. These include the pozzolan content (blend) and particle size (grade). The investigation assessed each of the parameters independent of the other, and also considered the likely combined effect on compressive strength development of pozzolans lime mortar. The aim was to establish the nature of the effect of each of these parameters, independently and in combination, on engineering performance in terms of compressive strength development, and the extent and significance of such an effect.

3 Results

The variations of trends revealed from the assessment of one factor at a time pointed to the possibility that the observed effect of one factor could actually be dependent on the level of the other factor at which it occurred. Therefore, examination of the interaction between the two factors, pozzolan content and particle size, to influence the observed compressive strength values was conducted. The cross-tabulation of the findings for 90 days is given in Table 1.

Table 1 Compressive strength variation with pozzolan grade and content

7-day tests									
	45 µm	**63 µm**	**75 µm**	**90 µm**	**106 µm**	**125 µm**	**150 µm**	**180 µm**	**212 µm**
10%	0.2968	0.2650	0.2120	0.2014	0.1802	0.1696	0.1484	0.1272	0.1166
30%	0.3604	0.3604	0.2650	0.2332	0.2332	0.2014	0.2014	0.1696	0.1590
50%	0.4240	0.3392	0.3074	0.2014	0.2014	0.2014	0.1590	0.1484	0.1166
70%	0.2544	0.2226	0.2226	0.2226	0.1590	0.1590	0.1484	0.1378	0.0064
90%	0.2544	0.2332	0.2014	0.1802	0.1802	0.1590	0.1166	0.0636	0.0424
28-day tests									
	45 µm	**63 µm**	**75 µm**	**90 µm**	**106 µm**	**125 µm**	**150 µm**	**180 µm**	**212 µm**
10%	0.4134	0.4134	0.3922	0.3604	0.3074	0.2862	0.2650	0.2120	0.0000
30%	0.7950	0.5194	0.4452	0.4240	0.3922	0.3710	0.3710	0.3604	0.2756
50%	0.5512	0.5194	0.4770	0.4452	0.4452	0.3922	0.3074	0.2438	0.2438
70%	0.6360	0.4134	0.4028	0.3286	0.2650	0.2120	0.2120	0.1696	0.1272
90%	0.4558	0.2544	0.2226	0.1272	0.1060	0.0954	0.0636	0.0551	0.0000
90-day tests									
	45 µm	**63 µm**	**75 µm**	**90 µm**	**106 µm**	**125 µm**	**150 µm**	**180 µm**	**212 µm**
10%	0.5194	0.4664	0.4664	0.4400	0.4240	0.3900	0.3816	0.3500	0.3180
30%	0.8480	0.5830	0.5300	0.5088	0.4770	0.4400	0.4240	0.4000	0.3900
50%	0.6200	0.5600	0.5300	0.5000	0.4982	0.4770	0.4558	0.2120	0.2120
70%	0.6890	0.6800	0.6000	0.5500	0.3710	0.2120	0.1908	0.1590	0.1484
90%	0.3816	0.3816	0.3100	0.2400	0.2120	0.1696	0.1590	0.1378	0.0530

This examination established that not only did each factor have an effect on the observed values, but there was also an influence from interaction between the two factors. There was no single blend or grade that produced consistently high or low compressive strength values. As such, the combined effect was found to be more relevant in determining the behavior of pozzolan-lime mortars.

Further examination aimed at optimizing the contribution from both. The 50 and 70% blends exhibited the highest interaction between the two factors at 7 days. The 28-day experiments exhibited clear interaction between the two factors for all the blends except for the 10 and 90% experiments. Observations from long-term experiments after 90 days showed virtually no interaction for the 10 and 90% blends. Figure 1 presents the findings for the two-factor interactions.

The high interaction exhibited by the 50 and 70% blends at 7 days indicates the need to have both lime and pozzolans

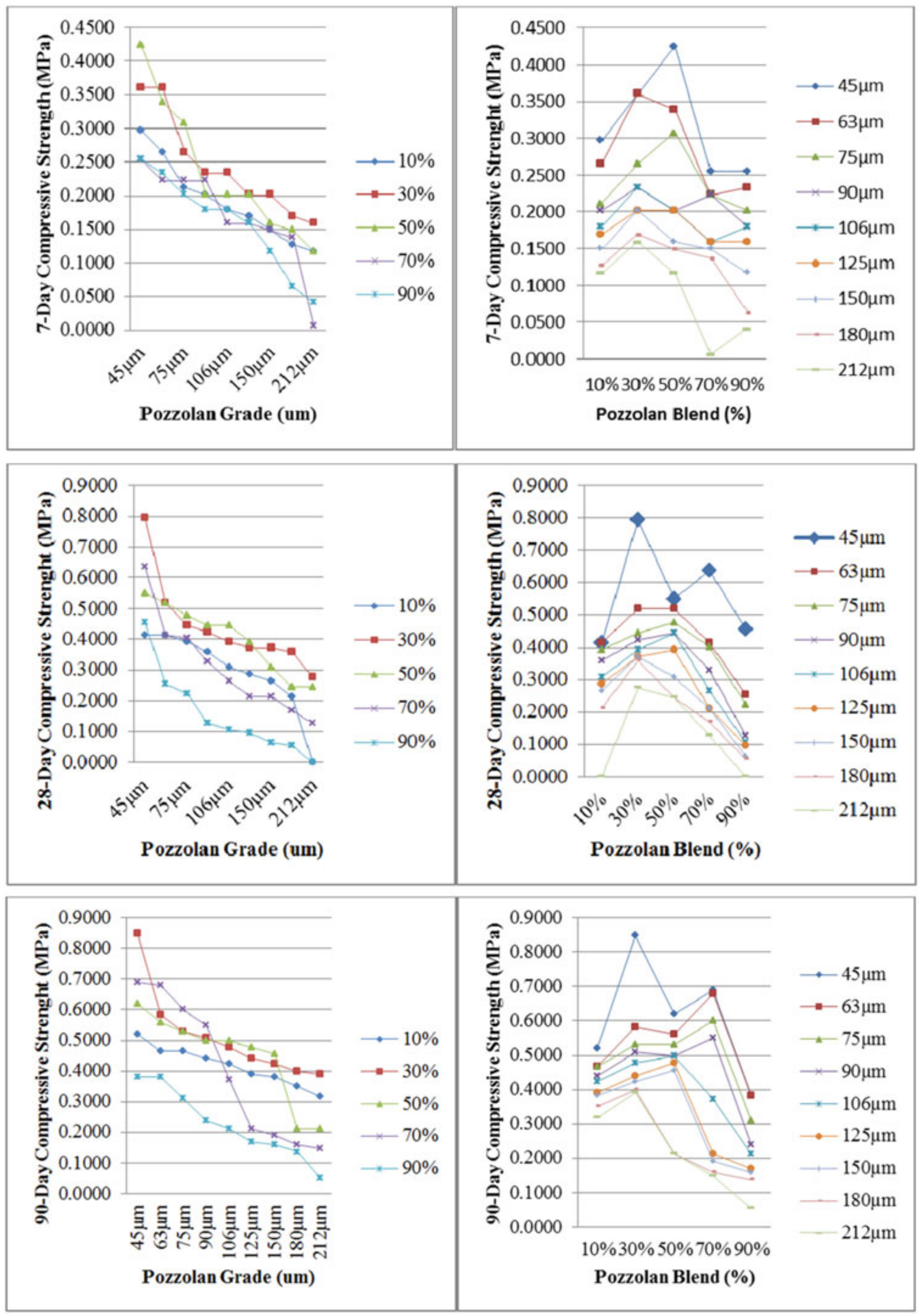

Fig. 1 The two-factor interaction for 7-day, 28-day and 90-day experiments

in comparable proportions skewed towards more pozzolans. On the other hand, the improved interaction at 28 days can be attributed to prolonged contact between pozzolans and lime that allowed more of the reactive compounds to contribute to the compressive strength development. The 90-day findings affirmed the inference that for higher quantities of either constituent, there is little or no interaction of the dependent variables, and any observations made could be a result of the filler effect of the excess material.

4 Discussion

The interchange in performance between 50 and 70% mixes with respect to maximum attainable compressive strength and stability against changes in grade over time, implies that in between the two mixes lies the mix that would yield optimum performance. This mix was established by examining the variation of compressive strength with respect to the pozzolan content in the mix. The observations revealed significant interaction of the pozzolan content and pozzolan grade in influencing compressive strength for the 50% and 70% blends. This interaction was consistent for the entire duration of the experiments as opposed to other blends that exhibited interaction only for ultimate strength tests. Interaction was also observed for the fine grades up to 125 μm. This upper limit of pozzolan grade would enable effective reaction of the pozzolan and lime. Any finer grades would be more expensive to produce, while less fine grades would be less effective in compressive strength development.

The experiments generally confirmed that the compressive strength of the pozzolan—lime system increases up to a certain point beyond which it begins to reduce. The peak points for early age compressive strength are skewed to the right. This implies a bigger influence by pozzolans on the early peak compressive strength attainable than lime. However, the peaks are closer to the 50% pozzolan content level than the 90% content, which implies the need for pozzolans and lime in comparable proportions.

The pozzolan blends that registered peak early age compressive strength for all pozzolan grades were above 50%. However, these followed no particular trend. This is an indication of no clear link between the blend that gives peak strength and the pozzolan grade. While the compressive strength generally increases with finer grades, it was not the case with the critical blends producing peak compressive strength values. This suggests greater stability for pozzolan content with respect to compressive strength variability. Hence, irrespective of the pozzolan grade, the range of the pozzolan content that gives peak strength varied less.

Where two factors are contributing to the observed effect, the effect of each factor depends on which level of the other factor it occurs (Navidi 2008). This is a result of the interaction of the two factors in contributing to the observed effect. It was, therefore, important to establish the level or range of each of the factors within which the observed effect is optimized sustainably and consistently. The derived polynomial expressions were used to predict the range within which interaction consistence is maintained. The pozzolan content was varied between 0 and 100% in the 7-day, 28-day, and 90-day experiments with the 125 μm grade to obtain the resultant illustrations given in Fig. 2.

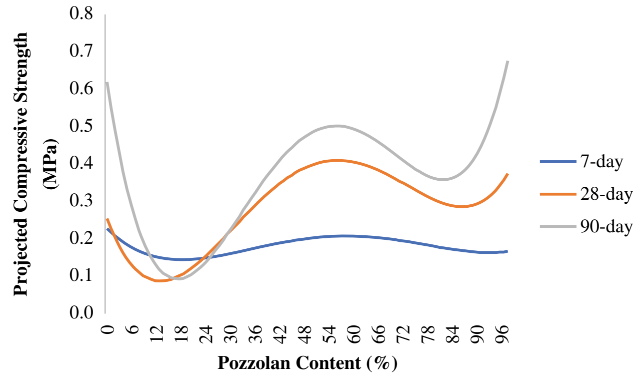

Fig. 2 Prediction of optimal strength development in the pozzolan—lime system

It can observed that the range of pozzolan content that gives the same strength values for the same duration irrespective of the pozzolan content is 47% to 68%. It is in this region that there is noticeable increase in compressive strength values between 7-day, 28-day, and 90-day experiments, irrespective of the pozzolan content. The best results are however obtained in the range of 54–60% pozzolan content.

5 Conclusions

It can be deduced from the findings that the best compressive strength performance values can be obtained in the pozzolan-lime system if the predominant pozzolan particle size is in the range of 125 μm, and the pozzolan content between 54 and 60%.

The maximum strength attainable for any grade is less sensitive to pozzolan content, provided adequate pozzolans are available to react with the available lime. This is important in practice as it may not be practical to have strict content guidelines for a craftsperson using the material. This should provide confidence in application because the less sensitivity of attainable strength values over a wide range of pozzolan content values allows for greater flexibility when using the material.

The registered peak value for compressive strength was 0.9 MPa. This is much more inferior to that attained with Portland cement, but would pass for a number of low-grade mortars and low-strength construction applications like mortars and soil stabilization.

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External Components of Premature Construction Project Closure

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Abstract

Construction project failures are often attributed to the slackness of different project stakeholders. However, it is important to note that the success or failure of construction projects can span from characteristics that could either be internal or external to the project. Thus, this study explores the elements external to a construction project that can lead to premature closure. Data for the study was gathered through a survey of construction professionals within the Gauteng Province of South Africa. The questionnaire survey was designed to collect data pertinent to achieving the aim of the study. The data gathered was analysed using descriptive analysis to rank the measured factors. The results revealed that environmental, social and political considerations are the important elements that lead to the failure of construction projects and lead to premature closure. It was, therefore, concluded that before project take-off, various environmental forecasts and analyses should be conducted to reduce the probability of project flow interruption, thus reducing the risk of closing projects prematurely.

Keywords

Project external factors • Project failure • Project success • Construction projects • Premature project closure

1 Background

Construction projects are controlled by a budget, schedule, as well as a scope of work which are set for a specific purpose to be achieved within a stipulated period. However, some projects do not end successfully as they might have to be terminated before their goals and objectives are met (Havila et al. 2013). Youker (1992) argued that the success or failure of a construction project often depends on the environment. Similarly, Arman et al. (2009) also pointed out that factors that may lead to premature project closure may be internal or external to the project. Kuye (2004) submitted that a project is doomed if it is managed in isolation from its environment. It is, therefore, essential to study, analyse and gain a perfect understanding of construction project environment in order to effectively and strategically plan for all possible external anomalies that could affect the project (Kuye 2004). The volatility of the present-day business environment significantly affects construction projects and dominantly poses a risk of project failure even before projects are commenced (Akanni et al. 2015). This means that construction project management team must ensure there are smooth relations with all environment dynamics that can affect project decisions, directions, actions, size, health, profitability and performance (Ansah and Sorooshian 2017).

To ensure uninterrupted progress in construction projects execution, Bennett (1991) advocates that construction project leaders must essentially be cautious of external environmental factors. It is also important to note that the more volatile a project environment is, the greater the risk of project failure (Ansah and Sorooshian 2017). Numerous projects have been affected and subsequently shut down because of external surrounding issues including environmental, social, political, economic, climatic as well as geological conditions (Akanni et al. 2015). In view of this, the current study was channelled to examine the elements external to a project that can cause premature project closure.

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Social influence on projects is on the increase with major concerns on the quality of their immediate built environment. Although securing necessary documentation and approval from relevant parties is vital, it does not necessarily guarantee that the immediate society where the project is located will not challenge or try to instigate project shut down (Uher and Loosemore 2004). For instance, a local building council may approve a project proposal to construct a high-rise building within a high-density residential area, but residents may oppose such construction projects by claiming it would increase traffic, noise, security threats, and destroy the unique character of the neighbourhood (Uher and Loosemore 2004). In addition, economic changes affect all national sectors and the construction industry is no exception. Construction projects could get stranded if credit insurance becomes increasingly tough to obtain, thus causing construction companies which are heavily reliant on financial institutions for capital funding to experience difficulties which in some extreme cases cause bankruptcy (Nistorescu and Ploscaru 2010).

Due to political differences, government policies are bound to change, which will affect different phases of a construction project as well as project duration. Government instability usually can bring about premature project closure especially in large-scale projects (Uher and Loosemore 2004). The government is a very important stakeholder in the construction industry as it usually can be the construction client, funder, economy regulator, and construction environment regulator. Regulating the construction environment gives the government power to influence any development and building approval processes and enforce compliance within the stipulated regulations (Uher and Loosemore 2004). Sunjka and Jacob (2013) forwarded that when there is a change in government, policies are bound to also change which might cause certain projects to close prematurely. For instance, a change in monetary policy will affect the cost of construction materials and equipment. In such cases, contractors might find it extremely difficult to continue with the project at the agreed cost which might, in turn, lead to premature project closure. Similarly, Doraisamy et al. (2014) submitted that government policies are not always consistent, thus bringing lack of accountability. Moreover, the government is known for corruption, which affects the construction industry and its projects.

According to El-Rayes and Moselhi (2001), construction projects are sensitive to change in weather conditions, which often leads to a substantial loss in efficiency as well as output, and in some rare cases, premature project closure. Since construction projects are executed usually in an outdoor environment, projects must be subject to Environmental Impact Assessment. All construction projects in any geographic location are subject to different types of natural disasters such as windstorms, volcanoes, earthquakes, floods and other hazards. Since the occurrence of such incidences cannot be precisely predicted, and their impact on projects must be well understood in order to take necessary assertive actions (National Institute of Building Sciences 2018).

2 Research Settings

The concise theoretical background of this study has discussed various external components that can lead to premature project closure in line with the objectives of the study. Hence the study was channelled to follow a descriptive nature. The quantitative model was adopted and thus survey was the appropriate tool for collecting the primary data for this study. A five-point Likert scale structured questionnaire was used to collect data with the sole purpose of achieving the objective of the study. Primary data was sourced from built environment professionals in Gauteng Province of South Africa. A total of 120 questionnaires were distributed and 82 were retrieved and deemed usable for this study after they were checked for completeness. The data collected through the questionnaire were analysed using mean item score (MIS) and presented in tables as shown in the succeeding section of this paper.

3 Findings

Background data collected revealed that 47.56% of the respondents are Civil Engineers, 21.95% are Construction Project Managers, 12.20% are Quantity Surveyors, 9.76% are Architects, 6.10% are Contracts Managers and 2.44% are Project Managers. Distribution of the respondents based on the length of work experience in the construction industry shows that 64.63% has 1–5 years of experience, 30.49% has 6–10 years of experience while 4.88% has above 10 years of experience in the construction industry. 61.11% of the respondents worked in the private sector, 32.94% of the respondents worked for both private and public sectors while 6.15% of the respondents worked in the public sector. The background information reveals that the respondents widely cut across different built environment professions and are engaged in different sectors of the economy. From this, it can be assumed that data collected in this study is reliable.

Table 1 ranks external components that contribute to premature project closure. From the table, it can be deduced that possible damage to the environment, weather conditions, social influences and natural disasters are at the top of external factors responsible for premature project closure with mean item scores of 3.78, 3.77, 3.71 and 3.70, respectively. Since all components measured are above the

Table 1 External components that contribute to premature project closure

External components	Mean item score	Standard deviation	Rank
Possible damage to the environment	3.78	0.754	1st
Weather conditions	3.77	0.708	2nd
Social influences	3.71	0.728	3rd
Natural disasters	3.70	0.732	4th
Political instability	3.55	0.834	5th
Disruptions caused by hostile activities (e.g. riots)	3.51	0.671	6th
Economic instability	3.40	0.664	7th

average value of 3, and it could be purported that all the elements are significant external factors that could easily lead to premature project closure.

4 Discussion

Abbasi et al. (2014) agrees with the results of the current study as it confirmed that possible damage to the environment and extreme weather conditions as possible causes of premature project closure. Furthermore, the construction industry conducts most of its projects outdoors, leaving the projects sensitive to weather conditions such as rainfall and sunlight. Results from the study conducted by El-Rayes and Moselhi (2001) agree with these findings as it affirms that weather conditions may favour or sabotage a construction project. Too much rainfall may lead to a project being terminated before objectives are met, and too many sunny days may assist in swift completion. On the other hand, Uher and Loosemore (2004) also noted that the society can push or delay a project, thus causing it to close prematurely. Sunjka and Jacob (2013) believes political instability can cause premature project closure in the construction industry.

The empirical findings and theoretical review of this study revealed that the construction industry is easily influenced by the geographical location of a project. Some geographic locations are more prone to natural disasters such as windstorms, volcanoes, earthquakes, floods and other hazards which can lead to premature project closure. In addition, weather conditions, social, economic and political influences may also easily cause a project to close prematurely. They could either lead to a project's objectives being met before the deadline or lead to a project being prematurely closed before objectives are met. Therefore, external environmental considerations are a very important part of project success. Since individual construction projects are part of a larger environmental system, it is imperative to take all necessary precautions to mitigate the effects of the surrounding physical and nonphysical environment on projects. Most importantly, various environmental forecasts and analyses should be conducted as part of the project planning phase to reduce the probability of project flow interruption, thus reducing the risk of closing projects prematurely. In risk management, it is important to learn from past mistakes, this will help in making swift and better project decisions.

5 Conclusions

Construction projects cannot be carried out in isolation of its external environment as both the physical and abstract surrounding influences project progress and success. Since it is the ultimate goal of every project to successfully reach a state of completion with all project objectives achieved, it is imperative to take into consideration all components external to the project that may hinder the smooth completion of the construction project. In view of this, the study found out that environmental, climatic, social, and political considerations are major external components that could determine the success of a construction project. Although construction projects cannot be completely void of environmentally or naturally occurring interruptions, they could be adequately managed in such a way that will reduce impacts on projects. Adequate forecast should be carried out and critically analysed in order to develop suitable strategies that could be deployed to mitigate the effects of these external components thus increasing the probability of project success.

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Health and Safety Elements of Premature Construction Project Closure

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Abstract

Construction projects are usually bounded by a predefined start and end date within which project objectives must be met. Negligence by one or more project stakeholders often results in project failure; however, other internal factors can also cause a project to fail. Thus, this study explores the health and safety components that can lead to premature construction project closure. Data for the study was gathered through a survey of construction professionals within the Gauteng Province of South Africa. The data gathered was analysed using a quantitative model to rank the measured factors in terms of their mean item scores. The results revealed that accidents, air quality considerations, and not providing various safety gears pose the most risk to the successful completion of construction projects. It was therefore concluded that proper plans and strategies should be put in place to reduce the risk of occurrence of hazardous events. Lastly, necessary emergency actions must be stipulated for any kind of unexpected occurrence that could jeopardize the wellbeing of workers.

Keywords

Construction health and safety • Project failure • Project success • Construction projects • Premature project closure

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1 Background

Projects are supposed to end when the predefined project goals have been met. Then again, when project objectives cannot be met or there is no longer need for the project, the project will be terminated prematurely. According to Doraisamy et al. (2014), a project may face difficulties and challenges that lead to it being abandoned and closed. In delivering construction projects successfully, clients and construction professionals face several obstacles as a result of the complex nature of construction projects (Doloi 2009). Havila et al. (2013) submitted that project stakeholders must remain proactive in order to ensure construction projects are completed successfully and within its success parameters.

Belassi and Tukel (1996) submitted that numerous factors are responsible for the successful completion of construction projects. A number of studies like that of (Alzahrani and Emsley 2013; Thomas Ng et al. 2009; Palaneeswaran and Kumaraswamy 2001) also attributed successful completion of construction projects to efficient project leadership. Similarly, Meredith and Mantel (2012) noted that usually, projects might need to close for internal reasons within the project. This kind of project closure essentially terminates all activities associated with the project irrespective of what stage they are, or the amount of funds, energy and time have been invested in the project. In another light, construction projects are considered as high-risk series of activities, detrimental to human health (Winge and Albrechtsen 2018). In view of this, the current study was guided to explore the health and safety considerations that lead to premature closure in construction projects.

Health and safety concerns remain a delicate matter in construction projects. This can be attributed to the fact that the construction industry is characterized by a very high number of accidents (Winge and Albrechtsen 2018). Bird (Bird and Germain 1986) submitted that the days of attributing accidents as a random phenomenon are over. Accidents are caused by a series of actions that could be

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avoided if recognized, comprehended and efficiently managed. It is worthy to note that these accidents do not only alter the wellbeing of workers but could ultimately lead to fatalities and demoralize the families involved (Hinze 2002). Waehrer et al. (2007) also pointed out that accidents are also sources of damages to clients and construction firms which might instigate a shutdown of current projects. Studies carried out by (Ale et al. 2008; Lipscomb et al. 2000) pointed out that the most frequent 'accident types' in construction projects include; being hit by falling objects; contact with moving parts of a machine, electrocution, falls from height such as roof, upper floor, platform, ladder, and scaffold.

In the study conducted by Wu et al. (2015), it was observed that safety in construction projects can be jeopardized by four main issues which are; safety climate—the common perceptions on safety among employees. Safety culture—the beliefs of a company on safety issues. Safety attitude—the mental state of workers during a project. Safety behaviour—the actions of workers as regards to safety. Furthermore, studies carried out by Winge et al. (2019) pointed out seven causal factors of occupational accidents. The first is 'workers action' which includes mistakes, dangerous acts, defiance of standard procedures, and cutting corners. Next is 'workers capabilities' which involves workers not knowing how to handle equipment, perform a task, or identify a hazardous situation. Third on the list is 'immediate supervision' which involves supervisors not properly planning activities in such a way to control dangerous situations and reduce the risk of accidents. The fourth is 'local hazards' which are perils peculiar to construction sites and they could be properly managed when identified. The fifth is 'usability of resources' which refers to the lack of specific material or equipment needed for a task. Sixth on the list is 'project management' and it refers to omission or misunderstanding of details of the project or activities within the project. Last on the list is 'Risk management' which involves inaccurate assessment of risks. Alarcón et al. (1457) suggested that occupational safety within construction projects can be enhanced if construction companies adopt the best combination of safety practices that suit the size and nature of its organizational structure.

2 Research Setup

The background of this study has discussed how health and safety considerations can jeopardize the successful completion of construction projects. It further outlined different actions that could lead to health and safety hazards on project sites. In view of this, the research was streamlined into a descriptive study and thus, the survey method was deemed appropriate for collecting the primary data. The research adopted a quantitative model and thus a five-point Likert scale structured questionnaire was designed and used as the medium of collecting primary data with the sole purpose of achieving the aim of the study. Primary data was sourced from built environment professionals in Gauteng Province of South Africa. A total of 120 questionnaires were sent out to prospective respondents. 82 questionnaires were retrieved back and serve as the basis for this research after they were checked for completeness. The retrieved questionnaires were analysed using descriptive statistics and presented in terms of their ranked mean item scores in the succeeding section of this paper.

3 Findings

Background data collected revealed that 47.56% of the respondents are Civil Engineers, 21.95% are Construction Project Managers, 12.20% are Quantity Surveyors, 9.76% are Architects, 6.10% are Contracts Managers and 2.44% are Project Managers. Distribution of the respondents based on the length of work experience in the construction industry shows that 64.63% has 1–5 years of experience, 30.49% has 6–10 years of experience while 4.88% has above 10 years of experience in the construction industry. 61.11% of the respondents worked in the private sector, 32.94% of the respondents worked for both private and public sectors while 6.15% of the respondents worked in the public sector. The background information collected in this study reveals that the respondents extensively span across various construction-related fields and are engaged in both public and private sectors. In line with this, it can be assumed that the data retrieved from the respondents is reliable.

Table 1 ranks the health and safety elements that contribute to premature project closure. From the table, it can be deduced that vehicle-related accidents; respiratory concerns; lack of personal protective equipment; lack of first aid and fire safety training drills; materials and equipment handling, and psychological state of workers are at the top of health and safety components responsible for premature project closure with mean item scores of 3.89; 3.88; 3.84; 3.84; 3.82; and 3.82 respectively. Since all components measured are above the average value of 3, it could be purported that all the elements are significant health and safety factors that could easily lead to premature project closure.

4 Discussion

Khodeir and Mohamed (2011) emphasized the importance of practicing health and safety strategies in the workplace as a way of minimizing injuries which may lead to premature project closure. Abbasi (Project Failure Case Studies and Suggestion 2014) agrees with the findings of the current

Table 1 Health and safety elements that contribute to premature project closure

Health and safety elements	Mean item score	Standard deviation	Rank
Vehicle related accidents	3.89	0.994	1st
Air quality and respiratory concerns	3.88	0.921	2nd
Lack of personal protective equipment	3.84	0.675	3rd
Lack of first aid and fire safety training drills	3.84	0.909	3rd
Materials and equipment handling	3.82	0.904	5th
Psychological state of workers (stress)	3.82	0.904	5th
Unavailability of warning signs	3.79	0.871	7th
Violence on site	3.78	0.952	8th
Fall of workers from heights	3.70	0.898	9th
Noise handling	3.56	1.020	10th

study as it ranked vehicle-related accidents first. Furthermore, Doraisamy et al. (2014) also agrees with these findings as it emphasized that the unavailability of personal protective equipment can have an influence on safety on site which in turn can contribute to the closure of projects prematurely. However, Alcumus (2014) believes that fall protection for workers working on heights, noise handling and availability of warning signs to prevent workers from slipping and falling are the most important factors.

The empirical findings and theoretical review of this study revealed that all the components measured are significant health and safety factors that could cause construction projects to close prematurely. However, vehicular accidents, respiratory safety, and availability of personal protective equipment are the major causal factors of premature project closure under health and safety considerations. Also, deficiency in first aid and fire safety training drills and mishandling equipment and materials were also identified as important elements of premature project closure, in terms of health and safety. It is worthy to note that all the elements identified as health and safety components of premature project closure can be mitigated with proper risk assessment, plan, and strategy as it is important for construction firms to ensure safety for all its workers. This can be achieved by adopting the best combination of safety practices that suit individual firms organisational structure as well as the size and nature of projects executed within the organisation.

It is important that construction sites be kept as safe as possible and necessary emergency equipment be provided. Personal protective equipment must also be provided for all workers involved in a project as well as people visiting the project site. The health of personnel on construction sites must also be specially considered in terms of air quality and how it can affect the respiratory systems of workers. Furthermore, construction site workers and team members should be taken through a mandatory induction stage at the commencement of individual projects. During the induction, all staff members involved in the project should be sensitized on the modalities and uniqueness of such new projects.

5 Conclusion

Construction projects are supposed to sequentially cover all stages of a project life cycle, from the conception stage all through to the project termination stage. However, numerous difficulties and challenges may be encountered during the course of project execution that can lead the project to close prematurely without achieving the predetermined goals. This study thus explored the health and safety elements that can cause construction projects to prematurely close and found out that accidents, air quality considerations, and not providing different safety gears pose the most risk to the successful completion of construction projects. Although construction projects cannot be completely void of accidents and hazardous risks, proper planning and management could reduce their occurrences and mitigate their impacts on projects.

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Exploring Critical Success Factors for Geothermal Investments

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Abstract

The number of geothermal energy investments has been increasing every year to satisfy the growing demand for energy. Determining the success factors in geothermal energy investments is crucial to ensure project success. This research aims to identify the critical success factors and their effectiveness rate for geothermal energy investments in Turkey. To achieve this objective, an extensive literature review was performed to determine the critical success factors associated with geothermal energy investments, and a questionnaire survey was conducted to assess the effect of each success factor. The results show that the three most important success factors are "feasibility of the project," "energy demand," and "tariff rate". These findings can help the investors to successfully implement a geothermal investment.

Keywords

Public–private partnership (PPP) • Geothermal • Renewable energy • Critical success factor (CSF) • Project

1 Introduction

Energy is vital for countries and economies. A large amount of the world energy demand is supplied from fossil fuels such as coal (%27), oil (%32), and natural gas (%22) (IEA 2016). These reserves are now in critical levels and have been decreasing day by day. In addition, the world energy demand will increase more than %25 until 2040 according to the International Energy Agency (IEA 2018). Therefore, finding different sources to satisfy the increasing energy demand is an important issue for countries. As the fossil fuels have been decreasing in recent years all over the world, renewable energy sources can be a potential solution to satisfy the increasing energy demand. Geothermal energy which is a type of renewable energy has been increasing its popularity due to its low maintenance cost and cleanliness. It has many advantages over the non-renewable energy alternatives. One of the main advantages of geothermal energy is not causing a rise in CO_2 level in the atmosphere as it does not involve any burning process while producing electricity. It uses the heat energy, which has already been in the earth, and uses a fluid such as hot water, vapor, and gas which is accumulated and compressed with the motions of earth crusts and magma in the depth of the earth.

Turkey is one of the developing country that gives importance to the geothermal energy in order to satisfy the energy demand. After United States, Philippines, and Indonesia, Turkey has the fourth largest available installed geothermal power plant capacity in the world (Ren 2018). Although the number of geothermal investments has been increasing day by day, and the installed geothermal power plants satisfy only 2.1% of Turkey's energy demand (TETC 2017). Turkish Government believes that this ratio is very low, and encourages investor to invest new geothermal power plants. The investments were performed by using Public–Private Partnership (PPP). PPP is a cooperation between government and private sector to provide public services in different areas such as health, energy, transportation, and infrastructure. Investors intend to make geothermal energy investments; however, they do not have enough information to pay attention to which factors in order to ensure project success. Therefore, this paper concentrates on critical success factors (CSFs) and their degree of effectiveness for geothermal energy investments carried out using PPP model in Turkey. For this purpose, an extensive literature review and a questionnaire survey were performed.

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2 Literature Review

Critical success factors for projects have been recently getting the attention of the researchers. Several research studies have been conducted to identify the critical success factors (CSFs) for different types of projects. These studies can be clustered into two main groups as (1) CSFs for construction projects (Ika et al. 2012; Baccarini and Collins 2003; Chen et al. 2012; Han et al. 2007), (2) CSFs for PPP investments (Chan et al. 2010; Shiying 2016; Chou and Pramudawardhani 2015; Ullah and Thaheem 2018; Almarri and Boussabaine 2017; Zhen-Yu et al. 2010). In order to ensure construction project success, it is important to identify CSFs and their effects (Chen et al. 2012). Baccarini and Collins (2003) identified 15 CSFs for construction projects by administering a survey with 150 members of Australian Project Management Institute. Ika et al. (2012) conducted a survey in order to determine world bank project success factors. Chen et al. (2012) identified 62 CSFs for construction projects by performing a literature review. They also showed the interrelations between the success factors. Han et al. (2007) identified CSFs for international construction projects. In addition, several research studies were performed to identify CSFs for different types of investment in different countries carried out using PPP. For instance, Chan et al. (2010) identified 18 CSFs for PPP infrastructure projects in China. By performing an extensive literature review, Chou and Pramudawardhani (2015) identified the CSFs for Taiwan, Singapore, China, and the United Kingdom. Zhen-Yu et al. (2010) determined 31 success factors for PPP thermal power investments in China. Although there have been several research studies related to CSFs for different types of PPP investments, there is not any specific study in the literature that focuses on CSFs for PPP geothermal energy investments in Turkey. Therefore, this research identifies CSFs and their degree of effectiveness for PPP geothermal energy investments in Turkey.

3 Methodology of Study

The methodology of this study involves two main steps. In the first step, a comprehensive literature review related the critical success factors (CSFs) for geothermal investments was performed. A total number of 30 critical success factors for geothermal investments were identified by using these studies, and are depicted in Table 1.

In the second step, a questionnaire survey that includes two parts was performed. The questionnaire survey was conducted to 10 participants from 10 different companies; the renewable energy experience of the companies varies from five to twenty years. 80% of the participating companies have experience in renewable energy more than ten years. The information about companies is presented in Table 2. According to Table 2, all companies have geothermal investments in the different regions of Turkey. It should be noted that Turkey has seven different regions, so the variety of the location of investments can help to obtain more consistent results. In addition, all companies have different energy investments apart from the geothermal energy investment.

In the first part of the questionnaire, the participants were asked to give information about profile of their companies such as “experience of their companies,” “types of their renewable investments,” “other renewable investments and their production capacities,” and “locations of their investments”. In the second part, the participants rated the effectiveness of critical success factors with 1–5 rating scale.

After all the critical success factors for geothermal investments were rated by the participants, the average values of their evaluation were calculated as an effectiveness rate of critical success factors. The average values and corresponding percentage values are depicted in Table 3.

4 Discussion of Results and Conclusion

According to the results, “feasibility of the project,” “tariff rate,” and “energy demand” are listed as the three most important critical success factors with 100% effect to the project success. The participants were also asked to rank these three most important critical success factors. “Feasibility of the project” was ranked as the first most important critical success factor by all the participants. The feasibility of the project is a study that performed before starting to the project, predicts the operationability of the project taking into account the past datas and cashflow calculations related to the project. It should be performed as accurate as possible in order to ensure project success. “Tariff rate” was ranked as the second most important critical success factor by 60% of the participants and the third most important critical success factor by 40% of the participants. In addition, “energy demand” was ranked as the third most important critical success factor by 60% of the participants and the second most important critical success factor by 40% of the participants. The participants also noted that there is a strong positive correlation between “tariff rate” and “energy demand.” An increase in energy demand causes an increase in the tariff rate, so they can be combined, and consolidated as a single factor.

In summary, this paper presents an overview of global energy demand. The importance of the renewable sources have increased recently, as the countries have to find new

Table 1 Critical success factors for geothermal energy investments

Critical success factors (CSFs)		Articles																	
		Zhen-Yu et al. (2010)	Li et al. (2005)	Tiong et al. (1992)	Tiong (1996)	Chan et al. (2010)	Chou and Pramudawardhani (2015)	Ahmadabadi and Heravi (2019)	Wang et al. (2018)	Ullah and Thaheem (2018)	Muhammad and Johar (2018)	Osei-Kyei et al. (2017)	Kavishe and Chileshe (2018)	Almarri and Boussabaine (2017)	Lam and Chan (2008)	Babatunde et al. (2016))	Shiying et al. (2016)))	Babatunde et al. (201	Kahwajian et al. (2014))
CSF1	Feasibility of the project	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●
CSF2	Public support to project	●	●			●	●		●	●	●	●	●	●	●		●	●	●
CSF3	Complexity of the project	●	●	●				●	●	●		●			●				●
CSF4	Operation/construction cost			●				●		●		●					●		
CSF5	Construction quality							●	●										
CSF6	Energy demand		●			●	●		●				●	●		●			●
CSF7	Government support		●	●		●	●			●	●		●	●		●	●	●	●
CSF8	Well-organized public agency		●			●	●				●		●	●					●
CSF9	Political stability	●	●		●	●	●			●	●		●	●		●	●	●	●
CSF10	Exchange rate	●	●				●							●			●	●	●
CSF11	Interest rate	●	●			●	●						●	●			●	●	●
CSF12	Favorable legal framework	●	●			●	●						●	●	●	●	●		
CSF13	Tariff rate			●															
CSF14	Scope of the project		●			●	●						●	●				●	●
CSF15	Government control mechanism						●										●		
CSF16	Organization of the company	●	●	●	●	●	●		●	●	●		●	●	●		●	●	●
CSF17	Effective risk assessment	●	●	●		●	●		●	●	●	●	●	●	●	●	●	●	●
CSF18	Management level of the company	●	●	●		●	●	●			●		●	●	●		●	●	●
CSF19	Cooperation of the stakeholders			●				●	●	●									
CSF20	Financial structure of the company	●	●	●		●	●		●	●	●		●	●	●		●	●	●
CSF21	Well-defined responsibilities and roles	●	●	●		●	●		●			●	●	●		●	●	●	●
CSF22	Experience of the company										●						●		

(continued)

Table 1 (continued)

Critical success factors (CSFs)		Articles																	
		Zhen-Yu et al. (2010)	Li et al. (2005)	Tiong et al. (1992)	Tiong (1996)	Chan et al. (2010)	Chou and Pramudawardhani (2015)	Ahmadabadi and Heravi (2019)	Wang et al. (2018)	Ullah and Thaheem (2018)	Muhammad and Johar (2018)	Osei-Kyei et al. (2017)	Kavishe and Chileshe (2018)	Almarri and Boussabaine (2017)	Lam and Chan (2008)	Babatunde et al. (2016))	Shiying et al. (2016)))	Babatunde et al. (201	Kahwajian et al. (2014))
CSF23	Experience of the designer										●						●		
CSF24	Performance of the designer										●				●		●		
CSF25	Experience of the contractor										●						●		
CSF26	Performance of the contractor										●						●		
CSF27	Construction techniques	●		●	●														
CSF28	Experience of the operator							●			●						●		
CSF29	Performance of the operator							●			●						●		
CSF30	Operation productivity							●			●	●					●		

Table 2 Profiles of the companies

Company name	Geothermal energy production capacity (MW)	Location of the investment (number of different regions)	Experience (years)	Other renewable investments and their production capacities (MW)			
				Solar	Wind	Hydropower	Biomass
Company 1	7.5	3	13	5	25	19	–
Company 2	9	4	14	3	6	8	–
Company 3	12	6	10	12	22	42	2
Company 4	5	6	17	12	35	9	–
Company 5	11	5	19	3	7	8	–
Company 6	5	3	7	10	10	10	5
Company 7	6	4	15	6	15	17	7
Company 8	3	3	6	4	5	5	–
Company 9	15	4	17	15	36	29	–
Company 10	9.5	6	12	11	13	15	3

Table 3 Effectiveness of critical success factors

Critical success factors	Average	Percentage of effectiveness (%)
CSF 1—Feasibility of the project	5.00	100
CSF 13—Tariff rate	5.00	100
CSF 6—Energy demand	5.00	100
CSF 14—Scope of the project	4.90	98
CSF 30—Operation productivity	4.80	96
CSF 29—Performance of the operator	4.70	94
CSF 22—Experience of the company	4.60	92
CSF 23—Experience of the designer	4.60	92
CSF 25—Experience of the contractor	4.50	90
CSF 28—Experience of the operator	4.40	88
CSF 11—Interest rate	4.00	80
CSF 26—Performance of the contractor	4.00	80
CSF 8—Well-organized public agency	3.90	78
CSF 20—Financial structure of the company	3.90	78
CSF 10—Exchange rate	3.80	76
CSF 27—Construction techniques	3.70	74
CSF 4—Operation/Construction cost	3.50	70
CSF 5—Construction quality	3.50	70
CSF 2—Public support to project	3.40	68
CSF 7—Government support	3.40	68
CSF 9—Political stability	3.40	68
CSF 16—Organization of the company	3.40	68
CSF 12—Favorable legal framework	3.20	64
CSF 15—Government control mechanism	3.10	62
CSF 17—Effective risk assessment	3.10	62
CSF 24—Performance of the designer	2.50	50
CSF 19—Cooperation of the stakeholders	2.40	48
CSF 18—Management level of the company	2.30	46
CSF 21—Well-defined responsibilities and roles	2.20	44
CSF 3—Complexity of the project	1.40	28

energy sources. Geothermal energy is a type of renewable energy that countries have given importance in order to supply their energy demand. In this research, the critical success factors and their degree of effectiveness identified for geothermal investments were carried out using PPP in Turkey. For the identification process, an extensive literature review was performed, and in order to determine the effectiveness of factors, a questionnaire was conducted with 10 different participants from 10 different companies. For further research, a different model that shows interrelations between critical success factors can be constructed.

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Effect of Insulation Thickness on Energy Consumption for Different Shaped Buildings

Esra Bostancioglu

Abstract

Control and management of energy consumption are becoming more and more important due to the rapid depletion of fossil energy resources and the increased environmental problems caused by them. A large amount of energy is consumed in the buildings. Therefore, priority is given to applications that reduce the amount of energy consumed during the utilization phase of buildings. Decisions regarding building shape and insulation thickness have a considerable effect on building energy costs. Therefore, this study will analyze the effect of insulation thickness on the energy consumption of residential buildings that have different shapes. The building shape is evaluated with an external envelope area to the building's gross volume (A/V) ratio and external wall area/floor area (EWA/FA) ratio. 4 building shapes with different external wall area are selected for this study. The maximum and minimum energy costs of each building shapes are calculated based on 14 different envelopes and 8 different orientation alternatives taking into consideration the solar gain. The effects of insulation thicknesses on energy costs for different shaped buildings are determined by comparing energy costs. It will provide pre-design information for future reference for residential buildings with less energy consumption and less environmental pollution.

Keywords

Energy cost • Insulation thickness • Building shape • Energy consumption • Building envelope

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1 Introduction

Today, with the rapid depletion of fossil energy sources and the increasing environmental problems caused by fossil fuels, supervision, and management of energy consumption becomes more important. The energy requirement of developing countries such as Turkey increases every year. According to the National Energy Conservation Center data, residential and service buildings consume 34% of total energy in Turkey (National Energy Conservation Center 2006). Therefore, priority is given to applications that reduce the amount of energy consumed during the utilization phase throughout the life cycle of buildings. When reducing the cost of residential buildings, decreasing operational costs along with the construction costs will prove beneficial not only for the owner and/or user of the residence but also for the national economy. If we consider the big share of the residential sector within energy-related expenditures, it becomes obvious that ensuring a decrease in the housing energy expenses will also substantially contribute to decreasing energy-related expenditures of the country. Heating energy consumption in buildings have an important part of total energy consumption. 33% of energy-use in Turkey is for heating purposes (Acikgoz 2015). A large amount of energy demand for residential buildings is caused by heat losses (Yucer and Hepbasli 2011). Thermal insulation application reduces environmental effects, carbon emissions and energy costs. Efficient heating applications can be provided by determining optimum insulation thickness.

There are a lot of studies on the insulation thickness of buildings. Kaynakli et al. (2018) optimized the thermal insulation thickness used in the external walls of buildings composing of different applications. Gonzalo and Bovea (2017) presented a methodology to analyze optimum insulation material for the building envelope. Reductions up to 40% in energy demand compared to regulations standards can be achieved in the telco-efficiency context. Kurekci

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(2016) determined the optimum insulation thicknesses required in Turkey's 81 provincial centers based on four different fuels and five different insulation materials. Ozel et al. (2015) investigated the optimum insulation thickness according to entransy loss for Bilecik in Turkey. The optimum thickness, which is determined by environmental impact analysis are 0.15 and 0.064 m for glass wool and rock wool respectively. The optimum insulation thicknesses depending on life cycle cost analysis are calculated as 0.012 and 0.07 m, respectively for glass wool and rock wool. Nyers et al. (2015) analyzed the optimum thickness of the thermal insulation layer for the external wall and obtained the optimum thickness for energy-economic conditions in Serbia in 2014.

Besides the insulation thickness, plan shape affects the energy consumption of the buildings. Studies in literature are about the effect of insulation thickness or building shape, there is no study about the effect of insulation thickness and building shape together. Therefore, this study analyses the effect of insulation thickness on the energy consumption of residential buildings that have different shapes.

2 Methods

For analyzing the effect of insulation thickness on energy consumption of buildings that have different shapes, building envelope alternatives that have different insulation alternatives and different building shapes are identified. After that, the maximum and minimum annual energy costs (AEC) of residential buildings that have different shapes and insulation thicknesses are calculated based on 14 different envelope and 8 different orientation alternatives taking into consideration the solar gain. Calculated AEC is compared and the effects of insulation thicknesses on AEC for different shaped buildings are determined.

2.1 Identification of Building Insulation Alternatives

The building components forming a building envelope are the walls, roof and ground flooring. Different body and insulation materials used in the walls, roof and flooring, and different thicknesses will result in different energy costs of a building. External walls constitute the largest part of the building envelope and have a substantial impact on the energy costs of the building. Therefore, for the assessment of the insulation thickness on the energy costs of the buildings, extruded polystyrene foam (XPS) in different thicknesses (2–6 cm) are selected as wall insulation materials in this study. Since it is a more convenient system in buildings that are used for a prolonged period, such as housing, and there is a reduced risk of condensation as a result of steam diffusion, it is assumed that insulation is applied externally on the walls. It is assumed that brick and gasbeton can be used as wall body materials. A fixed wooden roof is approved. XPS with a thickness of 4 cm is deemed appropriate for use as an insulation material in ground flooring, and 10 cm thick glass wool is found appropriate for use in roofs. In building alternatives, double-glazed windows with wood casing are used as the transparent component type. Envelope alternatives of buildings are displayed in Table 1.

Table 1 Envelope alternatives

Alternative	Wall body material	Roof insulation material	Wall insulation material
t	19 cm brick	–	–
t10c	19 cm brick	10 cm glass wool	–
t2x10c	19 cm brick	10 cm glass wool	2 cm XPS
t3x10c	19 cm brick	10 cm glass wool	3 cm XPS
t4x10c	19 cm brick	10 cm glass wool	4 cm XPS
t5x 10c	19 cm brick	10 cm glass wool	5 cm XPS
t6x10c	19 cm brick	10 cm glass wool	6 cm XPS
g	19 cm gasbeton	–	–
g10c	19 cm gasbeton	10 cm glass wool	–
g2x10c	19 cm gasbeton	10 cm glass wool	2 cm XPS
g3x10c	19 cm gasbeton	10 cm glass wool	3 cm XPS
g4x10c	19 cm gasbeton	10 cm glass wool	4 cm XPS
g5x10c	19 cm gasbeton	10 cm glass wool	5 cm XPS
g6x10c	19 cm gasbeton	10 cm glass wool	6 cm XPS

2.2 Identification of Building Shapes

In the studies that evaluated heating energy costs, building shapes were evaluated with A/V (external envelope area/building's gross volume) (Hegger et al. 2008; Depecker et al. 2001; Ourghi et al. 2007; Tuhus-Dubrow and Krarti 2010), A/S (the area of building envelope per unit of heated area) (Gonzalo and Habermann 2006), S/V (area of building envelope surface/volume of the building) (Bekkouche et al. 2013) or EWA/FA (external wall area/floor area) ratios (Bostancioglu 2010). In this study, the building shape will be evaluated with A/V and EWA/FA ratio. Four building shapes with different external wall area are selected. They have the same characteristics and equal height, they are differentiated based on their plan shapes. It is assumed that alternatives to these shapes can be square, rectangular, H- or star-shaped. Buildings and residential units have approximately the same floor area and same characteristics. Windows and doors have approximately the same area. Only the external wall area of the buildings are varied.

2.3 Calculation of Annual Energy Costs (AEC)

In TS 825 (Turkish Standard Number 825 (TS 825) 2008), Turkey is divided into four climatic regions by provincial centers. Region 1 represents the areas that require the least energy for heating, and Region 4 represents the areas that require the most energy for heating. The heating energy demand and annual fuel amounts for project alternatives are calculated for the second climate zone, which is a temperate climate zone and which also covers Istanbul. Wall alternatives are checked for the presence of condensation and no condensation is found in these wall alternatives. To calculate heating energy costs, the "TS 825 Heat Requirement Calculations" computer program is used. This calculation program, designed by Izoder, is based on the "TS 825 Heat Insulation Rules in Buildings" standard and Turkey's meteorological data for the last 20 years. Using this program, it is possible to calculate condensation values and the specific heat loss as defined in the "TS 825 Thermal Insulation Requirements for Buildings" standard and compare the calculated values to the thresholds defined in the standard and hence evaluate the conformity of the designed building to national legislation on energy efficiency. The program operation is parallel to the TS 825 standard. First, data regarding the building subject to the standard are entered into the program, and then the building's annual heating energy demand and condensation values are calculated and checked against the criteria outlined in the standard. In the defined calculation method, annual heating energy demand is calculated by adding the monthly heating energy demand for the heating period. Hence, it becomes possible to make a more realistic evaluation of the thermal performance of the building. Also, the program enables the designer to evaluate the proposed design's capacity to take advantage of solar energy (Izoder 2016).

It is assumed that natural gas is consumed in all project alternatives. Calculation of heating energy costs is based on the natural gas prices applicable for March 2019 in Istanbul (Igdaş et al. 2019). AECs are calculated both based on different wall alternatives and also different orientations. Taking into consideration the solar gain of the buildings, AECs are calculated based on each shape and envelope alternative with eight different orientations. AECs that are calculated in TL is changed to \$. The exchange rate of \$ is taken from the Central Bank of the Republic of Turkey for 1 March 2019 (Central Bank of the Republic of Turkey Web Page 2019).

3 Results and Discussion

AECs per m^2 of buildings with 4 different building shapes (have different EWA/FA ratio and A/V ratio) are calculated based on 14 different envelopes and 8 different orientation alternatives. In Table 2, Figs. 1 and 2, buildings with different

Table 2 Assessment of minimum AEC per m^2 of buildings that have different shapes with different insulation thicknesses

EWA/FA		2.700		2.811		3.139		3.606
A/V		0.348		0.356		0.381		0.415
	AEC per m^2 (\$/m^2)	Relative AEC per m^2	AEC per m^2 (\$/m^2)	Relative AEC per m^2	AEC per m^2 (\$/m^2)	Relative AEC per m^2	AEC per m^2 (\$/m^2)	Relative AEC per m^2
Wall body material—19 cm brick								
t	19.71	279.55	20.75	282.35	22.29	292.89	23.72	303.54
t10c	14.33	203.20	15.21	206.98	16.66	218.95	18.15	232.22
t2x10c	8.57	121.48	8.99	122.34	9.51	124.94	10.02	128.16
t3x10c	7.96	112.83	8.32	113.25	8.74	114.85	9.13	116.83
t4x10c	7.53	106.83	7.88	107.25	8.24	108.21	8.55	109.39
t5x10c	7.26	102.92	7.57	102.99	7.87	103.38	8.13	103.97
t6x10c	7.05	100.00	7.35	100.00	7.61	100.00	7.82	100.00
Wall body material—19 cm gasbeton								
g	18.02	262.19	18.94	264.23	20.13	272.04	21.16	279.52
g10c	12.65	184.08	13.42	187.22	14.54	196.47	15.64	206.57
g2x10c	8.07	117.45	8.45	117.92	8.86	119.76	9.25	122.15
g3x10c	7.58	110.33	7.92	110.53	8.27	111.73	8.59	113.47
g4x10c	7.27	105.87	7.59	105.89	7.88	106.51	8.13	107.38
g5x10c	7.05	102.63	7.35	102.58	7.61	102.80	7.80	103.06
g6x10c	6.87	100.00	7.17	100.00	7.40	100.00	7.57	100.00

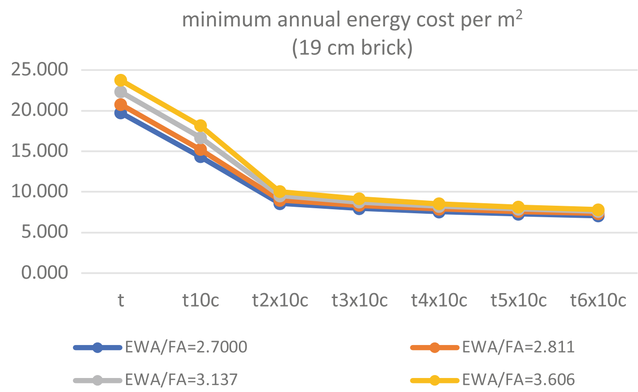

Fig. 1 Minimum annual energy cost per m^2 of buildings that have different shapes with different insulation thickness (wall body material-19 cm brick)

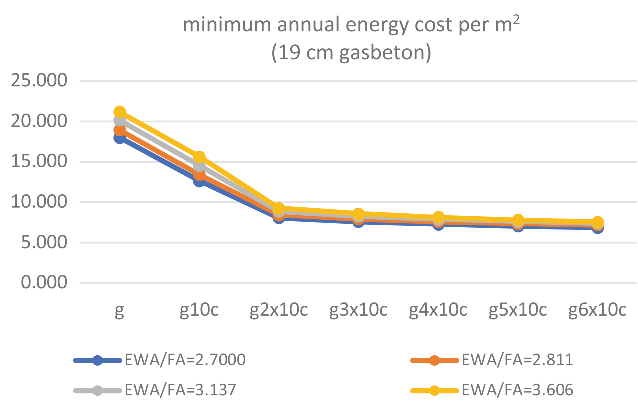

Fig. 2 Minimum annual energy cost per m^2 of buildings that have different shapes with different insulation thickness (wall body material-19 cm gasbeton)

building shapes (EWA/FA and A/V ratio) and insulation alternatives are compared in terms of minimum AECs per m2 considering 8 different orientation alternatives. AEC decreases with the usage of insulation material. When insulation material thickness increases, AEC decreases. AEC per m^2 of square building without insulation material (EWA/FA = 2.700 and A/V = 0.348) is %179.55 more than the same building with 6 cm XPS wall insulation and 10 cm glass wool roof insulation. AEC per m^2 of rectangular building without insulation material (EWA/FA = 2.811 and A/V = 0.356) is % 182.35 more than the same building with 6 cm XPS wall insulation and 10 cm glass wool roof insulation. AEC per m^2 of star-shaped building without insulation material (EWA/FA = 3.139 and A/V = 0.381) is %192.89 more than the same building with 6 cm XPS wall insulation and 10 cm glass wool roof insulation. AEC per m^2 of H-shaped building without insulation material (EWA/FA = 3.606 and A/V = 0.415) is %203.54 more than the same building with 6 cm XPS wall insulation and 10 cm glass wool roof insulation. As it is seen in Table 2, Figs. 1 and 2, when insulation material thickness increases, AEC decreases. AEC per m^2 of different shaped buildings increases rapidly when the roof or wall insulation applied to a building without insulation. AEC per m^2 of buildings decreases slowly in the buildings with wall insulation 2–6 cm buildings with different building shapes (EWA/FA and A/V ratio). Insulation alternatives are compared in terms of maximum AECs per m^2 considering 8 different orientation alternatives in Table 3. The changes of minimum AECs per m^2 according to insulation thicknesses are close to the changes of maximum AECs per m^2. As it is

Table 3 Assessment of maximum AEC per m^2 of buildings that have different shapes with different insulation thickness

EWA/FA		2.700		2.811		3.139		3.606
A/V		0.348		0.356		0.381		0.415
	AEC per m^2 (\$/m^2)	Relative AEC per m^2	AEC per m^2 (\$/m^2)	Relative AEC per m^2	AEC per m^2 (\$/m^2)	Relative AEC per m^2	AEC per m^2 (\$/m^2)	Relative AEC per m^2
Wall body material—19 cm brick								
t	19.75	279.54	20.80	281.56	22.32	292.71	23.78	301.69
t10c	14.35	203.13	15.21	206.35	16.67	218.60	18.22	231.10
t2x10c	8.60	121.67	8.99	122.33	9.54	125.15	10.08	127.82
t3x10c	7.98	112.96	8.32	113.17	8.76	114.92	9.19	116.58
t4x10c	7.56	107.05	7.88	107.23	8.27	108.42	8.59	109.02
t5x10c	7.28	103.09	7.57	103.10	7.90	103.59	8.19	103.93
t6x10c	7.07	100.00	7.35	100.00	7.63	100.00	7.88	100.00
Wall body material—19 cm gasbeton								
g	18.04	261.28	18.99	263.69	20.14	271.63	21.22	278.40
g10c	12.67	183.48	13.46	186.90	14.56	196.35	15.71	206.07
g2x10c	8.08	116.99	8.49	117.89	8.89	119.95	9.30	121.99
g3x10c	7.61	110.14	7.98	110.76	8.32	112.18	8.63	113.19
g4 x10c	7.30	105.71	7.64	106.04	7.91	106.73	8.20	107.54
g5x10c	7.06	102.22	7.39	102.62	7.62	102.79	7.87	103.25
g6x10c	6.91	100.00	7.20	100.00	7.42	100.00	7.62	100.00

seen in Tables 1 and 2; when EWA/FA or A/V ratio increases, both minimum, and maximum AEC increases even though the usage of insulation and increasing thickness of insulation.

4 Conclusions

In line with the amount of energy consumed by subsystems that provide comfort; the drop-off in the energy resources used, dependency to other countries for these resources, harms of gases emitted by the consumption of energy, increasing air pollution and related global warming issues have gained serious importance. In Turkey, heat loses from the buildings is one of the primary sources of energy waste. Based on all the preceding, it is required to produce and operate residential buildings that provide the necessary thermal comfort conditions while consuming minimum energy. And one way of ensuring this is the building envelope design.

The effect of insulation thickness on the energy consumption of residential buildings that have different shapes is analyzed in this study. When insulation material thickness increases, AEC decreases. AEC per m^2 of different shaped buildings increases rapidly when the roof or wall insulation applied to a building without insulation. AEC per m^2 of buildings decreases slowly in the buildings with wall insulation 2–6 cm buildings with different building shapes (EWA/FA and A/V ratio). It was seen that increasing the thickness is not necessary to achieve more effective insulation. As the thickness of the insulation material increases, the saving achieved in annual heating costs increases less compared to the increase in insulation material thickness. Looking at the wall body material usages, gasbeton provides the most effective saving in heating energy compared to other materials.

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Construction Site Fire Safety Using BIM and Virtual Reality

Asif Abu Bakar, Todd Sirotiak, and Achintyamugdha Sharma

Abstract

Due to the dynamic nature of a construction job site, it is challenging to ensure safe operations and avoid accidents. It is imperative to provide/facilitate effective safety workshop/training programs, especially for new employees to familiarize them with the existing hazardous situations on site and ways to address them. Although various visualization techniques were investigated in the past in other industries, their implementation in the construction industry with an emphasis on site safety is still in its infancy. This paper provides the use of Building Information Modeling (BIM) and Virtual Reality (VR) in improving the current scenario of safety in the construction industry, with a particular emphasis on fire safety. This work deals with a combined approach of BIM and VR technologies. These technologies are linked together to develop an immersive environment that provides access to critical locations in case of an emergency such as, the location of fire extinguishers, and exit route for emergency evacuation. This paper investigates the potential of site safety and emergency response management in the construction industry.

Keywords

Construction safety • Building information modeling • Virtual reality • Fire safety

1 Introduction

The Construction industry is inherently prone to safety hazards due to its dynamic and random nature. The census data from the U.S. Bureau of Labor Statistics shows that the construction industry is one of the most hazardous industries in the United States based on the number of fatalities. In the year 2015, 937 or 21.4% out of 4739 worker fatalities in the private sector were in construction, which is equal to one out of five worker deaths (United States Bureau of Labor Statistics 2015). Various reasons for this may include lack of awareness and inadequate implementation of safety measures. One of the primary reasons for high fatalities in the construction industry is the lack of proper education and training available to construction project personnel (Guo et al. 2012). Safety performance at a construction site may be improved through safety trainings or workshops. This may help predict accident scenarios. Safety training is generally provided on site, in the form of toolbox meetings, and also by using workshops or seminars. It helps in familiarizing new employees with the hazards on-site, with the help of mentoring programs and pairing individuals (Ashraf et al. 2009). However, a large percentage of these workshops have demonstrated unproductive results in effectively communicating the vulnerabilities associated with a construction site (Li et al. 2012).

The complexity and uncertainty in the nature of construction industry requires the safety planners to adopt new and innovative technologies to improve the construction safety scenario (Hassan 2012). One such technology is Building Information Modeling (BIM).

Building Information modeling or BIM is one of the most promising developments in the construction industry (Eastman et al. 2011). This innovative technology has changed the way construction projects are executed from their inception to handover. Associated General Contractors of America (AGC) defines BIM as "*the development and use of a computer software model to simulate the construction and operation of a facility. The resulting model, a Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information*

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that can be used to make decisions and improve the process of delivering the facility" (AGC 2005).

Another new technology that is gaining ground in the industry is Virtual Reality (VR). Rheingold defined virtual reality as "*an experience in which a person is surrounded by a three-dimensional, computer-generated representation, and is able to move around in the virtual world and see it from different angles, to reach into it, grab it, and reshape it.*" (Rheingold 1991). Virtual reality (VR) technology uses computers, software and peripheral hardware to generate a simulated environment for its user. The simulated environment may consist of real or imaginary surroundings. It is a computer-generated environment that gives a person a sense of being within it by engaging their senses and reducing or removing their perception of the real environment. While there is a wide range of technical implementations, VR typically has the following features: it will surround its user, obscuring cues from the physical environment, provide a three-dimensional visual representation of the virtual environment; track the user's location and orientation and update the virtual scene to match the user's movements; and give the user some degree of control over the objects in it (Bailenson et al. 2008). A central notion is that of 'presence' in the virtual environment. This means that the subjects' responses in the virtual environment are similar to those in a real environment (Sanchez-Vives and Slater 2005). The use of visualization not only presents a more comprehensive construction process than 2D drawings and information (Chau et al. 2003), but also helps in communication between different project stakeholders (Jongeling and Olofsson 2007).

The virtual reality technology has provided benefits to many industries. The military have used it for training recruits. In the field of medicine VR technology has been used to provide medical students with an opportunity to experience dangerous surgical procedures in a virtual environment. Although the technology is relatively new in the construction industry, there is tremendous potential of utilizing it for construction safety.

2 Research Significance

Although prior literature has shown the significance of using Virtual Reality in different industries, the use of BIM along with VR in the construction industry is very limited. This research helps in demonstrating the use of BIM and VR in construction safety training especially focusing on fire safety. There is a potential of changing traditional methods of safety training, and implementing a more proactive approach with the help of new cutting edge technologies.

3 Discussion

The Research process starts off with a thorough literature review. The literature required for this project was collected through extensive search of journal articles, conference papers, reports and books. Mostly recent and relevant papers were collected. The main focus of the literature review was to identify limitations in the construction industry regarding safety and training techniques. After a thorough literature review, appropriate VR headset and BIM software were identified. There were a number of different VR products available in the market. HTC Vive, was specifically acquired for the study due to its low cost and user friendly interface.

The following BIM technologies were selected on the basis of their low-cost, and the presence of extensive tutorials on the internet:

- Autodesk Revit for creating 3D model
- Google SketchUp for editing and exporting all the equipment, characters and related families needed onsite
- Autodesk Navisworks for 4D phasing simulations
- MS Project for creating construction schedule
- Iris VR-For visual training

For this study, a BIM model of a shed was generated using Revit as shown in Fig. 1. Different site equipment i.e. cranes, vehicles, scaffold, and dumpster were downloaded and edited from Google Sketchup's *Ware House* and Revit *Family* to incorporate into the model. The easy availability of these equipment made an otherwise time-consuming process of creating each equipment individually, faster and more convenient.

The Fire Extinguishers downloaded from Revit's Family (refer to Fig. 2) were then added to the model according to the OSHA specifications. The shed's components like doors and windows were finally added to complete the 3D model. As a part of project planning, a simple project schedule was developed using *MS Project* (MSP) which listed all the activities to be executed in the project along with their Planned Start and End dates. This MSP schedule and the 3D model in Revit were exported to Navisworks, in order to link all the individual components to their respective line item on schedule to create 4D simulation of the project. This 4D simulation shows animated visualization of the project and pinpoints the exact scenario of the site on any particular day.

The model was transformed into virtual reality walkthrough using *IrisVR Prospect* (as shown in Figs. 3 and 4). *IrisVR Prospect* is a Windows based platform that converts 3D models from Revit, Sketup and other similar software into VR experiences using head mounted displays (HMDs), that a person wears to get immersed in a Virtual Environment (VE).

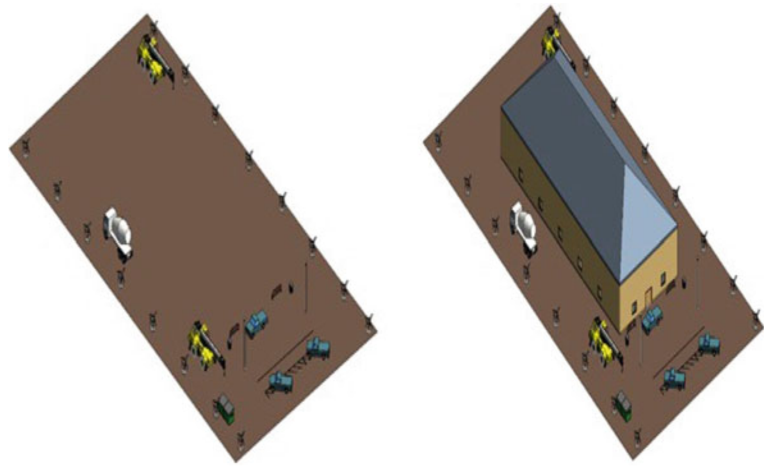

Fig. 1 Revit model of site area (left) and shed (right)

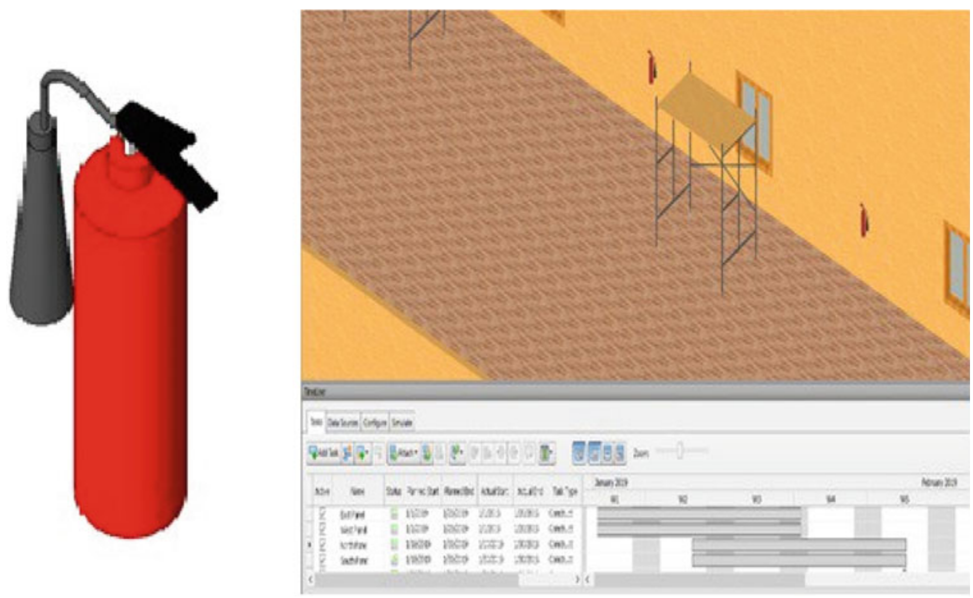

Fig. 2 Fire extinguisher model and Navisworks 4D model

By moving one's head and eye this VE can be explored from any perspective. Creating this VR walk through helps in identifying locations of Exit doors and Fire Extinguishers in case of a fire outbreak, and assists new employees to visually explore a virtual environment prior to construction.

4 Results and Conclusion

The paper provides a method of BIM based virtual environment with an intent to improve the safety training programs currently in practice in the construction industry. Through BIM models and VR tools a more proactive approach has been proposed to tackle safety issues. Exposing personnel to hazardous situation in a risk free virtual environment is a viable solution. This technique prepares them for unforeseen harmful situations on site before entering the actual worksite. The paper focuses on the fire safety scenario through a 3D model of a shed which was created using Autodesk Revit and included the fire extinguishers according to OSHA specifications. The safety model was simulated using Navisworks and then linked with IrisVR to give an immersive experience to the user by using Head mounted display (HMD). The authors believe that this method of safety training will create a positive impact in the safety scenario of construction industry, the likes of which may be investigated through surveys and field trials for future work.

There are some potential barriers in utilizing these techniques in the industry, like cost associated with VR equipment, BIM compatible computers, traditional thinking of safety officers, and lack of expertise of administrative personnel. Therefore, future research endeavors can focus on exploring these barriers and ways to resolve them.

Fig. 3 Viewing virtual environment through HTC vive

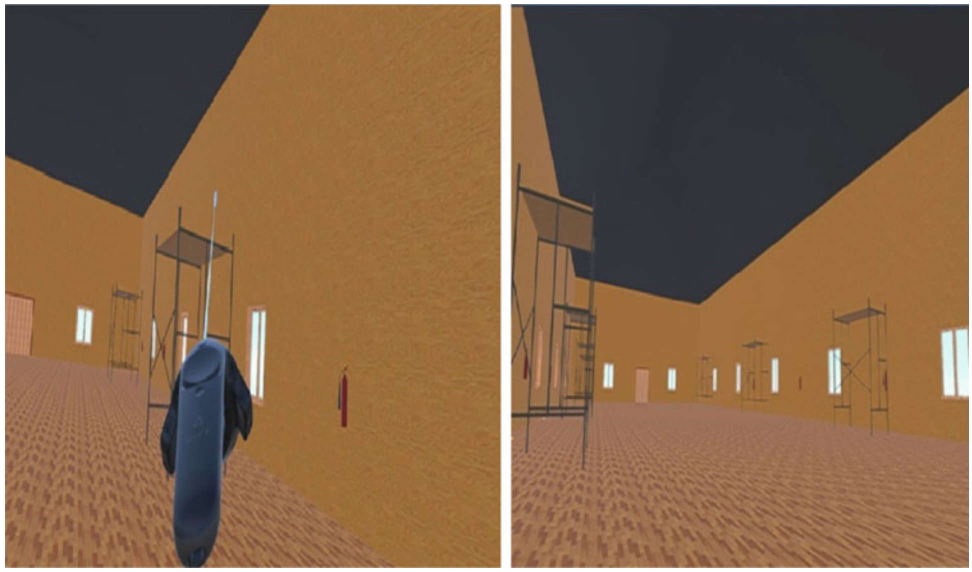

Fig. 4 Outside view of shed

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Forecasting Rental Values of Residential Properties: A Neural Network Model Approach

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Abstract

The current study intends to use the neural network (NN) algorithm for modelling and forecasting of rental values of residential properties located in Cape Town, South Africa. Data relating to property attributes and its rental value were collected. Neural network algorithm was applied in this study. The collected data was divided into two parts. The first part was used for the development of the model. Subsequently, the developed model was used to generate the forecast of rental values of residential properties. For the second part of the data, the accuracy of the model was evaluated by comparing the predicted class and actual class. Experimental results gave an accuracy of 66.67% for the test dataset. It was also found that floor area has the most significant impact on the rental value of residential properties within the study area. This study demonstrates that the neural network algorithm could be applied to real-world investigations focused on the prediction of rental values of residential properties.

Keywords

Classification • Forecasting • Modelling • Property economics • Rental value

1 Introduction

The importance of prediction of rental values of residential properties has been a subject of several investigations in the field of property economics. The significance of property values stems from the fact that it influences decisions related to real estate investment (Abidoye and Chan 2018). However, inaccuracies in property values have been widely reported in the literature, and it is a subject of international debates (Crosby 2000). Also, Jiang et al. (2013) assert that the global financial crisis of 2007, has been linked to the events in the US property market. Based on the information presented previously, it is evident that the reliability of the estimate of the value of a property is essential to all stakeholders (private investors and government, amongst others). In a bid to develop reliable models for forecasting of the rental value of residential properties, several investigations have been carried out. The modelling techniques used to generate the forecast of the value of residential properties include traditional multiple regression, neural network and support vector machine, amongst others (Abidoye and Chan 2018; Lam et al. 2009).

Comparative analysis has shown that non-linear models (such as neural network and support vector machine) tend to outperform linear models (multiple regression) when considering predictive accuracy and reliability of forecasts (Abidoye and Chan 2018; Selim 2009). This finding from previous research has led to call for a shift in methods used for estimating property values.

Several studies have evaluated the effects of several variables on values of properties in the South African real estate market. Du Preez and Sale (2013) used regression to examine the impact of proximity to low-cost housing development on property values in Nelson Mandela Bay. It was found that the presence of railway stations had a positive influence on the values of commercial properties (Boshoff 2017). Yacim and Boshoff (2018) developed models for prediction of the sale value of residential properties using the neural network and regression models. It is now well established that the property attributes (location, structural and neighbourhood) have an impact on the value of properties (Abidoye and Chan 2018; Lam et al. 2008). However, the influence of these attributes on rental values of

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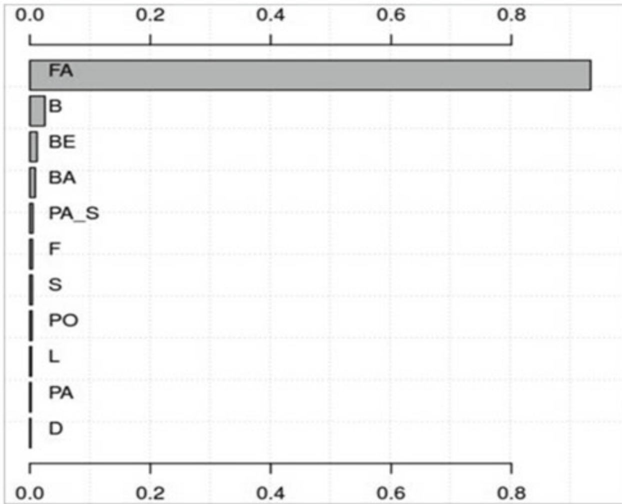

Fig. 1 Relative importance of the attributes of residential properties

Table 1 Classified into three groups (less than 15,000, between 15,001 and 30,000, and Over 30,001)

VN	Variable	Definition of variable
BE	Number of bedrooms	Numeric values of 1, 2, 3, 4, …
BA	Number of bathrooms	Numeric values of 1, 2, 3, 4, …
PA	Parking type	Classified into three groups (covered, open, none)
PA_S	Number of car park space	Numeric values of 0,1, 2, 3, …
D	Dining room	Numeric values of 0,1, 2, 3, …
L	Lounge	Numeric values of 0,1, 2, 3, …
B	Balcony	Binary values of 0 and 1
K	Kitchen	Binary values of 0 and 1
PO	Swimming pool	Binary values of 0 and 1
FA	Floor area (in Sq. metres	Numeric values of 0,1, 2, 3, …
F	Furnished	Classified into two groups (yes and no)
S	Services	Classified into two groups (yes and no)

Output variable
Monthly rental value (in South African Rands)
Note: VN = Variable name

Table 2 Summary of model validation

Observed	Predicted			Accuracy (%)
	A	B	C	
A	6	6	0	
B	1	12	2	
C	0	1	2	
			Overall	

residential properties in South Africa, has remained unclear. The current study seeks to develop models for forecasting of the rental value of residential properties in South Africa, using the neural network algorithm. To achieve this aim, the study addresses two primary objectives:

(1) To examine the efficacy of using neural network algorithm for modelling and forecasting of rental values of residential properties and (2) To evaluate the impact of attributes of residential properties on its value.

2 Literature Review

A considerable amount of literature has been published on modelling and forecasting of rental values of residential properties. These studies have majorly examined the impact of property attributes on its value. These attributes have been classified by Chin and Chau (2002), into three main groups namely neighbourhood, locational and structural. Forecast models have been developed to understand the effect of these attributes on the rental value of residential properties in different parts of the world. For example, Zambrano-Monserrate (2016), demonstrated that the type of water supply, distance to central park and waste disposal have an impact on rental values of residential buildings in Ecuador. Similarly, Hoshino and Kuriyama (2010), reported that the distance to green areas has an impact on rental values of single-room dwellings in Tokyo, Japan.

However, it has a negative impact if the building is within a radius of 1,000 m. Flood risks have a significant impact on rental values of residential properties in Germany (Hirsch and Hahn 2018). The findings from these studies show that the impact of these attributes on rental prices of residential properties varies from country to country. Therefore, the study reported in this paper aims to develop a model for forecasting of rental values of residential properties in Cape Town, South Africa. Also, sensitivity analysis would be used to examine the impact of the attributes of residential properties on its rental value.

3 Research Methodology

3.1 Overview

In the past, researchers have utilised the hedonic price model (i.e. regression) to predict the value of residential properties (Selim 2009; Zambrano-Monserrate 2016). However, the results of recent studies have shown that non-linear models (such as Neural Network) tend to generate a better forecast of property value when compared with linear regression model (Abidoye and Chan 2018). One advantage of the neural network algorithm is that it can capture the non-linear relationship which exists between residential property and its attributes. Thus, this study adopted the neural network algorithm in modelling and forecasting of the rental value of residential homes in Cape Town, South Africa.

3.2 Results

Data mining models (such as a neural network) are applied to two types of forecasting problems: (i) regression and (ii) classification. Classification problems refer to cases where the output variable is categorical. In contrast, the output variable is continuous for predicting problems referred to as regression. In the present study, the output variable (i.e. rent paid on a monthly basis) is partitioned into three groups (less than 15,000 South African Rands, between 15,001 and 30,000 South African Rands and Over 30,001 South African Rands). Classification models have been widely used in various disciplines, such as medicine (Dreiseitl and Ohno-Machado 2002) and finance (Dreiseitl and Ohno-Machado 2002) amongst others. The effectiveness of classification models is rarely exploited in the field of property economics. The neural network model utilised in this study is described in the next Section 99.

3.3 Model Validation

In this study, a three-layer feedforward neural network (NN) model was applied to forecasting of the rental value of residential properties. NN model is inspired by the human brain. The NN model is made up of interconnected neurons whose functioning is similar to the human brain. The neurons in the NN model are calibrated during the learning phase. The final forecast computed by the model is mainly dependent on the initial weights of the neurons. To reduce the variations in the final forecast from the NN model due to randomisation, an ensemble of NNs was applied in this study. The final prediction from each NN model was averaged following the suggestion of Hastie et al. (2008). The architecture of the NN model is 12-H-1. The input layer has 12 neurons (i.e. 12 independent variables). The number of nodes in the hidden layer (H) is the only parameter of the artificial neural network (ANN) model that was tuned using the grid search algorithm. The output layer (neuron) of the NN model is the rental value. The predictive experiments were carried out using the R-programming (2015) and rminer package, which facilitates application of artificial intelligence models (such as ANN) to real-world problems (Cortez 2010). The process of developing predictive models entails two important phases: model estimation and model validation. The NN model was estimated by capturing the relationship between the 10 independent variables and rental value. To validate the model, the collected data was divided into two groups (i.e. training and test data set). Zhang et al. 1998), mentioned that the ratio for training and test data set in previous studies include 90:10; 80:20 and 70:30, respectively. For this study, the collected data were randomly divided into two groups based on 70 and 30%. Thus, 70% of the data was used to develop the neural network model, whilst the remaining 30% was used to evaluate the predictive accuracy of the developed model.

3.4 Data Collection and Pre-processing

Evidence shows that the listing prices of residential properties tend to provide a realistic estimate of its value (Abidoye and Chan 2017), when compared to transaction data. In this study, listed rental values were retrieved from a reliable source (www.property24.com). At the end of the data collection phase, data on 225 rental values of residential properties in Cape Town was retrieved. The data was pre-processed and cleaned to ensure that the incomplete entries were excluded. At the end of the cleaning process, 101 observations remained, and this data was used for the development of the neural network model (Table 1).

4 Model Performance and Sensitivity Analysis

4.1 Model Performance

The neural network model was used for forecasting of the categorical rental values of residential properties in Cape Town, South Africa. For the computational experiment, the neural network model was developed using the 71 data set (i.e. training data). The test data set (30 observations) was then used to verify and evaluate the predictive performance of the developed neural network model. For classification problems, the predictive performance of the developed model is evaluated based on the percentage of "correctly classified" and "incorrectly classified". This value ranges between 0 and 100% (Cortez 2015). Generally, a value close to 100% indicates that the model can correctly classify all the test data set.

The results from model validation (i.e. prediction of the test dataset using the trained neural network model) are summarised and presented in Table 2. The overall predictive accuracy of the neural network model is 66.67%. Also, 50% of A class were incorrectly predicted as B (6 out of the 12 cases were incorrect).

4.2 Sensitivity Analysis

The output of the ANN models does not contain coefficients or t-values like the hedonic price model. This outcome makes it difficult to establish the impact of each attribute of a residential property on its rental value. Based on this, neural network models are often referred to as "black box" techniques. Cortez and Embrechts (Abidoye and Chan 2018) developed sensitivity analysis as a technique to be used for visualising the impact of independent variables on a predicted variable in black box models. In the present study, a sensitivity analysis was used to evaluate the influence of property attributes on its rental value. Figure 1 shows the relative importance of the 12 attributes used in developing the neural network model. As can be seen from Fig. 1, floor area (FA), balcony (B) and a number of bedrooms (BE) are the significant attributes affecting the rental value of residential properties in Cape Town, South Africa.

5 Discussion

As mentioned in the literature review, the impact of attributes of a residential property on its value tends to vary from country to country. With respect to the first research question, it was found that the neural network model can be used for prediction of rental values of residential properties. Also, floor area has a significant impact on the rental value of residential properties located within the study area. The result of this study shows that the presence of kitchen did not affect the rental value of residential properties. A possible explanation for this finding could be attributed to the availability of kitchen in all the residential properties sampled in this study. Consistent with the literature, this research found that the attributes of the residential property are good predictors of its value (Abidoye and Chan 2018; Selim 2009). Abidoye and Chan (2018) found that numbers of boy's quarters, number of bedrooms, sea view are important attributes that influence the value of residential properties in Lagos, Nigeria. Access to air conditioning, number of bedrooms, pool facilities, closeness to the beach, golf facilities and marketing to upscale travellers are significant on rental values of villas and cottages in Barbados (Kaidou et al. 2014). However, it must be noted that the most critical attribute influencing the value of residential properties vary from market to market. For example, the number of rooms in the boys' quarters is reported as the most important attribute affecting the value of residential properties in Nigeria (Cortez and Embrechts 2013).

These findings suggest that the value of residential properties can be predicted using its attributes. Also, floor area remains as the main factor affecting the value of residential properties. These findings may help stakeholders (property developers, property economist, government and investors) to gain an understanding of attributes influencing the value of residential properties located in Cape Town, South Africa.

Although the results of the predictions are disappointing, it is known that the size of datasets affects the forecasts generated by neural network models. A further study with a larger dataset is needed to validate the findings reported in this study.

6 Conclusion

The aim of this study was to use the neural network algorithm for modelling and forecasting of the rental value of residential properties. Floor area, balcony and the number of bedrooms emerged as the most critical attributes affecting the rental value of residential properties in Cape Town, South Africa. In general, the findings of this investigation show that the neural network algorithm is a good modelling technique for forecasting the rental value of residential properties. These findings contribute in several ways to knowledge in the field of property economics concerning rental value of residential properties. Despite the contribution of the findings of this study to the body of existing knowledge in property economic, the results are subject to certain limitations. For instance, the dataset used to develop the neural network model is considered to be small.

Shin et al. (2005) affirm that the quality of forecast generated by the neural network model depends on the size of data used for its development. However, it is important to reiterate that unavailability of data remains a challenge faced by researchers in the field of construction economics and property economics. Also, the scope of this study was limited to Cape Town, South Africa. In spite of these limitations, the study adds to the current knowledge on the impact of attributes of residential properties on its rental value. Also, this South African study can be used to predict residential prices in other similar developing countries. Further work needs to be done to establish the influence of proximity to green areas (such as parks) on the rental value of residential properties. Also, future studies could be conducted to determine the effectiveness of using a neural network model for forecasting of rental values of commercial properties.

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Costing of Health and Safety Elements in Construction Projects in Gauteng, South Africa

Jirel Akawi and Innocent Musonda

Abstract

The current study reports on findings from a study on the costing of health and safety elements in construction projects. Nine construction projects were purposively enrolled to the study, comprising six civil engineering and three building construction projects. The findings showed that H&S elements were costed by contractors using an itemised breakdown even though such items were not included as a trade items in the Bills of Quantities (BOQs). The costs established from actual expenses incurred on construction projects revealed that H&S expenditure ranged between 3 and 4% for projects with a value below R500 million and between 4 and 5% for projects with a value above R500 million. Further, H&S costs were found to be directly proportional to the projects value and indirectly influenced by the client. Costing of H&S elements has been a challenging task as there is no standard on how H&S elements should be priced in the South African construction industry. The lack of a framework to assist with costing of H&S elements on construction projects makes accurate and adequate monitoring of H&S costs to be problematic. Thus, a standardised pricing framework can assist contractors to cost and for clients to adequately evaluate bids and or variations on construction projects, and to ensure that provision for H&S as provided for by the Construction Regulations 2014 is made.

Keywords

Construction • Costing • Health and safety (H&S) • South Africa

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1 Introduction

The construction industry still faces the challenge of a poor H&S performance. Statistics provided by the Health and Safety Executive (HSE) revealed that in 2013/14, injuries and new cases of ill-health of workers was largely from working conditions (HSE 2015). HSE reported that these injuries and illness cost an estimated £14.3 billion (HSE 2015). Similarly, in South Africa, the Construction Industry Development Board (2009) reported that the cost of accidents, both direct and indirect, amounted to R3.5 billion per year. The financial loss caused by occupational accidents is great amounting to as much as 1.2 trillion USD (International Labour Organization (ILO) 2009). Occupational accidents cause significant financial losses in the workplace (Yilmaz and Çelebi 2015). According to (Rikhardsson 2005), these costs can be reduced if accidents can be prevented. However, prevention of accidents partly depend on correctly providing finance for H&S. Having a pricing guide is, therefore, essential.

2 Pricing for H&S on Construction Projects

As Motchar and Arditi (2001) stated that the construction industry is characterised by extreme competitiveness, with high risks and generally low-profit margins when compared to other areas of the economy. The competitive nature of the industry hinders H&S performance (Cole 2003). Sumner and Farrell (2003) remark that such competition has often forced contractors to look for cost savings during the construction phase and such practice leads to H&S being compromised.

Sumner and Farrell (2003) argues that inadequate and poor H&S do not only affect other project parameters, namely: cost, quality and schedule negatively, but the sustainability of the environment as well. According to Smallwood (1999), the construction industry is perceived to be price-driven. Projects are awarded on the lowest tendered price and not enough

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consideration is given to other factors such as H&S and quality. López-Alonzo et al. (2013) argue that making adequate provisions for H&S on construction projects could yield benefits to the project. Clients are responsibe for safety implementation on a project. Consequently, we ask how can the client ensure that the contractor has made adequate allowance for H&S measures on the project if a standard pricing tool to measure such output is non-existent?

For many contractors, H&S is priced as a line item in the Preliminaries and General (P&Gs) section of Bills Of Quantities (BOQ) and not as an itemised trade showing a breakdown of H&S costs even though studies by the CIDB (2009), Sumner and Farrell (2003) and Smallwood and Emuze (2014) recommended that H&S costs should be itemised in the BOQ; be laid out using a structured approach and be priced in a special section in the BOQ, respectively.

A H&S pricing framework for construction projects will not only assist contractors to make adequate provision for H&S on construction projects or client to ensure that the contractor has made adequate allowance for H&S on said projects but to manage and report on the H&S costs on the said projects. The lack of such pricing model makes accurate, adequate budgeting and controlling of H&S costs unlikely.

2.1 Personal Protective Equipment (PPE)

PPE is defined as an article of clothing or accessory, that, when used correctly, will create a barrier between a person and the H&S hazard to which they are exposed. It is designed to reduce the adverse health effects (HSA 2010). A worker needs to wear a combination of PPEs to have adequate protection against a combination of several H&S hazards (HSA 2010). Unlike PPEs which protect a person from H&S risks at work, safety equipments (SEs) are essential for the effective operations of work on site. For PPEs, example of items to be pricing for should include protective footwear, protective clothing, hand protection, eyes and earing protection, head protection, fall arrest/prevention; respiratory protection, reflective wear, special PPEs. Smallwood recommends that one of the elements that need to be included in costing for H&S on construction projects is the inspection of safety equipments (Smallwood 1999).

2.2 H&S Staffing and Training

The cost of Health and Safety staffing should include training. According to the Construction regulation 2014 “no contractor may allow or permit any employee or person to enter any site, unless that employee or person has undergone health and safety induction training pertaining to the hazards prevalent on the site at the time of entry” (Republic of South Africa 2014). Training and induction courses are, therefore, part of the safety cost in a project.

2.3 H&S Programmes and Activities

The cost drivers in this category encompass various activities and initiatives taken by management within an organisation to raise health and safety awareness and engage with workers on safety matters in driving the successful implementation of H&S objectives on a given project in order to achieve the desired outcomes. Amongst others, the cost for H&S programmes and activities should include H&S audits, (Innes 2009); H&S incentives and rewards (Musonda and Pretorius 2015); H&S meetings (Kikwasi 2008); accident investigation and reporting (Kartam et al. 2000); H&S Branding (Musonda and Haupt 2011); security features (Farinyole et al. 2013); emergency preparedness (Wells and Hawkins 2009) and insurance costs (Babu 2014) Compensation for Occupational Injuries and Deceases Act (Republic of South Africa 1993).

3 The Study Methods

We studied nine projects comprising civil engineering and building projects in two different organisations. Data was collected through both interviews (Bowen 2009) and documents analysis (Dawson 2002) in organisations with a reported good H&S records and expertise. The interviewees included four were H&S Managers and a H&S executive. Their work experience ranged between 10 and 25 years. The goal of the project was to establish the costs of H&S on a project. The choice of projects used in the case study was based on value and type. As projects are different in nature and have different requirements and scope, such factors have an impact on H&S costs.

Data obtained were analysed using descriptive statistics, namely, frequency count (Dawson 2002), percentage ratios (Kumar 2011) and rankings (Saunders et al. 2009). Frequency count was used to identify the most and least frequent H&S cost drivers found on projects (Fig. 1). Rankings were used to classify various cost drivers based on their FS in descending order.

4 Findings

The project values included in the study ranged between R31 million and R687 million. In terms of duration, the shortest project period was 10 months and the longest 27 months (Table 1).

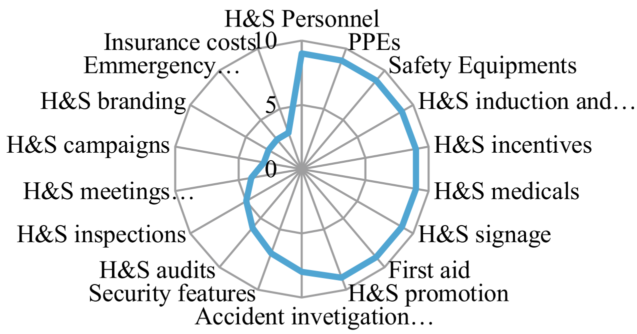

Fig. 1 H&S elements priced for on construction projects

Document analysis revealed that the actual expenses on H&S elements ranged from R900 thousand for a R30 million project and about R34 million for a 650 million project (Table 2). In terms of the actual expenses on H&S and the project value ratios, it was found that the actual costs ranged between 2 and 5% (Table 3). It was also observed that projects with a value of R500 million and above had a higher H&S expense to project value ratio. These projects had a ratio of 4% and above. Of interest, however, a R31 million value for project C had about 3% of its project value on H&S provisions.

On average on building projects, the percentage spent on H&S equated to 3 and 4% on civil engineering projects. Nine elements were found to be the most frequent in all projects with a frequency score of 9 (see Fig. 1). These included H&S personnel, PPEs, induction and training, incentives, medicals, signage, first aid and H&S promotions. Investigations were ranked second with a frequency rate of 8. Security features were ranked third at 7. H&S audits were ranked fourth at 6. H&S inspection was ranked fifth with a frequency rate of 5. In sixth position were expenses to do with H&S meeting with frequency of 4. H&S campaigns, H&S branding, emergency preparedness and insurances were ranked last at 126.

It was observed that projects with higher values also had a higher H&S expense for the project compared to those with lesser value. H&S costs were found to be directly proportional to the project value. Considering all elements being equal, it was observed that for projects valued below R500 million had H&S expenses of between 3% and 4%, Projects valued above R500 million had H&S expenses of between 4% and 5%. Thus, the higher the project value, the higher the cost of H&S.

Table 1 H&S cost drivers

Item no.	Cost Drivers	References
1	PPEs	HSA I2010)
2	H&S Personnel	Republic of South Africa (2014), Smallwood and Emuze (2014)
3	Safety Equipments (SEs)	Smallwood (1999), Sawasha et al. (1999)
4	H&S induction & training	Hinze and Gambatese (2003)
5	H&S Inspections	HSE (2015)
6	H&S Audits	Republic of South Africa (2014), Alli (2008)
7	H&S Incentives	Musonda and Pretorius (2015)
8	H&S Meetings	Republic of South Africa (2014), Bizzell (2008)
9	Accident investigations and reporting	Sadus and Griffiths (2004)
10	H&S Medicals	Republic of South Africa (2014) HSA (2010)
11	H&S Signage	Hymel et al. (2011)
12	H&S Campaigns	Construction Industry Development Board (CIDB) (2009)
13	First Aid	Wells and Hawkins (2009)
14	H&S Promotions	Kothari (2004)
15	H&S Branding	Musonda and Haupt (2011)
16	Security features	Farinyole et al. (2013)
17	Emergency Preparedness	Wells and Hawkins (2009)
18	Insurance costs	Babu (2014)

Table 2 H&S expenditure ratios

Item no.	Project names	Project budget expenditure	H&S expenditure	% ratio
1	Project A	R400 000 000.00	R9 553 995.79	2.39
2	Project B	R195 000 000.00	R5 203 248.74	2.67
3	Project C	R31 500 000.00	R957 454.78	3.04
4	Project D	R630 000 000.00	R25 690 909.42	4.08
5	Project E	R500 000 000.00	R20 688 493.19	4.14
6	Project F	R687 000 000.00	R33 664 777.73	4.90
7	Project G	R86 000 000.00	R2 680 986.22	3.12
8	Project H	R72 000 000.00	R2 410 426.05	3.35
9	Project I	R372 000 000.00	R14 791 563.62	3.98

Table 3 H&S cost elements

Item no.	Category	Cost components
1	PPEs	Footwear, clothing, gloves, eyes and earing protection, hard hat, fall arrest strap; mouth mask, reflective wear
2	Induction and Training	On PPE; emergency response; crane/machinery operations; accidents investigation and reporting; first aid; special training
3	SHE personnel	Managers; Officers (Site based); first aiders
4	Medicals	Entry & exit medicals; cost of consultation
5	Site Security	Fencing, site enclosure; access control; site illumination
6	Safety Equipments	Fire extinguishers; harnesses; cones; alarm canisters; flags; speed bumps/humps; breathalysers; ladders; scaffolding; lifelines
7	Welfare, well-being	Accommodation; transportation; skips; food; bins; ablutions; eating & cooking area; cleaning equipment; storage; cleaning personnel
8	Signage	Warning, directional prohibitory signs; mandatory; emergency traffic control signs (i.e. speed limits, Stops blocks, etc.) signs
9	Administration	SHE file; Permits approval; Police clearance; Inspection & audits
10	Investigations and reporting	Direct costs
11	Insurances	COID, Insurance premiums
12	Sundries	Awards; branding; incentives

4.1 Findings from Interviews

Interiew participants acknowledged that with the lack of a standardised pricing model, clients in the CI cannot ensure that H&S measures are adequately provided for.

Participant 3, a Safety, Health and Environmental manager said:

> There is no method for pricing for H&S in the construction industry. A pricing tool is non-existent. How do clients adjudicate for H&S? How can the costs of H&S be managed on projects?

We found that most participants itemised the cost of health and safety on their projects as opposed to using percentages as such method is considered not accurate. According to the participants, itemised costing approach for H&S is better and cost control can be achieved. Participant 5 argued that the cost of H&S should be itemised in the BOQ in order to manage expenditure and report adequately on PPE; emergency response; crane/machinery operations; accidents investigation and reporting; first aid and special training.

5 Conclusions

The study aimed at identifying key H&S pricing elements on construction projects. In order to achieve the said objectives, it was imperative to identify the cost drivers that should be considered when pricing for H&S and how much should be allowed for. H&S cost drivers presented in the findings are regarded as the minimum to be priced for if it at all H&S performance can be assured and monitored on construction projects.

From the findings, it was evident that contractors itemised the cost of H&S on their projects even though such breakdown is not included as a trade in the BOQs. With the lack of a standardised pricing model, each contractor has its own way of pricing for H&S, which makes it difficult for client to adjudicate and ensure that contractors have made adequate allowance for health and safety measures on their projects as required by the Construction Regulations (Republic of South Africa 2014).

With regards to budget, health and safety costs on projects were found to be directly proportional to the project values. Higher H&S specifications will have an impact on H&S cost compared to projects with lower specifications. Since projects are driven by clients, it was also observed that clients had an indirect impact on H&S cost on projects. An H&S minded client would have a higher H&S specifications, thus affecting H&S costs.

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An Assessment of Factors Influencing Collaboration Impacts on Organisational Performance: A Review

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Abstract

Poor organisational performance is partly attributed to lack of collaboration within an organisation. Therefore, this paper sought to establish the factors that influence collaboration and the impact of collaboration on organisational performance. A literature review was conducted to achieve the objectives of the study. Literature from Google Scholar, Emerald and Science Direct were used, based on the keywords relevant to the study. The materials consulted included journals and conference proceedings. Thematic content analysis was used to identify factors that influence collaboration in an organisation. The findings revealed that collaborative leadership, collaborative culture, attributes of partners, strategic and external environment factors influence collaboration. Further findings revealed that collaboration could influence an organisation's performance in terms of knowledge creation and transfer, innovativeness, ability to leverage resources to achieve maximum benefits, as well as competitive advantage. This study provides knowledge on factors that influence collaboration in order to devise strategies to improve the quality or extent of collaboration in an organisation. By understanding the factors of collaboration, which in turn influence organisational performance, strategies can be developed by stakeholders and managers to encourage collaboration and thus performance.

Keywords

Collaboration • Organisations • Performance • Success

1 Introduction

The construction industry all over the world contributes to more than 10% of the world's economy (Hussin et al. 2013). Often, the construction industry is utilised by government to stimulate growth toward the economy since it is a prime indicator of economic activity (Baloyi and Bekker 2011). With construction being the prime economic activity, it is crucial that construction projects become successful. However, performance in the construction industry has been poor due to poor communication and poor exchange of information and knowledge amongst project participants or project team (Isikdag and Underwood 2010). This is as a result of lack of or inadequate collaboration amongst the project teams. Collaboration has been described as 'shared accountability between individuals, some interdependence between individuals and clarity of roles/goals" (Reeves et al. 2018). In this arrangement, team tasks were regarded as generally a little more predictable, less urgent and complex. When done right, collaboration can improve productivity and profitability, increase innovation and result in a cost reduction (Lee et al. 2010). Collaboration can be beneficial for all stakeholders during a project in order to improve organisational performance and create long-term relationships and value to the organisation (Eriksson 2008; Zwikael et al. 2012).

Previous similar studies revealed that the functioning and knowledge sharing of the collaboration team have direct effects on the quality and inter-instituted collaboration and team performance (Mohammadi et al. 2010). It is further stated that the collaboration attitude, culture behind each individual and competence reflects the team performance involved in the project (Wu and Chen 2014). Collaboration

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has characteristics and attributes that contribute to quality improvement and performance in an organisation.

Other case studies conducted by Chan et al. (2003), Naoum (2003), Bresnen and Marshall (2000) in Hong Kong, United States of America (USA) and in the United Kingdom (UK), respectively, posited that collaboration increases the chances of a construction project being completed on time, at the budgeted cost, with the quality satisfaction from the client, with the least amounts of conflicts, a better relationship with the client and less defects claimed. However, the current study sought to identify the factors of collaboration using a literature review.

The current study's objective was, therefore, to identify factors that influence collaboration and in turn, organisational performance. The methods used in conducting the review are presented briefly in the subsequent section. Thereafter, the information distilled from the review is presented. Conclusions drawn from the findings are subsequently presented.

2 Methods

The current paper is part of an on-going Master's study. It presents findings from a literature review stage. Therefore, a desktop study approach was used to conduct the current study in order to identify common themes from existing studies, on the factors that influence collaboration in construction organisations and projects. Materials were sought from databases including Science Direct, Google Scholar, Emerald Insight and Google. The materials used included journal articles and conference papers. The materials were used based on the possession of the keywords relevant to the study including collaboration, construction, teamwork, organisational performance and project performance. Thematic content analysis was used to identify themes on the factors which influence collaboration and the impact of collaboration on organisational performance. The framework of factors developed will be tested using quantitative data in an on-going second phase of the study, in order to validate the framework of factors and test hypothesised relationships. The current paper presents findings from the review.

3 Factors Influencing Collaboration

Numerous factors influence the development and success of collaboration in any industry aimed at improving organisational and project performance. Daft (2001) identified factors such as the environment, strategy, size of the organisation, technology and how it is improving, age of the participants and their cultural background. Other studies identified strategic factors, external environment, attributes of the partners, collaborative leadership and culture as collaboration influencers.

3.1 Strategic Factors

Strategic factors affecting collaboration may include setting goals that are clear for supplementary purposes (Van de Vrande 2009; Feller et al. 2011); the regulation of distributing results for collaboration in order to prevent important information from leaking out before time (Buse and Harmer 2007); methods of resolving common problems before resorting to harsh methods that involve domination, arbitration or persuasion; governance in order to clarify role of each individual in the collaboration and governance in defining how performance will be measured amongst the main agents (Sherer 2003; Feller et al. 2009).

3.2 External Environment

The external environment incorporates three factors including IT capacity and integration and information system (Sherer 2003); similar geographic location of the partners, which affect collaboration positively when they are closer to each other; and the management of knowledge and assets (Sherer 2003).

3.3 Attributes of the Partners

The attributes of partners or team members influence their level of collaboration. Such attributes include technological ability, where they are able to develop and innovate new technology (Sherer 2003), complementarities, where partners can complement one another's technological abilities, experience in collaboration, diversity in gender, age, education levels, knowledge absorption and integration of new knowledge (Bullinger et al. 2012; Nakagaki et al. 2006).

3.4 Collaborative Leadership

Collaborative leadership influences collaboration in an entity. Effective leadership brings about competitive advantage (Hurley 2011). The traditional form of leadership mostly consists of power, hierarchical, command and control structure. An organisation requires leadership skills in a hierarchical model from top down; however, that approach and model of leadership is no longer enough (Hauswirth et al. 2004). With collaboration being about bringing individuals together with a shared goal to address shared concerns of the organisation, there must be a collaborative leader that is employed in almost any situation. Therefore, collaborative leadership involves the process of engaging collectively in order to achieve common goals (Hurley 2011). It is 'the process of engaging collective intelligence to deliver results across organisational boundaries when ordinary mechanisms of control are absent' (Hurley 2011). Intellectual individuals gathered together are smarter and more creative, and believe that power is greatest in a collective team. This encourages suggestions and ideas from the team, allows roles and responsibilities to evolve and fluctuate, and offers on-going and immediate feedback with personalised coaching (Hurley 2011).

3.5 Collaborative Culture

Collaborative culture between the partners should be fair in order to overcome differences quicker. Confidence in perceiving the partners' honesty, believing that information is to remain within the organisation and believing in the collaboration to be of a positive effect influence the extent of collaboration in an entity (Lichtenthaler 2009; Westergren 2011; Colombo et al. 2011; Schiele 2012). Further, immersion in forming a long-term relationship and investing in a good collaborative relationship as well as communication to allow information flow, participation, exchange of information, and mutual communication determines the level of collaboration amongst partners and culture in an organisation (Sherer 2003; Schiele 2012).

3.6 Political Factors

Political influences have great potential outcome on collaboration due to organisations being able to increase the amount of certainty and have a certain degree of organisational influence (Hardy et al. 2003). For example, stakeholders that are more powerful in the organisation collaborate with the 'weaker' individuals in order for the stakeholders to have control over what they do; whilst the stakeholders also collaborate amongst themselves in order to prevent opponents from reconditioning the domain in which they work (Boaz et al. 2018). A political perspective on inter-organisational collaboration is said to have an advantage due to it being a tool also for acquisition of power and influence (Vangen and Huxham 2003). In summary, the above factors, strategic, political, external environment, leadership and culture, influence collaboration in an organisation, which in turn affect an organisation in one way or another.

4 Effects of Collaboration on Organisational Performance

There is a wide variety of literature that has been studied all over the world, each of which is written about the different effects of collaboration on knowledge creation and organisational performance creation (Hardy et al. 2003; McEwan et al. 2017). Collaboration is about working together with partners or stakeholders in order to leverage all kinds of resources and provide maximum benefits (Gulati et al. 2000). In addition, one of the most crucial effects of collaboration is its potential to build an organisation capacity through the transfer of knowledge (Hardy et al. 2003). Collaboration is about learning from each other or your partners whereas it is used as a necessary tool that creates transfer of organisational or individual knowledge (Hardy et al. 2003).

Amongst the context of a community or organisation is where the process of knowledge creation occurs. Not only can the transfer of knowledge exist from one organisation to another, through collaboration, new knowledge is able to be created and transferred within an organisation (Tshuma et al. 2018).

Knowledge exchange has been found to be the fundamental role of what people in collaboration are supposed to be doing (Choo et al. 2000). According to Staykova and Underwood (2017), the central position of the concept of collaboration is taken by knowledge exchange. An industry of knowledge intensity, such as construction, requires different combinations of knowledge sharing for innovation (Ruan et al. 2012). This suggests that knowledge creation is related to innovativeness in an organisation. These views are shared by Rezgui et al. (2010) who viewed that in order for industries to innovate, there should be combinations of knowledge sharing. Since knowledge exchange spans throughout all the project phases, it provides a continuous assessment and improves the quality of collaboration.

In summary, the literature synthesis presented above revealed that the extent of collaboration in an organisation could depend on certain factors. The concept of a collaborative structure leads to critical thinking and with disposition such as habit, desire to be well-informed, a readiness to seek reason, inquisitiveness and flexibility, better collaborators are borne (Lai 2011; Subramaniam et al. 2012). Further, culture, leadership and strategic and external environment factors including geographic locations, knowledge and asset management were observed to influence the level of collaboration in an organisation. It was, therefore, hypothesised that these factors influence the degree of collaboration which in turn influences organisational performance. These relationships are depicted in Fig. 1. The framework, which is not

Fig. 1 Hypothesised relationships between collaboration and organisational performance

exhaustive at this stage of the Master's study, will be further developed and tested in the quantitative research.

5 Conclusion

The study sought to identify the factors that influence collaboration. As a smaller part of a wider study being conducted on the impact of collaboration on organisational performance, key concepts and relationships were identified from the preliminary review and presented in the current paper. The factors include strategic factors, leadership and culture, external environment and political factors. However, it is notable that the factors presented herein are not exhaustive. The findings of the study are envisaged to be beneficial to managers in different sectors in forming strategies to improve collaboration and thus performance in their organisation.

Further studies are on-going to test the identified relationships and validate the findings herein in order to determine the critical factors that influence collaboration and which should be encouraged or harnessed to improve performance and achieve desired targets or results.

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A Hybrid Conceptual Model for BIM Adoption in Facilities Management: A Descriptive Analysis for the Collected Data

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Abstract

Despite the approved benefits of Building Information Modelling (BIM) for the whole project life cycle, the adoption of BIM in facilities management (FM) is only minimal. Still, BIM adoption and implementation in FM is unclear. Thus, this ongoing research aims at identifying the main factors that affect the acceptance of BIM in facility management and to framework a hybrid conceptual model that integrating Task Technology Fit (TTF) and Unified Theory of Acceptance and Use of Technology (UTAUT) for better understanding the use of BIM in FM. The methods that are being adopted in this research include a comprehensive literature review, interviews, and survey. The proposed conceptual model for BIM in FM was already developed in the previous paper. In this paper, a summary of interim findings and an overview of the online survey and data collection procedure are presented. Also, a descriptive analysis of the sample size of 134 responses is discussed. The general results showed interesting findings and acceptable level of participants' qualifications to answer the online survey. The future work will include the model constructs' validation and test of the research hypotheses

Keywords

Facilities management • Building information modelling (BIM) • Unified theory of acceptance and use of technology (UTAUT) • Technology task fit model (TTF)

1 Introduction

There has been no specific and clear definition for FM until now. Thus, there are a number of definitions of FM from different viewpoints (Hilal et al. 2019). For example; the International Facility Management Association defined FM as "A Profession that encompasses multiple disciplines to ensure the functionality of the built environment by integrating people, place, process, and technology". In fact, FM requires a huge amount of information. The reason is that FM consists of a wide range of tasks and activities. Availability of relevant information for various facilities stakeholders is required. Hence, the efficient access to information is very crucial for successful FM practices. At the end of the construction project, the constructor has to handover a huge amount of information and data to the operator/owner. Then, the operator/owner has to spend a great time and costs to specify useful and relevant information (Lee et al. 2012; Mendez 2006). Research has revealed the proven benefits of BIM and how it organizes and streamlines the provision of the necessary information for the whole project lifecycle including FM sector (Alvarez-Romero 2014; Hilal et al. 2017). However, the adoption of BIM is still very low in many countries (Xu et al. 2014), and even the analysis studies on the status of BIM is scarce, specifically in the FM sector (Hilal et al. 2018). In fact, technology adoption is a result of users acceptance of using that technology (Ammenwerth et al. 2006). Technology acceptance theories like TAM, TTF, UTAUT, etc. have the capacity to model how users come to accept new technology. Briefly, this research aims at identifying the key factors that influence the

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widespread acceptance and adoption of BIM in facility management sector and developing a hybrid conceptual acceptance framework for BIM in FM. The proposed conceptual model was already developed in the previous paper. In this paper, a summary of interim findings and an overview of the survey and the descriptive analysis of the collected data are presented.

2 Technology Acceptance Theories

Technology acceptance theories are information system theories that model how users come to accept and use new technology. There are different types of technology acceptance and behaviour theories such as technology acceptance model (TAM), theory of planned behaviour (TPB), task technology fit (TTF), and unified theory of acceptance and use of technology (UTAUT). This research applies the light on TAM, TTF, and UTAUT as they are considered more related to this research. Technology Acceptance Model (TAM) has been derived from the theory–TRA (Davis 1986). According to (Davis et al. 1989), a set of external variables of a system/technology can influence corresponding user motivation levels through perceptions on usefulness and ease of use and attitudes of using leading to actual use/user behaviour. The updated versions of TAM, which is known as TAM2 and TAM3 have included user behaviour factors and subjective norms (Lee and Yu 2013). The Unified Theory of Acceptance and Use of Technology (UTAUT) has been developed by Venkatesh et al. (Venkatesh et al. 2003) based on the updated version of the TAM and other related theories. The model has revealed that facilitating conditions, effort expectancy, performance expectancy, and social influence have a direct and indirect influence on behavioural intention and use behaviour. Also, those relations are mediated by gender, age, experience, and voluntariness of use which give the theory more reliability (Venkatesh et al. 2003). TTF is another technology acceptance theory that came up with a new concept and determinants. Many researches have been done mainly to explain user adoption of new technology from perceptions like subjective norm, perceived usefulness, and perceived ease of use (Davies and Harty 2013; Lee et al. 2015; Son et al. 2014). However, the adoption of a certain technology is not determined only by their perception regards it, but in addition, the aspect of whether that technology will fit the tasks requirements. Thus, if the technology does not fit the task then why the user needs to adopt it (Zhou et al. 2010). Standing on this fact, the TTF is a crucial determinant of the technology adoption (Goodhue and Thompson 1995).

3 The Developed Conceptual Model and Their Components

In the previous paper (Hilal and Maqsood 2017), the researchers have found the following key points: (1) The implementing of BIM in FM is still in its infancy and there are no clear studies that would encourage the industry stakeholders towards faster adoption, (2) Despite the importance of the TTF model as a significant determinate of users' adoption of technology, no study has been conducted yet using TTF regards the adoption of BIM in FM, and (3) The factors that influence the acceptance and adoption of BIM in FM is still a significant issue in this sector. To contribute in this area and give more clarity, a hybrid model of UTAUT and TTF was developed to measure facility management practitioners' perceptions regards BIM adoption in FM sector. The model was based on validated and reliable variables and items. In other words, the model provides the rationale for the constructs relied on the theoretical background on TTF and UTAUT. The comprehensive literature review was the key component in this regards. Synthesis, criticize and comparison techniques have been conducted to generate the model, taking into account the suitable modification and wording aspects to be compatible with BIM adoption in FM. The following (Table 1, Hilal and Maqsood 2017), shows the sources of the proposed model construct and their Sources.

Based on that, a novel hybrid model integrating TTF and UTAUT has been conceptualised to consolidate factors influencing the acceptance of BIM in FM sector as shown in Fig. 1 (Hilal and Maqsood 2017). These factors have been extracted from the related literature with some rewording process to be compatible with the FM context as shown in Table 1. Specifically, the proposed model considers a hybrid integration of: (a) UTAUT based rationale for model parameters and variables, and (b) Technology Task Fit Model.

Each factor above has its own items (scales) that measure the related factor as shown in the following Table 2, which was developed by the authors.

4 The Research Survey and the Data Collection

The data collection through a questionnaire survey was carried out between Nov 2017 and Dec 2018, in Australia. Prior to data collection stage, human research ethics clearance was first obtained from the Human Research Ethics Committee of Swinburne University of Technology

Table 1 Factors definition of the proposed model (Hilal and Maqsood 2017)

Factor	Definision	Ref.
Performance expectancy	The degree to which an individual believes that using the system will help him/her to attain gains in job performance	Venkatesh et al. (2003)
Effort expectancy	The degree of ease associated with the use of system	Venkatesh et al. (2003)
Social influence	The degree to which an individual perceives that important others believe he/she should use the new system	Venkatesh et al. (2003)
Facilitating conditions	The degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system	Venkatesh et al. (2003)
Task technology fit	Task technology fit is the rational perspective of what a new technology can do to optimize a job. It is affected by the nature of the task and practicality of the technology to complete the task	Oliveira (2014)
Technology characteristics	Main determinate of the task technology fit theory that considered the technology characteristics aspect	Goodhue and Thompson (1995)
Task characteristics	Main determinate of the task technology fit theory that considered the task characteristics aspect	Goodhue and Thompson (1995)

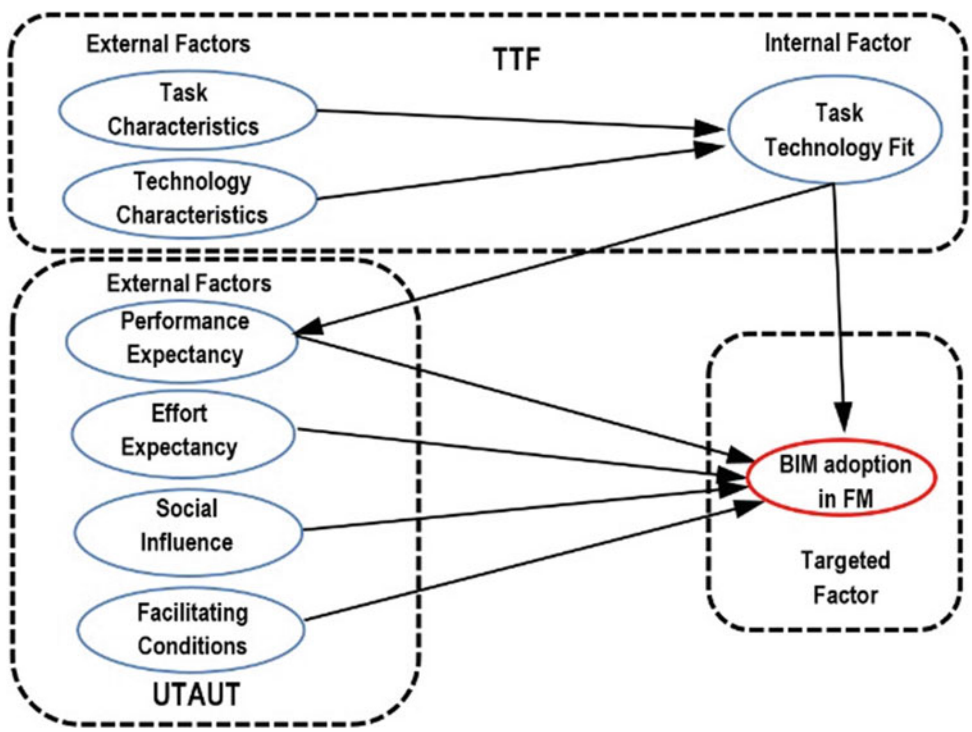

Fig. 1 Conceptualization of the model (Hilal and Maqsood 2017)

(SUHREC). Ethical clearance from SUHREC for the study number SHR Project 2017/131 was obtained in Aug 2017. Then, an expert judgement procedure was conducted between Aug and Nov 2017. The objectives of the expert judgement procedure were to explore whether the questions and the instructions of the questionnaire survey were clear and understandable. Also, to make sure that the questions conveyed consistent meaning for all respondents, two of the experts in BIM-FM area were chosen to this issue. The experts have been requested to give their general judgement of the questionnaire regarding the format, length, and any language/terminology issues. They emphasized that the questionnaire was simple, easy, and well designed, except for some changes that would help to make the questionnaire more understandable. After doing all the required corrections, the questionnaire was designed through Opinion and published online in Nov 2017, in different platform like LinkedIn, CNBR of yahoo group, and have been sent to many persons who are interested in BIM-FM. However, the rate of responses was quite low within 11 months. Accordingly, the way of getting the respondents was changed by targeting every single event and conference related to

Table 2 Items measurement used in the conceptual model

Construct	Item/measure	Ref.
User adoption	USE1: I often use BIM to manage my FM tasks USE2: I often use BIM to optimize the cost USE3: I often BIM to optimize the time	Venkatesh et al. (2003)
Performance expectancy	PE1 I would find BIM useful in my job PE2 Working with BIM enables me to accomplish tasks more quickly. PE3 Working with BIM increases my productivity PE4 If I work with BIM, I will increase my chances of getting a raise	Howard et al. (2017)
Effort expectancy	EE1 My interaction with BIM would be clear and understandable. EE2 It would be easy for me to become skilled at working with BIM. EE3 I would find BIM easy to use EE4 Leaning to operate BIM is easy for me	Howard et al. (2017)
Social influence	SI1 People who influence my behavior think I should use BIM. SI2 People who are important to me think that I should use BIM SI3 The senior management of this business has been helpful in the use of BIM SI4 In general, the organization has supported the use of BIM	Howard et al. (2017)
Facilitating conditions	FC1 I have the resources necessary to work with BIM FC2 I have the knowledge necessary to work with BIM FC3 BIM is not compatible with the work tools I use FC4 A specific person (or group) is available for assistance with BIM difficulties	Howard et al. (2017)
Task characteristics	TAC1: I need to manage FM tasks efficiently TAC2: I need to export accurate and actual information to FM systems TAC3: I need to acquire FM information in real time	Zhou et al. (2010)
Technology characteristics	TEC1: BIM provides ubiquitous services. TEC2: BIM provides real-time services. TEC3: BIM provides reliable services	Zhou et al. (2010)
Task technology fit	TTF1: In helping complete my FM tasks, the functions of BIM are enough. TTF2: In helping complete my FM tasks, the functions of BIM are appropriate TTF3: In general, the functions of BIM fully meet my task context	Zhou et al. (2010)

BIM-FM in Australia. The new strategy was to ask every interested expert during and after the end of the event, and explain the purpose of this research, gaols, and the possible contribution by doing an online survey within 15–30 min. By getting the participant's acceptance to participate in this online survey, the researcher would send them the online link so they can do the survey at the same time by using the researchers' platform devices or the participants own mobile devices. Although, the new strategy was very costly and effort consuming, as the researcher had to travel around all over Australia, targeting the related and interested experts, it was very successful and achieved a high rate of participation within four months only. Accordingly, the participants were 134 in total.

5 Descriptive Analysis: General Characteristics of Data

The objective of this descriptive analysis is to describe the general information with regard to the responses of participants who were actually engaging in the survey of this research, and the characteristics of them. It provides a comprehensive information and a better understanding of the survey data, including information concerning: the gender and the age of the participants; the level of education of the respondents; the Job experience; and the degree of implementation of BIM practices in the company. Table 3, which was developed by the authors, shows the general characteristics of the respondents. Although women make up a good proportion of the community, their participation in the survey was 29.9% only, and 70.1% for the men. Age of respondents was categorized into four clusters. The first cluster was under 30 years, and that was 35.1%, the second cluster was 30–39 years which made 38.1%, the third cluster was 40–49 years and that made 17.9%, and the last age cluster was 50 years and over which made 9%. Regarding the level of education of the respondents, the first level was undergraduate level that made(23.9%), and the second level was postgraduate that made (50.0%), other levels were certificate or associates degree/licensure that made (26.1%), from respondents were the part of research study. The largest percentage of Job experience was (1–3) years that made 45.5%, while the category (4–6) made 11.2%, which was the

Table 3 The general characteristics of the respondents

Variable	Category	Frequency	Percentage (%)
Gender	Male	94	70.1
	Female	40	29.9
Age of	Under 30	47	35.1
	30–39	51	38.1
	40–49	24	17.9
	50 and Over	12	9.0
Education	Undergraduate	32	23.9
	Postgraduate	67	50.5
	Others certificate or associates degree/licensure	35	26.1
Job experience	1–3	61	45.5
	4–6	15	11.2
	7–9	18	13.4
	10 and Over	40	29.9
Company using BIM	1–3	68	50.7
	4–6	28	20.9
	7–9	13	9.7
	10 and Over	25	18.7

lowest category. The category (7–9) was 13.4% and the category (10 and over) was 29.9%. Regarding the company using BIM, the largest percentage was (1–3) years that made 50.7%, while the category (4–6) made 20.9%, the lowest category. The category (7–9) made 9.7%, and finally, the category (10 and over) made 18.7%. Generally, the participants in this research provided reliable and useful information because the participants were well informed and within the targeted community.

6 Summary

A conceptual BIM-FM framework has been proposed in this ongoing research. The aim is to identify the key factors that affect the acceptance and implementation of BIM in FM. The proposed model consists of eight constructs. In order to validate the model factors, an extensive online survey that targeting the FM practitioners in Australia has been conducted. In this paper, the research survey and the data collection procedures are presented. Also, descriptive analysis and general characteristics of participants are discussed. For the future work, the measurement model should be tested for the reliability and validity using Confirmatory Factor Analysis, while the structural model should be examined by Structural Equation Modelling to test the model relations and hypotheses. In conclusion, this research is considered as a foundation for more mutual model for the future studies.

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A Model Validation and Predicting the Rental Values of Residential Properties Using Logistic Regression Model

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Abstract

The property market is a key contributor to the economic growth of many countries. This makes information from property valuation reports vital for decisions on real estate investments and property tax. Unfortunately, the literature reveals that inaccurate property valuation arising from a reliance on traditional methods of valuation remains a major problem facing real estate practice. To improve the prediction accuracy of property valuation estimates, modelling techniques such as neural networks have previously been applied to this problem. This present study uses a logistic regression model to predict the rental values of residential properties in Cape Town, South Africa. Field survey data was divided into two groups: training and test sets. The training set was used for model development while the test set was used for model validation. The results of the study revealed that parking, garden, number of bedrooms and floor area have the most significant impact on the rental values of residential properties. Surprisingly, proximity to a police station has one of the least effects on the rental values of residential properties. With a prediction performance of over 70% accuracy, findings indicate that the logistic regression model is suitable for predicting the rental values of residential properties. This study evaluates the factors that influence the rental values of residential properties located within the study area. The developed model can serve as a decision support tool for estimating the tax payable by property owners.

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Keywords

Residential property • Rental value • Logistic regression modelling • Prediction • Tax

1 Introduction

Residential property prices are an important reflection of an economy. This is because the housing sector is a major contributor to economic growth (Hadavandi et al. 2011). The ranges for rental prices interest property valuers, property owners, the users, and the local council that collect property taxes. Property valuers and property owners are interested in rental yields (Bracke 2013), while the potential occupants or renters are concerned about portions of their budget that goes towards rental payments (Berger et al. 2017). In all, society gets benefitted from the actions of both parties (i.e. valuers and users) through taxes collected by the local authorities. It is, therefore, fundamental that property valuation should follow a certain standard to ensure accuracy in the valuation practices. Accurately predicting residential rental prices has been a major area of concern in mortgage valuations. Consequently, literature has often discussed several methodologies for such property valuations with regression analysis and data mining techniques, the most commonly used methodologies (Guan et al. 2014). These methods, models, and techniques help researchers to empirically reveal the various factors that influence property rental prices. In general, the influential factors are classified into the neighbourhood or locational and structural (Chin and Chau 2002).

Globally, locational characteristics like parks and security, have been noted to influence residential rental values (Chin and Chau 2002; Won and Lee 2018). In addition, structural attributes of residential properties like the number of bedrooms available bathrooms, floor size, parking space, and garage also influence rental prices (Abidoye and Chan 2017). However, the impact of these identified variables

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differs across geographic locations. This is because the needs of renters vary, thereby influencing decision-making for property valuation. Property valuation serves as a decision support tool for estimating the tax payable by property owners. Property tax is a revenue-generating source for local governments (McCluskey 2018). An examination of property tax in 21 countries, including South Africa, Botswana, and Brazil shows that rental property tax is significant and annual rental value is used as a basis for tax in many locations (McCluskey 2018). In many of the locations, the payment of rental tax falls on the property owners. This applies in South Africa, Zimbabwe, and Australia. In Botswana, Brazil, and Poland, the payment of rental tax falls on the occupier, or both owner and occupier as in the case of Botswana and The Netherlands (McCluskey 2018). Therefore, the onus of paying property tax by these stakeholders calls for proper property valuation. Despite the high levels of crime rates, as well as the high rate of property ownership of approximately 53.5% in South Africa (Statistics South Africa 2018), there has been a paucity of research evidence on the factors influencing rental prices. This study attempts to measure the effect of proximity to the police station on residential rental prices using a logistic regression model. The following structure is adopted in this paper. The next section discussed the methodology applied in the study is discussed. This is followed by the results and discussion of the findings. The study ends with necessary conclusions.

2 Research Methodology

2.1 Overview

The top high-density cities in South Africa are Cape Town, Pretoria, Port Elizabeth, Durban, and Johannesburg. The increasing population of these cities makes residential rental valuation important. Notably, property ownership is of high national importance (Luüs 2003). To illustrate, Cape Town is termed the African city of opportunity (PwC 2018), as it is the second richest city in South Africa (New World Wealth 2018). Notwithstanding, the influx of people makes these cities prone to different types of crime. For instance, in Cape Town, residential crime rates drive homeowners to residential fortification measures (Cronje and Spocter 2017). Therefore, the presence of crime prevention or control facilities like a Police Station is necessary when addressing rental prices in such areas.

For this study, rent and feature data were obtained for 381 residential apartments from the website www.property24.com . Most of the property portal in South Africa have details of real estate firms in the country. The listing price rather than the sales price was taken because compared to transaction data of residential value, price listing provides a better estimate (Abidoye and Chan 2018). This is in addition to the fact that price listings are what is provided for properties in Cape Town, South Africa. What informed the data collected was mostly the reviewed literature on the factors that impact rental values. However, in order to examine the role of security, nearness (measured in kilometres) to a police station was included.

The dependent variable was the per annum rental prices. It was then grouped into bands A (0–189,880 South African Rands) and B (189,881–296,540 South African Rand). They were examined against the independent variables which included bedroom, bathroom, the presence of car park, number of parking spaces, dining, lounge, balcony, swimming pool, floor area, furnishing, services, garden, and police presence. Braakman (Braakmann 2017) described how security in a neighbourhood can influence rental prices. This study assumes that the proximity to a police station in a neighbourhood will influence its residential prices.

2.2 Logistics Regression Modelling

Logistic regression is used to predict the class (or category) of individuals based on one or more predictor variables (X). It is used to model a binary outcome which can only have two possible values such as 0 or 1, or yes or no. The simple logistic regression and multiple logistic regression are the approaches to logistic regression modelling. The simple logistic regression forecasts the probability of a dependent factor against one independent factor. The multiple logistic regression models predict the probability of a dependent variable based on multiple independent variables (Tranmer 2008). Past studies have used logistic regression to determine variables that influence rental values, for example, (Yu and Wu 2016). This present study makes use of multiple logistic regression.

The output of a multiple logistic regression model displays four components - the estimate, standard error, z-value, and p-value. The estimate is the intercept, and beta coefficient estimates associated with each predictor variable. It shows the strength of the relationship. Standard error represents the accuracy of the coefficients. Z-value is the result of the division of estimate and standard error. The p-value checks for the significance of the estimates. A small p-value shows higher significance for the estimate.

2.2.1 Results and Discussion

2.3 Computing Logistic Regression Model

The monthly rental value is based on the 14 independent variables from the collected data. Hosmer and Lemeshow

Table 1 Coefficients of the logistic regression model

Variable	Estimate	Std. Error	z-value	p-value
(Intercept)	6.84371617	1.093829473	6.2566573	0.00000
Bedroom	−0.677291	0.385797	−1.756	0.07916
Bathroom	−1.058707	0.427533	−2.476	0.01327
Parking	−0.547072	0.302566	−1.808	0.07059
Park	−0.653368	0.568963	−1.148	0.25082
Dining	0.202445	0.366713	0.552	0.58091
Lounge	−0.067425	0.3176	−0.212	0.83188
Balcony	−0.341771	0.344761	−0.991	0.32153
Swimming Pool	0.940621	0.369129	2.548	0.01083
Floor area	−0.026086	0.009759	−2.673	0.00752
Furnished	−1.884781	0.369715	−5.098	0.00000
Services	−0.602996	0.576351	−1.046	0.29545
Garden	0.271286	0.477845	0.568	0.57022
Police	0.096143	0.063208	1.521	0.12824

(Hosmer and Lemeshow 2000) described that logistic regression modelling tests the statistical significance of coefficients. In this study, the null hypothesis assumes that the independent variables/factors do not have statistical significance. The alternate hypothesis assumes that the independent factors have statistical significance. At 95% confidence interval, the alpha value is $p = 0.05$. At p-value of less than or equal to 0.05, accept the alternate hypothesis else, reject. Table 1 shows that the bathroom, swimming pool, floor area, and a furnished apartment has values less than 0.05. This means that the variables are statistically significant. Hence, we reject the null hypothesis.

Estimate coefficient (b0) shows the strength of relationships between independent and dependent variables. The B-coefficients describes the extent to which a dependent variable (rental price) is influenced by a unit change in each of the independent variables (Liman et al. 2015). Positive coefficient estimate increases the probability and vice versa. The coefficient for the variable bathroom is $b = -1.058707$ and negative. This means that an increase in the number of bathrooms will be associated with a decreased probability of residential rental price rise. Also, the variable furnished (which implies whether a property is furnished or not) has a negative $b = -1.884781$. This shows that an inverse relationship exists between a furnished apartment and a decreased probability of a rental rise. However, the coefficient of the variable Swimming Pool is positive $b = 0.940621$. This means that the availability of a swimming pool is linked with a probability of a residential rental value increase. These three variables have p-values less than or equal to 0.05, which make them statistically significant compared to other independent variables that have a p-value greater than 0.05.

2.4 Model Validation and Predictive Performance of the Developed Logistic Regression Model

This study predicts the rental values of residential properties in Cape Town using logistic regression. Predictive performance value ranges between a percentage of 0 and 100 (Cortez 2015). Generally, a value close to 100% indicates that the model can correctly classify all the test data set. In this study, the prediction of the data sets based on the groupings A and B as earlier described to reveal an overall accuracy of 75.21% is shown in Table 2. This implies that the model can adequately classify the data set. The result of model validation is summarized and presented in Table 2.

2.4.1 Discussion

As reviewed in the literature, inherent attributes of properties which consumers esteem influence rental values. The result from this study is an evidence that each independent variable affect rental price of residential properties differently (see Table 1). Findings from the study reveal that the number of bathrooms, the presence of a swimming pool, floor area, and furnished property have the most significant effect on

Table 2 Summary of model validation logistic regression

Observed	Predicted		Accuracy (%)
	A	B	
A	59	8	88.06
B	21	29	58.00
	Overall		75.21

residential property prices in Cape Town, South Africa, while the police station is insignificant.

Bathroom and conveniences are vital parts of a building. This study also indicated that the number of bathrooms (toilet inclusive) can influence rental value. Bathrooms serve as a fundamental human function (Margolin and Poggiali 2017). Number of bathrooms can have significant effects on residential house prices as was reported by (Musa and Yusoff 2017). Likewise, the number of bedrooms can influence property prices as found in this study. Abidoye and Chan (Abidoye and Chan 2017) stated that the number of bedrooms increases the residential rental price. Other documented evidence reveals that the number of bedrooms can significantly influence residential rental prices (Sanga 2017). Surprisingly, this contradicts the findings of (Liman et al. 2015), who noted that the number of bedrooms do not have a significant effect on rental prices.

This could be attributed to differences in the density of geographical locations (Sirmans et al. 2006). In this study, while the previous studies posited that the number of bedrooms was a factor; it was insignificant to residential rental values in Cape Town, South Africa.

The presence of a swimming pool raises property value and benefits the users in terms of health and recreation. It gives a higher level of relaxation compared to traditional bathroom facilities. This study reveals that a swimming pool is a significant variable that influences rental prices in the study area. Evidence shows that swimming pool presence is valued in properties across the country (Gnagey and Tans 2018), especially if it is a lower floor building where the swimming pool can be easily accessed (Keskin 2008). However, a swimming pool is a luxury that renters or homeowners could choose whether to have or not. Floor area or floor size represents the space in a property. Floor size is a significant variable that affects rental prices as we have demonstrated in this study (Chin and Chau 2002; Zietz et al. 2008). Floor number or level can also affect rental values. Some consumers prefer higher floor levels since it gives a wider view (Abidoye and Chan 2017). This is down to consumer choice or preference. Chin and Chan (Chin and Chau 2002), however, stated that the floor area is the most important attribute of a building influencing rental values. In addition, the results of this study found that a furnished apartment is one of the most important/significant factors impacting rental values. In a furnished apartment, there is furniture in place before the property is rented out or mortgaged out. In general, furnished apartments are more expensive than an unfurnished apartment (Hasanah and Yudhistira 2017). Findings from this study agree with that of Buiga and Toth (Buiga and Toth 2015), who examined properties in Romania. In terms of security, a police station is described as a social amenity that is relevant to the proper function of society. Police presence provides a sense of security for house owners and intending buyers. The fear of crime or sensation of safety influences property value (Buiga and Toth 2015). Police presence, therefore, is expected to reduce property crime (Klimova and Lee 2014). Other studies have reported that police presence influenced residential property values (Andresen and Lau 2014). This shows that there is a correlation between crime, property price, and police presence. In this study, while nearness to a police station was a factor, it was insignificant to residential rental values in Cape Town, South Africa. This study has shown that logistic regression can produce a reliable prediction of the factors that influence the rental values of residential properties. The results support the findings of (Abidoye and Chan 2017), who reported that logistic regression modelling technique has a reliable predictive ability that can help address the property attributes and valuation challenges.

3 Conclusion

This study predicts the rental values of residential properties in Cape Town, South Africa using logistic regression. The predictive accuracy of the developed model suggests that logistic regression modelling can produce reliable estimates of the rental values of residential properties. In addition, it was discovered that aside from a furnished apartment, number of bathrooms and the presence of a swimming pool, parking space, garden, number of bedrooms, and floor area all impact rental values of residential properties. The findings imply that in Cape Town, South Africa, residential property rental prices are determined by these significant factors. However, the nearness to a police station does not significantly influence rental values. This means that consumers' choice of residential property is not affected by the presence or absence of a police station. An explanation could be that this is due to the high prevalence of private security firms in South Africa. This study predicts the rental values of residential properties in Cape Town, South Africa, using logistic regression. The predictive accuracy of the developed model suggests that logistic regression modelling can produce reliable estimates of the rental values of residential properties. In addition, it was discovered that aside a furnished apartment, number of bathrooms and the presence of a swimming pool, parking space, garden, number of bedrooms, and floor area impact rental values of residential properties. The findings imply that in Cape Town, South Africa, residential property rental prices are determined by these significant factors. However, the nearness to a police station does not significantly influence rental values. This means that consumers' choice of residential property is not affected by the presence or absence of a police station. An explanation could be that this is due to the high prevalence of private security firms in South Africa. This study contributes to the body of existing knowledge in property economics. It adds to current knowledge on the impact of the attributes of a residential property on its rental value. However, it must be reiterated that the availability of data remains a challenge to researchers in the fields of construction economics and property economics. It is also important to point out that the geographical scope of this study was limited to Cape Town, South Africa. However, these results can be applied to study areas similar to Cape Town, South Africa. It would be necessary for further research to be carried out on property valuation using logistic regression model so as to better understand the identified trends.

This study contributes to the body of existing knowledge in property economics. It adds to current knowledge on the impact of the attributes of a residential property on its rental value. However, it must be reiterated that the availability of data remains a challenge to researchers in the fields of construction economics and property economics. It is also important to point out that the geographical scope of this study was limited to Cape Town, South Africa. However, the results of this study can be applied to similar research study areas. It would be necessary for further research to be carried out on property valuation using logistic regression model so as to better understand the identified trends.

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Blockchain in Construction Practice

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Abstract

The construction industry is one of the most important sectors of most economies. However, the sector has been plagued with many challenges, including low productivity, lack of collaboration, inadequate/insecure information sharing, and lack of trust between participants. To overcome some of these challenges, blockchain, one of the emerging technologies has been hailed as a solution for sharing and distributing information securely. While blockchain has been widely popularized in the financial fields through well-established cryptocurrencies such as Bitcoins and Ethereum, the same cannot be said of the construction industry. The application of blockchain in the construction sector is yet to be widely documented in academic literature. This study explores the application of blockchain technologies in the construction sector. Specifically, the operational principles, applications, associated benefits, and weaknesses of blockchain in construction practice are examined in this paper. The paper concludes that there is definitely a huge potential in the adoption of blockchain in different construction processes.

Keywords

Blockchain • Distributed ledger technology • Built environment • Construction • Innovation

1 Introduction

The construction industry is one of the main contributors to the UK's prosperity (DBIS 2013). In 2017, the sector was appraised to be worth approximately £103 billion, contributing up to 6.6% of the country's economy (Richardson 2018). However, the industry is facing many challenges, including low output, lack of collaboration, inadequate/insecure information sharing, and lack of trust between project team members and stakeholders (Carpenter 2019). McKinsey (McKinsey 2017) reports that $1.6 trillion savings could be achieved globally by improving the performance of the industry alone. Blockchain is rising as one of the emerging technologies hailed as a solution to improve the performance of the construction industry vis-à-vis building trust, transparency in information exchange, and enhancing contract conflict resolution (Penzes 2018). The construction sector is generally known for distrust and disputes (Allen 2016). This being said, payments are one of the major problems, which are commonly tied to contractual entitlements being paid late, not in full, or not being paid at all (Government 2013). Additionally, based on many case studies in the industry (Hawkins 2013; Mansons 2016; NBS 2018), the mainstream contractual frameworks are believed not to foster collaboration and intraorganizational trust. The use of blockchain technologies and in particular the smart contracts could limit the amount of disputes and enhance collaboration and trust (Li et al. 2019). The key questions are what are the wider applications of blockchain in construction practice? What are the benefits and barriers of the applications of blockchain in construction practice? In order to attempt these questions, it is imperative to critically examine what constitutes blockchain.

2 Overview of Blockchain

A blockchain is a data storage that takes a number of records and organizes them in blocks of information. Each block is then "chained" to the next block using a cryptographic signature (GOS 2016). This allows blockchains to be used as a ledger, which can be shared and authorized by anyone with the appropriate permissions. The key advantage of

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blockchain is its ability to be applied in various settings and offer solutions that are durable, transparent, and secure (Underwood 2016). Due to decentralization, the database can securely exist even if up to 50% of its network fails or is disengaged (Konstantopoulos 2017). It is guaranteed as blockchain is based on a peer-to-peer system of computers (nodes), which poses identical copies of the database. This ensures transparency and resilience to counterfeit as no single entity has control over it. The structure of blockchains depends on shared information that enables checks through algorithms to uncover any anomalies. To authenticate the transaction/data, a proof-of-work mechanism is used. That is achieved by deterministic currency issuance mechanism to keep numerous network and reward its miners (Li et al. 2019). When a network accepts transmitted transaction, it is received by all nodes, which authenticates it through predefined algorithms regarding its structure and activity within the transaction. While the block is being mined, each node's version is being updated (Martinez 2018).

3 Application in Construction Practice

Blockchains have been applied to solve practical challenges.

Smart contracts and BIM: Smart contracts can be adopted in conventional and BIM-based projects. The agreements between particular individuals can be formulated in the form of computer programs which follow an established schedule and automatically withdraw payments once all the conditions are met. This enables the reduction of documentation and organization of the budget into smaller installments. Breaking large lump payments is not only more sustainable but also divides the schedule into more achievable milestones (Ramage 2018a). In a project developed in 3D software, contracts can be tied to the model. When the physical construction matches its initial design, a fee agreed beforehand is automatically transferred to the contractor. Also, the contract can be divided into multiple tasks and hence limit the risk of layering errors. Once each activity is completed, it is measured using, e.g., laser scanners and aligned to the model. If it is verified as accurately realized, a smart contract is fulfilled and a payment issued (McDermott 2017). This function improves inspection checks—once recorded, they are available to those performing the checks and hence limit the risk of errors and oversights. Similarly, blockchains could also store information on the buildings structural and maintenance work (Rothrie 2018). Such a system enables all those involved to see an up-to-date model and its constant progress. Each update creates a unique block of information added to the chain, which makes it transparent and indisputable. This boosts the movement toward interactive on-site project productivity and schedule metrics (Ramage 2018b).

BIM model ownership and insurance: Blockchain is said to be the solution for problems raised around model ownership and insurance. BIMCHAIN.io is developing a traceability system which supports legally binding agreements disclosed in a smart contract. Using the technology would limit the risk of copyright theft to a minimum and reduce delays, disputes, and expenses associated with their resolution (Gueguen 2018). All the contributions, changes, and validations of the BIM model would be tracked and saved in an invariable environment available to project team members and stakeholders (Cousins 2018).

Smart energy and smart homes: The affordability of residential electricity production (prosumers) systems opens up the possibility for the use of blockchain. The excess energy can be micromanaged using the tool and sold to the grid or neighbors to balance supply and demand at a local level (Christie 2018). Such an innovative approach has been tested in the United States, where LO3 Energy (a company developing blockchain based innovations to revolutionize how energy can be generated, stored, bought, sold and used, all at the local level) is giving a trial to peer-to-peer blockchain network. Houses connected to the system using smart meters can trade electricity between each other to minimize the usage of grid-provided power (Business 2018). A similar experiment has been announced in the UK by Centrica (Richardson 2018).

Smart cities and sharing economy: The definition of smart city is an evolving concept, but it is generally understood as an idealistic city where the quality of life is significantly improved. This can be achieved through the use of information and communication technologies (ICT), new services, urban infrastructure. The vision assumes consideration of the issues and seeking solutions from the perspective of the citizens and their engagement in the city management. This is understood as the integration of resources, where individuals interact using technological solutions (Pieroni et al. 2019). The Internet of Things (IoT) and ICT innovations such as blockchain make shared economy much easier and accessible (Li et al. 2019).

Smart governance: Enormous savings could be achieved by the implementation of autonomous executing administration to record, store, protect, and share information (Treasury 2018). Also, blockchains are being investigated for use in: automated tax collection, property and land registry and regulatory compliance. Transparency and immutability of blockchains can significantly reduce the time needed for bureaucracy as a result of provision of indisputable and trackable data (EPRS 2017).

Supply chain management: The use of blockchain for supply chain has a great potential to improve its transparency, tracking, and reduction of costs of related administrative activities (Deloitte 2019). The supply chain often consists of a vast network of diverse organizations, which manage large quantities of goods, contracts and payments. As the product passes through many locations and organizations, all the data about the product needs to be recorded and updated according to its current stage. The scale and complexity of systems combined with needed manpower lead to high transactional costs and regular errors in paperwork (EPRS 2017). The use of blockchain technology offers the possibility to associate the transport of a physical item with its digital profile (POST 2018). The essential updates can be added to the digital ledger as items pass through the supply chain. This is believed to have a positive effect on the trust between stakeholders as it limits the fraud and counterfeit of goods (Kersten et al. 2017). According to Deloitte (2019), blockchain within the supply chain can be used to document prices, dates, locations, quality, certifications, and other relevant information.

3.1 Benefits of the Technology

Blockchains offer a wide range of advantages from improved reliability to security to enhanced collaboration (Novoseltseva 2017).

Directness and transparency: Limitation of intermediaries' involvement fosters transparency and direct relationships with customers (Agrawal 2018), and additionally, strengthen corporate reputation through transparent transaction history (Killmeyer and Holdowsky 2019).

Resiliance to failure: Blockchain data is stored across a network, hence no single entity or even an organization is in control of the encrypted records. Moreover, decentralization means that even if one or more individuals leave the network, it will continue to function with no loss of data or integrity (Konstantopoulos 2017). *Resiliance to counterfeiting and security*: The dependency between the blocks is one of the key properties which makes the chain secure. Tempering with a single block consequently causes an individual serial code to change and warns the network; hence blockchain is more secure than other record-keeping systems (Decuyper 2017).

Cost benefits: Cost savings can be achieved through the reduction of third parties and their fees. Furthermore, potential benefits stem from easier data collection, consolidation, and sharing for management or supervisory purposes, as well as shortened dispute resolution (EPRS 2016). In addition, decrease of operational costs was stated by 73% of respondents to the 2016 Statista questionnaire on the technology's features (Statista 2016).

Ensured payment and financial stability: Attachment of smart contracts to particular BIM model elements not only automates and streamlines the payment processes, but also validates if the client is capable of complying with their financial obligations (Thomson 2018). Furthermore, by associating smart contracts with completion percentage and breaking large lump sums into smaller installments, project cash flow becomes more sustainable and healthier for employers and contractors (Ramage 2018a).

Record keeping and accountability: All the parties involved in the network share the same data, which if to be changed, requires a consensus (Hooper 2018). As reported by Statista (2016), more than half of the respondents to its blockchain-related questionnaire announced significant reduction of issues caused by information loss or inconsistency. Moreover, unalterable record keeping partly solves the accountability issues (Penzes 2018). All the model modifications, time stamps, and contributors are recorded and copyrighted once blockchain is embedded in BIM system (Thomson 2018).

Increased efficiency and speed: Through the reduction of paperwork and automation of processes, blockchain adapters experience quicker settlement of disputes and trading (Hooper 2018). The settlement time reduction was reported by as much as 69% of blockchain users (Statista 2016).

Better supply chain management: The possibility to track products, their origin, and quantity strengthens the relations between parties and guarantees the ordered services or goods meet the initial quality and sourcing requirements (Agrawal 2018). The extent of supply chain which can be noted in the construction (e.g., Cross-rail construction in London involved 700 various suppliers) sector requires enormous effort and resources; hence any way to improve the management processes is at a premium (Penzes 2018).

Better asset management: Storing a "Digital Twin" model in a distributed ledger guarantees its accuracy and uninterrupted access for O&M personnel. Accountability further leads to provision of better services and maintenance (Penzes 2018).

3.2 Barriers to Adoption of Blockchain in Construction Practice

Despite the wide range of benefits, the technology is still facing some challenges hindering its wider uptake in construction (EPRS 2016). The main challenges focus on issues related to regulatory uncertainty, volatility of cryptocurrencies, and lack of trust among users. Besides, lack of maturity and understanding create other issues—as blockchain is a relatively new technological innovation, there is deficiency of terminology and vision of what can be its purpose. The lack of universal standards raises questions on how to ensure quality controls and procedures to be performed on the desired level. It is crucial to clarify the scope of blockchain adaptation beforehand and ensure that all the parties have the same expectations (Cousins 2018).

Furthermore, there are the legal implications of smart contracts. There is a fundamental need for legal perspectives, rules, and policies, developed, and supported by the government (Winfield 2018) to be reinforced in blockchain smart contracts. Also, cryptocurrency payments are not yet a common practice in the sector. A great majority of construction professionals are not eager to switch from traditional cash payments due to either lack of understanding of the technology or fear of possible consequences of such a change (Winfield 2018). Furthermore, according to POST (2018), there are currently uncertainties about the scalability and speed of transactions. As the number of transactions increases, the energy consumption needed to run proof-of-work protocols might have massive impact if implemented on global scale (Li et al. 2019). Some estimates compare the annual electricity consumption of blockchain to that of the entire Austria (POST 2018).

Another barrier is the cost of implementation and the need of skilled workforce (Hughes et al. 2019). Additionally, in order to fully grasp the benefits of blockchain-based business, there must be changes in the organizational structures and culture. As much as blockchain is transparent and hacker impermeable, it also discourages many companies which are not willing to risk disclosure of their data (Cousins 2018). Furthermore, narrow margins in the construction industry might limit the implementation of blockchain as investments into research and development are limited. The core of the barriers associated with blockchains, and in particular smart contracts creation, are the complexity considerations. Taking into account the complexity of construction agreements, it is hard to imagine how such documents could be enclosed within a program code. The reality is, Smart Contracts do not take into account too complex mitigating circumstances, which are quite common in construction projects. With that in mind, it would be fundamental to consider all possible solutions and design the source code in such manner to ensure it is executed as intended. Bug-free codes are extremely rare even when not developed as a contract framework, which makes it hard to formulate a defect-free and fully reliable smart contract (Song 2018). Lastly, it is important to note that the beneficial features of the network solely depend on the grid integrity (Cousins 2018). Thus, the main fear of the early adopters has been the crash of the network and all its related chaos (Blockgeek 2017).

4 Conclusions

The development of blockchain is definitely one of the most ground-breaking innovations of the century. It offers a wide range of advantages, which include transparency, verifiability, privacy, and security. Decentralized network protects the data against tampering and copyright theft, as well as provides foundations for innovative methods of payments and contracts. Despite presenting many benefits to the construction industry, a majority of professionals are not eager to adopt it just yet. Those who do, use it for handling payments and procurement by so-called smart contracts. More advanced firms further adapt them within BIM systems and attach to BIM models. Nevertheless, its nascent nature may be one of the reasons to its low adoption. With time and further development, the barriers to the adoption of blockchains may become an issue of the past and its benefits may further spur its wider uptake. This will significantly improve the performance of the construction industry.

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Emerging BIM-3D-Laser Scanning Integration in Construction Practice

Donato Pica and Fonbeyin Henry Abanda

Abstract

The upscaling of innovative information and communication technologies to a feasible application within the construction industry is receiving increasing attention, research and funding from public and private agencies. Emerging Building Information Modelling (BIM) and 3D laser scanners are amongst the leading technologies being recommended for use in construction. Although the potential of BIM in the capture and exchange of construction information has gained interests amongst researchers, the same cannot be said of the 3D-laser scanners. By appropriately integrating data from 3D laser scanners with BIM can lead to greater benefits in managing construction information. However, the nascent nature of BIM and especially 3D laser scanners means the nexus of these technologies is yet to be fully understood. This study investigates the use of 3D- laser scanners together with BIM in the optimisation of information exchange across the life cycle of a construction project. The specific questions to be answered are what are the practical applications of 3D-laser scanners? How can 3D-laser scanning be integrated with BIM to maximise information gathering and processing for the different applications? What are the benefits and challenges of adopting integrated 3D laser scanners and BIM in practice? After addressing these research questions, this paper concluded by a way of summary and further discussed the direction of future research.

Keywords

Building information modelling (BIM) • 3D laser scanning • Point clouds • 3D modelling • Automation

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1 Background

Recently, the construction industry has been engaged in increasing productivity, efficiency, output quality, infrastructures value and sustainability (Arayci et al. 2012) by implementing emerging technologies, such as BIM and 3D laser scanners (3DLSs). However, improving the performance of the construction industry has faced many challenges vis-a-vis 3D models creation (Kerosuo et al. 2015), progress measurements and monitoring of works (Leite et al. 2016), dimensional and surface quality assessment (Kim et al. 2015) and quality improvements in real-estate services (Mahdjoubi et al. 2013). The creation of 3D models is particularly challenging for all existing buildings because building survey is a time-consuming activity, easily prone to errors. Generally, a building is composed of a wide array of components which can be difficult to identify and opportunely defined in a model. The difficulty level for this task increases exponentially with increasing building size, especially if there are structural damages (Zeibak-Shini et al. 2016). Structural damage can have various origins but after an earthquake, 3D modelling appears as a critical activity because, in general, time available for planning any action can be very limited. Challenges in both progress measurements during the execution of a building project and the dimensional and surface quality assessment are similar to the ones of 3D models creation. In fact, models updating requires a massive manual work in order to produce modifications to the digital model, even if it could be less dangerous because structures are built in a safer environment. Again, time can be a crucial factor because building activities can be executed quickly day by day. Dimensional and quality assessment of building materials is another challenging activity in an environment where automation is the final goal. In fact, materials need to be checked and accepted before entering on site. Today, it is common to perform this activity manually and, it can be repetitive, time-consuming and so prone to errors. Quality improvements in real-estate

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services need to be of detailed and high-quality 3D models and their creation can easily require significant efforts. A reliable and detailed digital twin could require the manual identification of any requested detail, in terms of geometrical and physical characteristics. 3D laser scanners appear as the panacea for all these issues and improve BIM models creation, automatizing main time-consuming and mundane activities.

With regards to new buildings, BIM technology is already being used with satisfactory results compared to existing buildings. However, building retrofitting is a valuable sector of the built environment. In fact, in some countries like Italy and Spain, existing buildings represent most of the real-estate asset. In Italy, 36.6% of real-estate (11.6 million homes) is more than 40 years old (Giordano 2014) and 80% of national real-estate needs refurbishment (Marchesini 2018). These buildings lack the digital equivalent. In this case, professionals facing refurbishment projects must put in significant effort in performing the classical time-consuming activities to retrieve data directly from the buildings, retrieve blueprints, generate models, validate them and only then they can start to design new solutions. In this workflow, BIM technology is often used in the last stage whilst previous ones are still conducted using traditional ways, with all related uncertainties and errors. Thus, 3D laser scanner is quite useful for collecting and managing data of the existing building. In fact, 3D laser scanners allow to automate almost the entire procedure, avoiding all time-consuming and mundane activities, extending the beneficial use of BIM technology also for existing buildings.

2 Overview of 3D Laser Scanners and BIM

A laser scanner is a technology based on the use of specific laser light and image sensors, opportunely assembled on a moving structure (Isa and Lazoglu 2017) generally positioned on a tripod support structure, that is directly posed on the ground. Laser scanners can be used for the identification levels and measurement of distances. Laser scanners can be used to measure the distance between a landmark and an assigned point belonging to the surrounding environment, fundamentally evaluating the time elapsed between two pulses or evaluating the phase difference between the emitted and the received wave. By automatically and consequentially repeating this operation for a considerable number of different points, the laser scanner can generate a point cloud (Xiong et al. 2013). Hence, a point cloud is composed of a set of distance measurements representing a discrete analysis of the studied environment (Fig. 1).

However, information obtained by means of a laser scanner, which is generally used for producing 3D models, orthophotos and in reverse engineering, needs to be

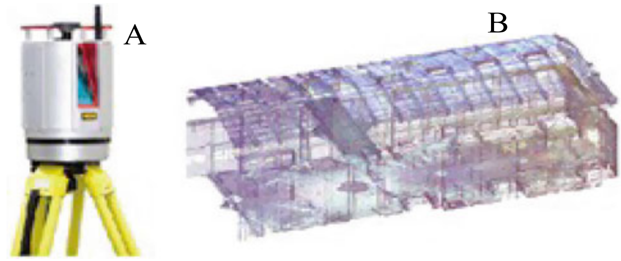


Fig. 1 A 3D laser scanner on a Tripod (**a**) and a point cloud obtained from a laser scanner (**b**) Jung et al. (2014)

processed in order to transform the point cloud into surfaces or volumes. In some cases, 3D laser scanners have specific cameras in order to enrich the cloud points with information about colours. Even if the optical control of 3D laser scanners can be considered mature enough (Kohlbrecher et al., 2011), recorded data analysis is affected by an outstanding number of parameters, such as laser uncertainty, lens imperfection, illumination conditions (Isa and Lazoglu 2017) and objects' surface physical conditions (Xiong et al. 2013). The scientific community has proposed different methodologies for improving the reliability and usability of this technology from the automated conversion of scanned information to an information model (Xiong et al. 2013), to different algorithms for registering point clouds (He et al. 2017), to the hardware improvement and calibration procedures (Isa and Lazoglu 2017; He et al. 2017).

3D laser scanners available on the market can be classified into fixed and mobile devices. Fixed 3D laser scanners are positioned on a specific support structure, usually tripod, in front of the objects that will be scanned. Mobile instruments can scan the surrounding environment whilst moving. Hence, they can be integrated into cars, drones and so on. In this case, scanners are much more sophisticated because of, at least, a stabilising and a Global Positioning System (GPS) device. In fact, mobile devices need to define their position whilst scanning. 3D laser scanners simultaneous localization and mapping (SLAM) devices (Kohlbrecher et al., 2011) common in robotic sector can be considered an evolution of classical mobile laser scanners. These devices can build a map of the surrounding environment and localise themselves on it, even if the GPS signal is absent.

3D laser scanner is a technology that facilitates the collection of physical data of real objects automatically, with various aims such as to define and control products shape, objects digitalisation, reverse engineering and mapping areas. During the last decade, it has experienced a significant development that has witnessed its use not only in manufacturing sector (Gerbino et al. 2015; Gronostajski et al. 2016) but in movies, virtual reality, archaeology, robotics (Lindner et al. 2016), mining (Janus and Krzwczyk 2018) and construction sector (Kim et al. 2015; Xiong et al. 2013;

Bosché et al. 2015). Concerning the construction industry, building surveying is an activity that is time-consuming, potentially dangerous and not always possible, especially in case of survey of damaged structures and subject to errors. In this last case, it is important to consider that if a building is surveyed with a low level of accuracy, the subsequent design phases could be heavily impacted.

BIM is a technology that has growing success for companies operating in the construction industry, even if it is not brand-new. The purpose of BIM is to improve performance in the construction industry under a plethora of aspects (Eadie et al. 2013), inter alia facilitating design operation and offering the possibility to integrate different design aspects, e.g. structural and Mechanical, Electrical and Plumbing (MEP) installations design. Even if BIM is not a brand-new technology, it is still facing significant challenges, especially concerning 3D models creation of existing structures and the facility management (Dixit et al. 2019). Once solved, the availability of a digital twin of any real structure will definitely revolutionise not only the built environment, but also security, digital economy (Kupriyanovsky et al. 2016) or rescue (Zeibak-Shini et al. 2016) as examples.

3 Application of 3D Laser Scanners in Construction Practice

As any new and advanced technology, related costs are high, and this has limited the 3D-laser scanner technology diffusion. However, possible applications of 3D laser scanners in the construction industry are numerous: automatic creation of 3D models (Xiong et al. 2013); progress measurement of construction works (Bosché et al. 2015; El-Omari and Moselhi 2008); dimensional and surface quality assessment of precast concrete elements (Kim et al. 2015); improve quality in real-estate services (Mahdjoubi et al. 2013); archaeological and cultural heritage assets evaluation (Ceccarelli et al. 2017).

3.1 Creation of 3D Models

3D models creation directly from laser scanner data represents one of the best advantages of 3D-laser scanners. In fact, current practices based on blueprints analysis, structures survey and then models creation are time-consuming and prone to errors. By means of a process known as scan-to-BIM (Xiong et al. 2013), 3D laser scanners allow to automate the process. In fact, professionals can simply place the device in different parts of the building and scan the areas. Alternatively, a mobile 3D scanner can be used. The scanner produces point clouds that can be immediately used for clash detection, or 3D digital models creation. However, current practices are still based on manual procedures: 2D primitive elements are positioned into the point cloud in order to fit with real elements. Then meta-data are attached to them (Tang et al. 2011). Currently, the need for automating this procedure has already been recognised and the scientific community is investigating and developing specific algorithms (Xiong et al. 2013) to deal with meta-data attachment.

3.2 Progress Measurements or Monitoring of Works

Usual procedures used for progress measurement of construction works are based on visual inspections, which can be massively influenced by personal perceptions. In a kind of modern quality control, buildings under construction are scanned in order to check their consistency with digital models (Bosché et al. 2015). In this case, the As-Built vs the As Designed check, synthetically known as Scan-vs-BIM, can be performed with the best accuracy level. Nowadays, it can be successfully applied to MEP installations (Bosché et al. 2015) where issues related to shapes and external finishes is a limitation in the use of 3D laser scanner technologies.

3.3 Dimensional and Surface Quality Assessment

3D laser scanners can be used for quality controls, which play an important role especially when they are inherent to structural elements: any structural defect or failure could heavily impact the entire financial investment. Nowadays, precast concrete elements are more and more used in the construction industry because of savings in terms of construction time and costs. However, their production cycle might generate goods of unsatisfactory characteristics and/or inadequate quality. Unfortunately, the common practice for dimensional and surface quality assessment of precast concrete elements is still based on visual inspections that are costly, time-consuming and subjective (Kim et al. 2015). In this sense, the use of 3D laser scanners represent a relevant innovation for the construction industry because: a BIM library of the produced precast concrete elements (the as-designed one) can be generated, according to the specific precast concrete element; laser scanner typology and parameters can be defined hence the structural element can be effectively scanned; captured data will be then cleaned by means of an opportune algorithm and inspection results will be stored in another BIM library (the as-built one) in order to effectively store information and allow comparisons (Kim et al. 2015).

3.4 Improve Quality in Real-Estate Services

3D laser scanners and BIM technologies can be used for: capturing building interior and exterior characteristics in order to create 3D rich and accurate digital models that allow to perform virtual 3D walks; efficiently store buildings information that allows to improve real-estate management activities thus offering a better service for potential buyers (Mahdjoubi et al. 2013). In each case, data acquisition, processing and storing activities are hot topics and several different strategies can be applied. Data acquisition is automatically performed by the 3D laser scanners depending, however, on a valuable number of parameters. Acquired data allows to generate 3D point clouds which should be first filtered, then they can be managed by means of specific software provided by the manufacturer of the 3D-laser scanners. However, nowadays there are several commercial 3D computer graphics and computer-aided design software able to open and modify 3D point clouds, e.g. Rhinoceros 3D from Robert McNeel & Associates. This allows to manually position the 2D elements within the point cloud in a way to generate the 3D digital model. Alternatively, data can be processed by means of specific segmentation algorithms that allow to trace boundaries so polygonal meshes can be created (Jung et al. 2014). Furthermore, commercial software usually allows to save 3D point clouds as .stl format file or .dwg format file, which can be opened by a number of commercial software, including BIM software. Assuming that interoperability plays a central role in BIM technology (Abanda et al. 2015), algorithms able to automatically translate the surface-based models into volumetric models and export them in Industry Foundation Classes (IFC) format file are under development (Xiong et al. 2013).

3.5 Cultural Heritage Assets Evaluation

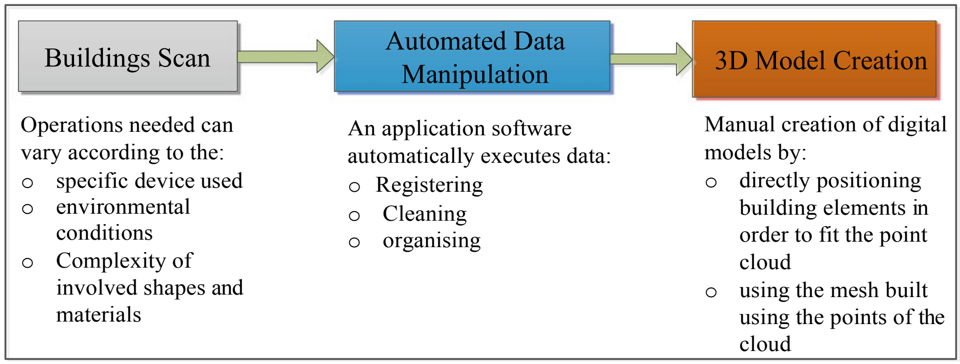
Historical, artistic and cultural heritage can be effectively scanned in order to produce 3D models that reflect the reality. The high level of details as well as shapes and possible defects produced by the elements elevate the difficulty level to its maximum. Furthermore, in certain cases, cultural heritage survey must be repeated at regular intervals. The use of BIM and 3D laser scanners allows to perform evaluation in the fastest way, with the best level of accuracy and optimising costs. Then data are organised and manually transferred to a digital model. Moreover, some techniques have been developed in order to capture colour information (Ceccarelli et al. 2017). Consequently, these technologies allow to move cultural heritage assets evaluations on a different level, revolutionising current practices and increasing productivity.

4 3D-Laser Scanner-BIM Integration

The process of integrating scanned data to a BIM digital model requires first the capturing of the data (see Fig. 2). The building has to be scanned and typically operations can vary according to the specific device used to scan and according to the typology of the building. In fact, referring to cultural heritage or to prestigious buildings, it can be necessary to add colour information by means of some high-resolution photographs (Mahdjoubi et al. 2013). The second step is composed of all activities needed for registering, cleaning and organising scanned data (Randall 2011). In fact, each point is registered attaching a specific set of geometrical information but not all points are related to the scanned building. This justifies the data cleaning activity. Furthermore, if the final user could be interested only in specific parts of the scanned information, the data organising activity is fundamental. Nowadays, there are specific software able to perform these activities. In some cases, especially when high detailed models are needed, it can be useful to repeat some scans in order to locally enrich the point cloud. In this case, data needs to be merged and recent software can also automate this activity. The third phase is composed of the digital model creation based on the registered point cloud. Some BIM software is able to directly import a point cloud so that the user positions the opportune building elements which can fit the point cloud. In this case, the user also assigns non-geometrical information to the objects. Unfortunately, it is a time-consuming activity that will produce the biggest advantage only when automated. Alternatively, models can be created based on mesh or surfaces defined by using scanned points information (Randall 2011). Currently, researchers are trying to implement specific algorithms that will be able to automatically transform complex point clouds into 3D models.

The proposed framework (see Fig. 2) is adequate for every application of 3D laser scanners in construction practice. However, concerning the heritage assets evaluation as well as the real-estate services improvement and the classical 3D models creation, in case of scanning of complex buildings, high-quality photographs and further detailed scans could be needed. A massive volume of information will be generated and the next two phases become more

Fig. 2 Scan-to-BIM framework



complex and time-consuming. Instead, referring to progress measurements and quality assessment, some simplifications could be possible. Progress measurement of construction works, and their monitoring could be directly evaluated from the point cloud, and therefore the 3D model creation phase might be avoided. Furthermore, in some environment performing scans may interfere less with the scanner activity. In this case, detailed scans as well as high-quality photographs might be avoided. This last advantage can be shared with the quality assessment activity. In fact, this activity carries the advantage of operating in the best-controlled environment and laser scanners properties can be set at their best. Upon completion of the 3D model creation, it can be imported in BIM models as libraries.

5 Benefits and Barriers to 3D-Laser Scanner Adoption

The most valuable aims of integrating BIM with 3D laser scanners are ensuring the efficiency of buildings, facilitating maintenance operations, reducing human workload and errors, as well as costs and inefficiencies. In fact, 3D laser scanners allow to easily digitalise buildings and the surrounding environment, producing 3D semantically rich models. These considerations can be extended to both MEP installations and structural precast elements, opening to the automatized acceptance controls activity. Defects incidence can be reduced, allowing to save the 5% of total construction costs (Kim et al. 2015). In case of refurbishments, the absence of data obliges professionals to perform time-consuming activities that can hugely impact performances and fees. Furthermore, real-estate services will have an increased accuracy, speed and quality.

Even if 3D laser scanners have the potential to revolutionise the approach to restructurings, the applied techniques are not considered mature yet for different reasons. Firstly, high devices cost can vary from US$ 40,000 to US$ 200,000 (Kim et al. 2015). Alternatively, scanning activities can be externalised, but prices for cloud surveys are 40%-50% higher than in-house surveys (Mahdjoubi et al. 2013). Choosing the appropriate 3D laser scanners is not easy also because of the relevant number of impacting factors, such as types of scans—fixed or moving, outdoors or indoors, with or without GPS signal availability; types of objects to be detected—structures, installations, colours, finishes (Kim et al. 2015); typical lighting conditions; level of precision required; relative position between objects to be scanned and the scanning device (Gerbino et al. 2015). Furthermore, making informed choices about which device to use is a challenge because of the wide spectrum of applicability of laser scanners in the market. The most relevant weakness for this technology is represented by the data processing: devices that produce a huge amount of data that requires a high computing power for opportune processing, filtering and manually transforming them into a 3D digital model. Unfortunately, algorithms for completely automating such operations are still under development.

6 Conclusions

This paper analyses the use of 3D laser scanners within the built environment, describing its potential beneficial effects, especially when integrated with BIM technology. Current practices, especially for existing buildings, are still massively depending on trivial manual activities, such as buildings survey, that can heavily impact projects performance and related costs. The 3D models generation activity is still a manual operation that has been only partially automated by means of 3D-laser scanners. However, it will be completely automated as soon as specific algorithms for the treatment of data collected by 3D-laser scanners will be developed. In this last case, professionals can only focus on design activities, improving the performance of the construction industry. The need for detailed 3D models is recognised as one of the main trends in scientific research (Kapliński 2018). In the context of the integrated BIM environment, the automation in 3D models creation and updating plays a central role. Future research is pointing towards new technical solutions which will be able to reduce the number of impacting factors in 3D laser scanners performance as well as new algorithms that will be able to improve the process of automated transformation of point clouds to 3D models (Xiong et al. 2013) with meta-data attached (Mahdjoubi et al. 2013). Furthermore, reliable metrics for laser-scanning applications, defined in terms of accuracy required, distance to target and point cloud density (Randall 2011) are needed in order to both standardise scanning activities and define minimum acceptable quality.

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Modelling Hospital Functional Performance Under Surge Conditions—The Application of FRAM and RAM

Farhad Mahmoudi, Sherif Mohamed, and Fahim Tonmoy

Abstract

Non-linear models for understanding complex socio-technical processes have not been fully adopted in the examination of hospitals' functional performance when managing the effects of disruptive events. In the literature, researchers have focused on the various dimensions of hospital functional performance (HFP) using different methods. However, they have not sufficiently addressed the inherent behaviours of systems that diminish the efficiency and effectiveness of HFP when operating under different protocols. The current paper aims to identify the pathway through which functional variabilities may propagate throughout the system when dealing with medical surge. To achieve this objective, the application of the functional resonance analysis method (FRAM) is integrated with the application of the resilience analysis matrix (RAM) to analyse HFP. The results identify 23 couplings in 153 interactions between 29 functions that have the potential to affect overall HFP. The approach of this research has revealed how managing the variability of certain interactions can enhance the efficiency and effectiveness of HFP in dealing with disruptive events.

Keywords

Hospital functional performance • Resilience • Functional resonance analysis method

1 Introduction

The continuity of hospital functional performance (HFP) is a significant public health concern in every society. Further, given that hospitals are one of the frontline services that deal with disruptive events, the resilience of HFP and maintaining the delivery of their primary services during disruptive events is a priority. As a complex socio-technical system, a hospital's performance can be affected by fluctuations of different types of individual functions (e.g. mechanical, human, organisational, technological) that are essential for its continuous operation. A combination of performance variabilities can accumulate over time and lead to system failure (i.e. accidents). The outcome of a combination of performance variabilities can be observed as the occurrence of accidents in the absence of any major technological failure (Macchi 2010). Therefore, it is critical to understand how functional performance variability can affect overall HFP. The general purpose of the functional resonance analysis method (FRAM) is to assess every system's work-as-done (WAD) rather than its work-as-imagined (WAI).

In FRAM, the complexity and social factors involve the interfaces between adaptable human agents and technology, coupling and dependence effects, non-linear dependencies between subsystems and functional performance variability (Woltjer and Hollnagel 2008). FRAM can be used as a technique of system-accident investigation and as a risk assessment method to inform and design activities for large distributed systems. The literature has shown the application of FRAM in the healthcare sector to be useful, and this method has been used to examine the hidden dynamics that can affect the delivery of services.

The following lists the principal points of focus of this literature:

- Identifying and managing emerging risks and opportunities (Sujan and Felici 2012; Laugaland et al. 2014; Clay-Williams et al. 2015; Pickup et al. 2017; Raben et al. 2018; Damen et al. 2018; Ross et al. 2018)
- Enhancing healthcare personnel, and staff performance capability under
- Different conditions (Wachs and Saurin 2018)

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- Allocating different types of resources to enhance the system's thresholds and
- Enlarge its buffering capacity (Saurin and Werle 2017)
- Implementing guidelines in the healthcare organisation (Clay-Williams et al. 2015; Das et al. 2018); and
- Enhancing the efficiency of everyday processes (Saurin et al. 2017).

Despite the above attempts, the available research seems to have been reluctant to highlight the criticality of certain functions to the overall workflow of a hospital, and how a stress or disruption to these functions can affect their performance. The lack of clarity about critical couplings between functions often results from the complexity of the FRAM representation. However, understanding these couplings and the importance of individual functions can help hospital management to understand which functions within the hospital's workflow are critical for continuous operation even under surge conditions. Hollnagel (2013) suggest the following steps for developing a FRAM model:

1. Definition of the purpose of the analysis (identifying whether the purpose of the modelling is to perform an accident investigation or a risk/safety assessment)
2. Identification of system's functions (identifying the activities that must be performed to produce a certain output)
3. Description of function (identifying six aspects a function needs to produce its outcome described in terms of input, output, time, precondition, resource, control)
4. Identification of potential variability of functions (evaluating the possibility of a function's output varying in isolation from the rest of the system)
5. Analysis of aggregated variability (analysing how the system reacts when dealing with functional variability under certain instantiations to produce a certain output).

To address the inherent limitation of FRAM (i.e. the complexity of its representation), Lundberg and Woltjer (2013) developed a tool based on the resilience analysis matrix (RAM) to support the traditional FRAM approach. RAM is proposed to aid the evaluation of a system in relation to safety and resilience. The following lists the general idea behind RAM (Laugaland et al. 2014):

- Revealing hidden patterns and functional interdependencies
- Providing an analytical overview of the complex system under examination
- Uncovering instantiations and differences between WAD and WAI
- Illustrating emergent properties of the system's resilience.

Based on the application of RAM, Patriarca et al. (2017), developed a supporting tool, called 'myFRAM'. The integration of these two approaches provides the opportunity to track the potential pathways through which functional variability can either be dampened or amplified. Patriarca et al. (2018) used the integration of RAM and FRAM to examine the couplings amongst the functions. Such integration makes it possible to focus on the impact of certain system couplings and functions on each other (Lundberg and Woltjer 2013; Patriarca et al. 2018) rather than dealing with FRAM visual presentation. Therefore, the aim of the current research is to identify the functions that are critical for maintaining HFP when dealing with abnormal conditions in which a hospital might be performing under the activation of its surge procedures, rather than performing business as usual. This aim is achieved by modelling the process of patient flow (from registration to discharge) within an emergency department (ED).

2 Methodology

This research took certain steps to collect the data necessary for developing the FRAM model to represent HFP in the process of patient flow from registration to discharge in the ED. The data collection began by reviewing and analysing documents. The analysis outcome was the identification of the functions that represent the general flow of patients, flow of data and resources, and the essential functions for the transition to, and operation under surge protocols. The primary identified functions and their relative aspects were then finalised in an interview with disaster management experts to merge and simplify the primary model. The primary model was then presented to disaster and emergency experts to conduct the case study. The experts were asked to identify missing links and functions that were believed critical for the system's successful operation. Finally, the normal and expected variability of each function's output in relation to its precision and timing were evaluated by the experts. Through employing RAM, the potential effect of variabilities in the upstream functions on their downstream functions were identified and analysed.

3 Results

Developed from the document analysis and rounds of interviews with the experts in disaster and emergency management, 29 functions (presented in Table 1), were selected for developing the FRAM model. Further, Fig. 1., presents a typical FRAM function and its couplings. The aspects of these functions interact via 171 couplings.

As stated, the purpose of identifying these functions is to investigate how HFP can be affected if a surge protocol is triggered. Therefore, the FRAM model involves key functions in the general pathway of hospital patient flow (from registration to discharge) and their supporting activities, policies and utilities (e.g. power supplies, water supply), as well as the performance of the hospital's external alliances. It is important to note that the identified functions can be broken down into smaller functions. However, this breakdown was considered to be outside the scope of this research. After identifying the functions, the potential sources of variability of each function were identified through the assessment of the deviation of each output's (WAD) from its expected output (WAI).

In contrast to the analysis of FRAM's traditional representation, the FRAM model was analysed using the application of RAM. The integration of RAM and FRAM helped to highlight the relationships amongst the couplings of functions rather than simply identifying the functional interactions (Lundberg and Woltjer 2013). Thus, the study was able to identify the relationships amongst the functions through which functional resonance can cascade. After identifying these relationships, by using myFRAM, a 171*171 RAM matrix was generated based on the couplings of functions, and the potential variability of each coupling was identified in relation to the timing of generating the output and the quality of the output.

Based on the generated RAM, the number of critical couplings generated by each upstream function is identified. The functions of Maintaining Power Supply and Maintaining Information/Communication System have the highest number of outputs, and therefore, the greatest effect on the overall HFP. The following functions have the next greatest effect on the overall HFP: Number of Available Beds; Procedures to Execute Surge Plans; Activating Medical Surge Capacity; Implementing Surge Staffing Procedures; Availability of Emergency Plans; Sharing Information, Assessing and Updating; Assessing, Tracking and Deploying Extra Assets and Resources. Figure 2 presents the downstream link (DL) index (i.e. the index that considers the number of DLs). The higher the value of the DL, the higher the potential of the system being affected by variability in the generated output. C86 = 18 (Performing Maintenance and Maintaining Information/Communication System) have the highest DL value; followed by C90 = 14 (Performing Maintenance and Maintaining Power Supply); C113 = 11 (Notification from Internal and External Stakeholders); C142,145,153 = 10 (Activating Procedures to Execute Surge Plans through Leadership, and Executing Surge Plans) and C94,159 = 9 (Available Beds Notification and Executing Surge Plans). Based on the generated matrix of couplings, the critical flow of tasks in the hospital is identified, as visually represented in Fig. 3. It is important to note that the model presented in Fig. 3, is only a representation of the potential sources of variability in the HFP via the application of RAM. The highlighted functions represent certain couplings amongst functions that functional variability may cascade through them.

Table 1 List of FRAM functions

Function	Function	Function
Triage, assessment and streaming	Number of available beds	Reassessing and prioritising Surge patient flow
Early treatment and fast track	Maintaining water supply	Direct medical surge tactical operations (Leadership)
Acute care	Maintaining medical gas supply	Procedures to execute the surge plans
Inpatient ward admission	Maintaining hospital spatial capacity	Activating medical surgery capacity
Discharge	Availability of emergency plans	Implementing surge staffing procedures
Bed management	Performing emergency trainings and Drills	Assessing, tracking and deploying extra assets and resources
Accessing patients' clinical history	Establishing disaster cooperation mechanism	Emergency triage and pre-hospital treatment
Performing maintenance	Reporting from external agents	Emergency operation centre management
Maintaining information communication system	Assessing the nature and scope of the event	Medical supplies management, distribution and logistics
Maintaining power supply	Sharing information, assessing and updating	

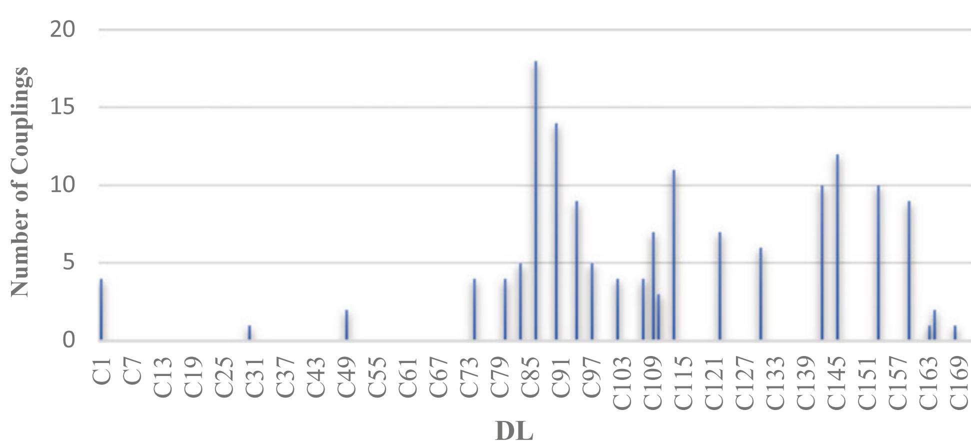
Reassessing and prioritising surge patient flow	Description	*Review triaging of all in-patients and transfer/discharge patients with lower priority*	
	Aspects	Description of the Aspect	UF Function's Name
	Input	*Expected number of casualties exceeds the hospital capacity*	*Assess the Nature and Scope of the Event*
	Precondition	*Execution of the surge plans*	*Procedures to execute the Surge Plans*
		Having agreements for medical facilities and equipment	*Establish Disaster Cooperation Mechanism*
	Resource	*Availability of the Information/Communication System*	*Maintaining Information / Communication System*
		Supplying Power	*Maintaining Power Supply*
	Control	*Calculated number of Available Beds*	*Number of Available Beds*
		Transition from pre-event bed utilization to access surge capabilities and Adding surge beds.	*Activate Medical Surge Capacity*
		Available Surge Plans	*Availability of Emergency Plans*
	Output	*Prioritisation of available beds*	
	Downstream Couplings	*Triage, Assessing and Streaming (C9), Early Treatment (C25), Acute Care (C43), Inpatient Ward Admission (C62), Discharge (C73), Direct Medical Surge Tactical Operations (Leadership)(C137), Activating Medical Surge Capacity (C149)*	

Fig. 1 Example of a function and its connections to UFs

4 Discussion

The approach to examining HFP used in this study can highlight the areas on which decision-makers must focus to enhance the effectiveness and efficiency of their protocols, polices, guidelines and practices, as well as of their resource allocation. This paper considers hospital's patient flow as a series of foreground functions getting supported by various types of background functions (technical, organisational, external). As shown in Fig. 2, the integration of two approaches of RAM and FRAM, highlighted which couplings have the greatest effect on the HFP resilience and those couplings potential effect on the performance of their downstream functions. Thus, using RAM can support FRAM by providing a better understanding of the effect of each coupling on the entire system. The other contribution of this study is the identification of the pathway through which functional variability can spread through specific couplings. The findings suggest that in HFP, information sharing throughout the system, performing technical maintenance, the availability of efficient procedures for implementing a surge plan and directing surge tactical operations play a critical role when managing function variability. These findings are in line with a previous publication by the same authors (Mahmoudi and Mohamed 2018), using a different modelling technique, which highlights the direct and indirect effects of leadership and procedures for executing surge plans on hospital surge capacity and cooperation. Further, these finding also shed light on the importance of the contextual factors that are involved in the implementation of particular efforts (Raben et al. 2018). In addition, the findings highlight the importance of increasing the buffering capacity of functions that may generate variability due to the lack of resources and enhancing the ability for self-organisation of these functions (e.g. adding vacant beds, providing extra assets and resources) (Saurin and Werle 2017). The use of RAM and its representation provided a new perspective on HFP and surge procedures. This perspective can help decision and policymakers to identify possible risks that propagate function variability and the existing buffers that can decrease generated variability in their upstream functions. Future studies should address the extent of the effect of the identified couplings on

Fig. 2 Representation of DL generated by RAM



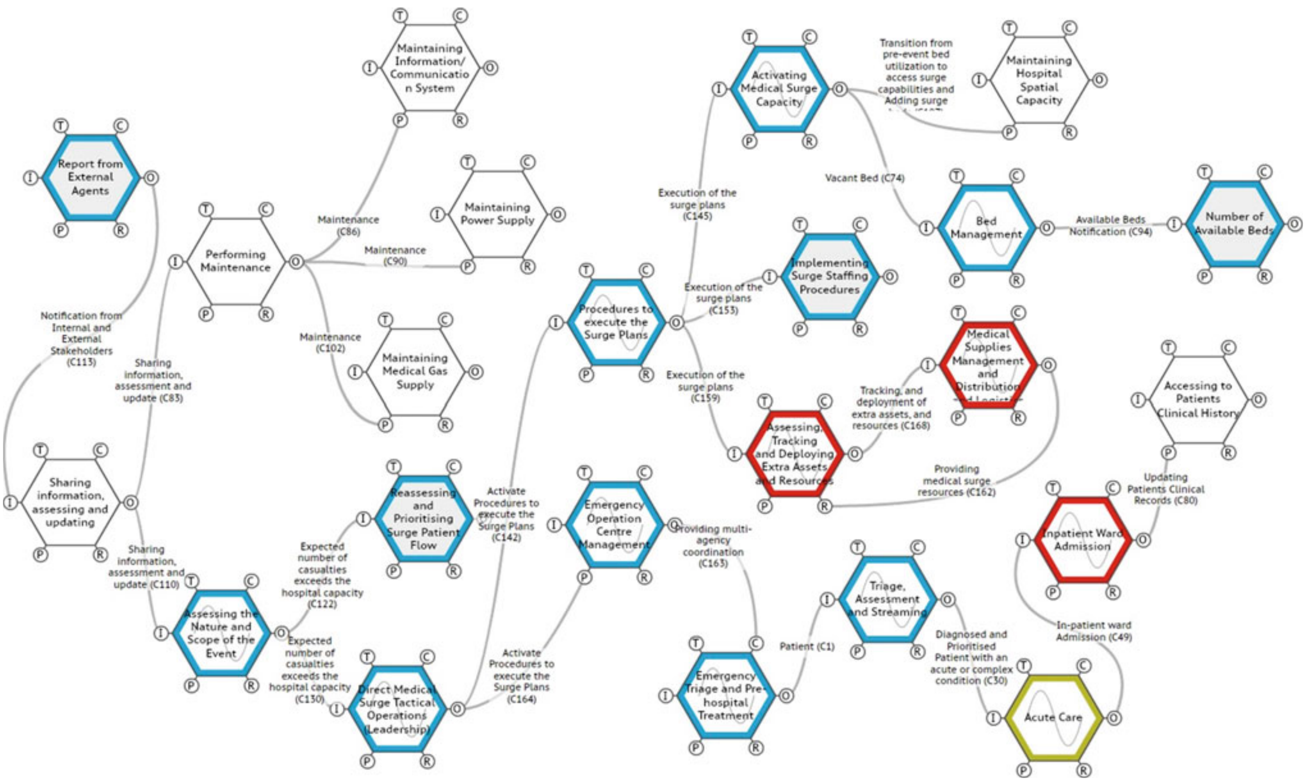


Fig. 3 Critical pathway of the hospital task flow under a surge condition

downstream functions and how they deal with the variability imposed by their upstream functions.

5 Conclusions

This paper examines HFP during events in which a hospital must perform under surge conditions. It also examines a socio-technical systems' behaviour when dealing with undesirable changes in the internal or external environment, and how those changes can affect their productivity and quality of services. Using FRAM as the method of modelling and analysis allowed identification of functions and parameters that can affect overall HFP. By focusing on a hospital system, the research identified the couplings that influence a hospital's primary services whilst operating under conditions that trigger surge protocols. Through a description of the interactions amongst the different functions of the HFP and the potential effect of each function on overall performance, FRAM provided new insight into HFP. Further, the integration of the applications of FRAM and RAM provided a method that enabled the complex representation of traditional FRAM to be simplified. This approach can be used to highlight different pathways via which hospital functions generate outputs. The use of RAM translated FRAM's visual representation into a matrix that enabled the simplification and identification of functional interdependencies, and the visualisation of the resilience of HFP. This study shed lights on the functions that can impose the risk of generating emergent outcomes, and on the system's buffering capacity. Through identifying the functions that can reduce emergent, decision-makers and disaster management teams can identify the thresholds and buffering capacities embedded into the hospital's system. The perspective offered in this paper can help disaster management teams to effectively target different tasks that can generate emergent via their performance variabilities and enhance the buffering capacity of a system. Future research, plans to examine the effect of different couplings on downstream functions to assess the hidden interactions amongst functions via scenario analysis.

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Water Content Effect on California Bearing Ratio of Cohesive Soil

Chigozie Collins Okafor and Clinton Aigbavboa

Abstract

The CBR test is a simple and well-recognized method of assessing the strength of subgrade. There are also many other Geotechnical tests which can be used to ascertain the quality of the subgrade soil, the quality of the soil that is used for subgrade may differ and this may depend on the amount of water that seeps through the soil. In this study, the degree of soaking was varied in days starting from un-soaked (day 0) to soaked (day 1) up to (day 5) to enable the measurement of the saturation level in different types of soil in Awgu LGA. Furthermore, the Engineering features of the soils which included the CBR at different saturation levels were also studied. According to the results obtained, as the soaking period increases from days 1 to 5 for all the samples, there was a remarkable decrease in the CBR of soil samples from 100 to 5% in all the samples.

Keywords

Moisture content • California bearing ratio • Cohesive soil

1 Introduction

Nigeria, a country in the tropical region is characterized by heavy rainfall and high temperature. It is, therefore, appropriate to say that climatic factors affect its roads.

Many of the roads are flooded with water after heavy rains due to inadequate drainage system. In other to design the pavement layers to be spread over the subgrade soil, the strength of subgrade must be estimated and the amount of traffic it's expected to carry as well. The California bearing ratio is mostly the prevalent test used in estimating the strength of the subgrade, the subgrade which is considered weak usually needs thicker layers while stronger subgrade can make do with thinner layers. Due to varying environmental conditions like precipitation, capillary action, flooding, etc., the subgrade always experiences a varying change in saturation level. The subgrade strength changes due to change in moisture level and this is critical for Engineers to understand the extent which moisture affects the subgrade strength, this will enable engineers make a better design.

The California bearing ratio is one soil test which can be used to assess the strength of a subgrade. With this test, different strength of the subgrade materials can be compared and better design and maintenance decisions can be made.

2 Aims and Objectives

This study investigates the variations of CBR with water content for different days using cohesive soil from Awgu in Enugu–Port-Harcourt expressway, South East Nigeria.

3 Research Methodology

The soil samples for this study were dug from different pits which are located at a distance of 1 km away from each other, the soil was dug up at a depth of 1 m to ensure the best quality of samples were collected. This study was conducted using two samples of soil. Some preliminary soil tests were done in other to determine the various features of the soil, the preliminary tests that were done are Atterberg-limit test and sieve analysis. In other to carry out the CBR test, compaction experiments were done to ascertain the OMC and its MDD. CBR experiments were conducted at varying water levels and the variations of the CBR

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with regards to various days of immersion in water, from un-soaked (day 0)–soaked (day 5) were observed. Soil sample at various layers along various points (East-side; North-side; South-side; West-side) were collected and the moisture content obtained. See Fig. 1, using this method, the moisture content at different days of soaking was also obtained. The diagram below (Fig. 1) represents the CBR mold and a depiction of how soil samples were collected from the mold.

CBR TEST

A compaction test was conducted using the modified proctor mold to ascertain the OMC and the maximum dry density of the soil sample. The soil specimen was tested using the CBR apparatus, the tests were conducted on the sample from un-soaked (day 0) to soaked (days 1, 2, 3, 4, and 5). For each sample and each day, the moisture content was also determined for top, middle and bottom at North-side; South-side; East-side; and West-side. (See Fig. 1).

4 Results

Tables 1 and 2 represents the average moisture content in % of the two samples from Unsoaked (day 0) to soaked (day 5).

Sample one

See Table 1.

Sample Two

See Table 2.

The Figs. 1 and 2 below represents the California bearing ratio reading of the two samples which was plotted against days of soaking, from unsoaked (day 0) to soaked (day 5).

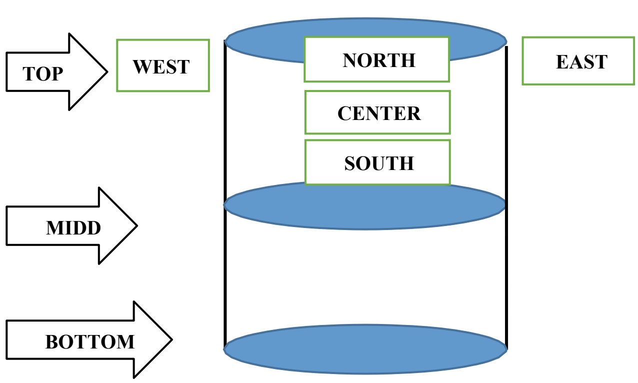

Fig. 1 The figure above represents the horizontal and vertical positions of soil sample

5 Discussion

5.1 Moisture Variation in Soil Samples

Tomer and Mallick (2011) opined that the CBR of a given soil sample can decrease quickly when immersed in water for 24 h and when the number of days of immersion in water increases the California bearing ratio of the given sample continues to decrease gradually. Talukdar (2008) also postulated that the CBR of a given soil sample can also depend on other factors like MDD, OMC, and Atterberg limit experiment, etc. Razouk and AL-Azawi (2003) also concurred in their study that when soil samples are soaked for a long period, it begins to lose its strength. Another study conducted by Alayaki and Bajomo (2011) showed that longer soaking period of a compacted soil sample decreases the CBR value, he also observed that the CBR of the top surface of the soaked soil is greater than the bottom face. Therefore, in this study, the moisture content tables above for samples 1 and 2, respectively, show how moisture behaves across the cohesive soil samples from Awgu local government, South East Nigeria. The average moisture content for unsoaked (day 0) to soaked (day 5) were computed for North, South, East, and West for the top, middle, and bottom, respectively. From Table 1. Sample 1, it is observed that there was no much water movement within the soil at unsoaked state. At soaked (day 1, sample 1) the average moisture at the top was 26%, at the middle was 19%, while at the bottom was 23%. At day 2, it was 26% at the top, 23% in the middle, and 24% at the bottom. At day 3, it was 24% at the top, 21% in the middle and 26% at the bottom. At day4, it increased to 30% at the top, 22% in the middle and 24% at the bottom. Then at day 5, it decreased by 2% to 28% at the top, 23% in the middle and 26% at the bottom. The same sequence of water movement continued in sample 2 only that the average moisture contents for sample 2 was higher than sample 1.

Furthermore, observations from sample 1 and sample 2 show that there was continues increase in the average water content at the top, middle, and bottom for samples 1 and 2, respectively, as the days of soaking continued to increase, this shows that Awgu soil has high seepage of water which can be a critical problem for building foundation and highway construction.

5.2 Variation of CBR with Days of Soaking

A California bearing ratio test was conducted for the samples at unsoaked state (day 0) to soaked state (days 5) for both samples 1 and 2, respectively. Presenting the California bearing ratio readings on the diagram in Figs. 2 and 3,

Table 1 Moisture content for sample 1

		Moisture content in %				
		North	South	East	West	Average
Unsoaked	Top	10	12	11	11	11
	Middle	13	12	14	13	13
	Bottom	11	11	12	11	11
Soaked day 1	Top	26	25	26	28	26
	Middle	19	19	19	19	19
	Bottom	21	23	24	24.41	23
Soaked day 2	Top	26	25	27	26	26
	Middle	22	23	23	23	23
	Bottom	20	25	26	23	24
Soaked day 3	Top	24	24	22	26	24
	Middle	22	22.22	20	20	21
	Bottom	24	24	32	25	26
Soaked day 4	Top	34	29	30	25	30
	Middle	22	22	27	18	22
	Bottom	21	26	21	26	24
Soaked day 5	Top	30	26	28	28	28
	Middle	22	25	23	21	23
	Bottom	26	25	26	28	26

Table 2 Moisture content for sample 2 Moisture content in %

		Moisture content in %				
		North	South	East	West	Average
Unsoaked	Top	8	8	9	9	9
	Middle	9	9	10	8	9
	Bottom	9	8	8	7	8
Soaked day 1	Top	18	16	16	17	17
	Middle	16	13	14	10	13
	Bottom	16	16	12	12	14
Soaked day 2	Top	29	26	26	30	28
	Middle	26	27	25	26	26
	Bottom	31	32	31	28	31
Soaked day 3	Top	31	37	36	31	34
	Middle	30	30	30	26	29
	Bottom	35	33	35	35	35
Soaked day 4	Top	35	37	32	33	34
	Middle	29	31	33	29	31
	Bottom	35	33	33	34	34
Soaked day 5	Top	35	36.03	35	35.04	35
	Middle	32.4	33	31.3	33	32
	Bottom	42	37.3	39.3	36	39

respectively, below, it was observed that the California bearing ratio values for sample 1 (Fig. 2) was high at 70 in un-soaked state and after 24 hours of immersion in water, the CBR value reduced to 6, on day two it went down further to 2, on day three it went down further to one, there was a slight increase to 10 on day 4; however, on day 5, it reduced to 2. These variations show that water greatly affected the CBR of sample 1.

For sample 2 (Fig. 3), the CBR values for samples (2) was the highest at 84 in unsoaked state, however, it reduced to 0 after 24 hours of immersion in water, on the second day it rose to 2, and remained constant at 2 all through the remaining days. This equally shows that water greatly affected the CBR of the sample just like it did in sample 1.

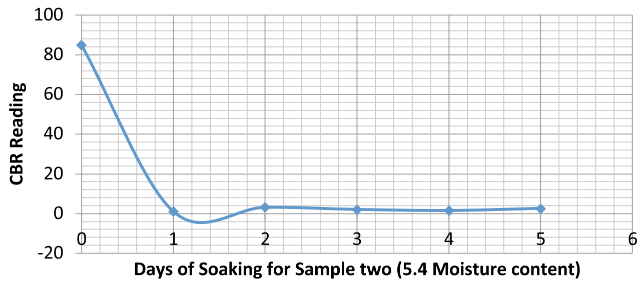

Fig. 3 CBR reading against days of soaking (sample 2)

6 Conclusions and Recommendation

In this study, an attempt has been made to explore the effect of moisture on the California bearing ratio values of two samples of soil collected along the Enugu–Port Harcourt expressway, Awgu LGA. The test results above showed that

1. Higher moisture contents resulted at both top layers and lower layers.
2. The reduction in strength of California bearing ratio value was the same.
3. All the samples experienced a decrease in CBR from unsoaked condition to 24 hours soaking.
4. When the number of days of soaking increased, there was a further reduction in the CBR which was gradual and at a slow rate.
5. From day 1 to day 5, there was no significant difference.

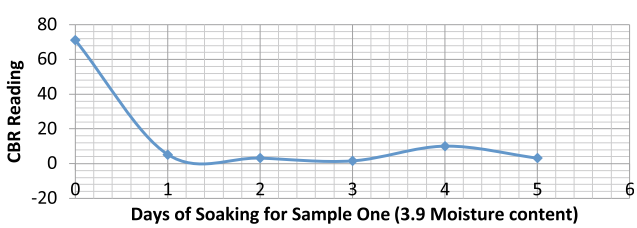

Fig. 2 CBR reading against days of soaking (sample 1)

6.1 Recommendations

1. To further substantiate the above findings, more research which will involve a variety of samples and increased number of days of soaking need to conducted.
2. Other engineering features need to be determined using the direct shear experiment, unconfined compression experiment, and triaxial experiment at varying levels of water saturation.
3. The engineering properties above and the corresponding results should be prepared in a database for a variety of soil samples and locations, this will enable engineers to have a CBR benchmark which can be used for pavement design.

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Investigation of Infrastructural Maintenance in Public Institutions in Nigeria

Chigozie Collins Okafor and Clinton Aigbavboa

Abstract

Maintenance is the act of protecting an infrastructure from decay or dilapidation so that it will continue to remain new, retain its economic importance and durability which will make the infrastructure more sustainable. When an infrastructure is sustainable it benefits and serves the present generation without denying the future generation its own benefits. This study was conducted between 2016 and 2018 to investigate the level of infrastructural maintenance in public institutions in Nigeria using the University of Nigeria, Nsukka campus, as a case study. From the field investigation conducted during this study, it was observed that the university rely more on corrective maintenance which involves conducting maintenance when the infrastructure is already damaged rather than implementing preventive maintenance which involves conducting maintenance to prevent unseen damages which may occur. It was also observed from the field investigation that one of the major problems of maintenance in government-owned institutions is lack funding for infrastructural maintenance. In this study, it was observed that offices and classrooms in the ten faculties housed by the University of Nigeria, Nsukka campus, needed over 40% maintenance work on their walls, floor, roof, paint, window, toilet, electrical installations and doors. The Faculty of Pharmaceutical Science had the most maintenance problem in both the offices and classrooms. It was recommended that a holistic maintenance model should be followed in line with international best practices in advanced countries. The university should develop and follow a preventive maintenance policy by employing the services of a good maintenance/management firm to maintain and manage the university infrastructures, while the works services department serves a supervisory body. In line with the trending fourth industrial revolution, it is recommended that the University should introduce the use of one-stop shop maintenance services using information and communication technology (ICT). Special soft wares should be developed which can be used to keep records of building projects starting from the design, as-built, till the end of the project, this can help to identify maintenance problems easily.

Keywords

Maintenance • Infrastructure • Institutions • Public • Investigation

1 Introduction

Maintenance of infrastructure is the act of preserving an infrastructure so that it will remain sustainable by retaining its initial outlook, durability and economic importance which will benefit the present and future generation. According to (cobbinah 2006), maintenance is simply the principle plans taken to preserve infrastructures like buildings, road, etc., so they can retain their initial functional state, structural and aesthetic states and their investment value over a lasting period of existence. Maintenance plan is a very important part of the infrastructural design which is neglected in Nigeria unlike in most developed countries where infrastructures are designed alongside its maintenance plan.

In most Nigerian government-owned institutions, lack of maintenance of infrastructure has been a major problem, most buildings and roads within the premises of the institutions are allowed to dilapidate to a large extent before any maintenance plan is made for it. This leads to serious

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economic loss because more money is spent to rebuild the entire dilapidated infrastructure than it would have cost if a proper preventive maintenance plan was followed. Most public institutions in Nigeria rely heavily on corrective maintenance which involves carrying out maintenance after some damages must have occurred. Maintenance problems have remained largely unsolved but it can be tackled by professionals at the project inception and planning, construction to completion stages via preventive rather than corrective method (Ademiji 1998).

It is interesting to note that in various institutions of learning, the state of the infrastructures, especially the buildings have a direct impact on both students and lectures productivity (Lavy and Bilbo 2009).

This study investigated the infrastructural maintenance in public institutions using the University of Nigeria, Nsukka campus, as a case study.

At the end, proper maintenance recommendations were made, and when implemented will help public institutions tackle the problems of infrastructural maintenance.

2 Aim and Objectives

To investigate the infrastructural maintenance in public institutions in Nigeria and make recommendations for proper maintenance of infrastructure in public institutions in Nigeria.

3 Research Methodology

This study was carried out between 2016 and 2018 on various faculties in the University of Nigeria, Nsukka campus, to investigate the current state of infrastructures within the university. As at the time of this study (2016–2018), the University of Nigeria, Nsukka campus, housed ten faculties. This study was carried out by means of a questionnaire survey which is a systematic mode of data collection from a target population. The target population in this study were staff who occupy offices in these various faculties (non-teaching staff and teaching staff) and students who use classrooms in these faculties. Five hundred questionnaires were distributed amongst staff and students and 378 were returned this represents a 75.6% response rate. Improper or half-filled questionnaires were returned back to the respondent on the point of collection to complete them.

The questionnaire used for this survey was categorized into the condition of building by parts. Condition of building by parts can be defined as a building maintenance analytical approach which breaks down a building into several parts for easy assessment.

For the purpose of this study, these conditions of buildings were analysed under eight different parts which include i. Condition of the floor, ii. Condition of the roof, iii. Condition of the wall, iv. Condition of the paint, v. Condition of the window, vi. Condition of the toilet, vii. Condition of electrical installations, viii. Condition of the doors.

4 Results

See Tables 1 and 2.

5 Discussion

The write up below discusses the general statistical condition of faculty offices in the University of Nigeria, Nsukka campus, which is represented in Table 1.

(i) Roof: 32.8% of the offices in different faculties have leaking roof, 12.6% have rusty roof, 8.9% have partly ripped off roof. Only 45.5% of the offices still have their roofs in good condition. This means that 55.3% of the offices need to have their roofs maintained urgently.

(ii) Floor: 13.8% of the offices in different faculties have cracked floor, 22.3% have peeled off floor, while 63.7% still have their floor in good condition. This means that 36.1% of the offices need to have their floor maintained.

(iii) Wall: 6.3% of the offices in different faculties have partially broken down walls, 27.8% have cracked walls, 10.8% have peeled off walls and 55.1% are in good condition. This means that 55.1% of the offices have their walls in good condition, while 44.9% of the offices need to have their walls urgently maintained.

(iv) Paint: 2.9% of the offices in different faculties have no painting, 40% have worn out painting, 11.9% have dirty painting and only 45.1% have their painting still in good condition. This means that 54.9% of the offices in the university need re-painting.

(v) Windows: According to the survey conducted, 5.1% of the offices in different faculties within the university have completely broken windows, 39.1% have partially brown down windows, while 55.8% have their windows still in good condition. This means that 44.2% of the offices have bad windows and are in need of maintenance.

(vi) Doors: 2.4% of the offices in different faculties within the University have their doors completely broken down, 28.7% have partially broken down

Table 1 Represents the general statistical condition of faculty offices in the University of Nigeria, Nsukka campus

Element	Leak (%)	Rusty (%)	Partly R/off (%)	Cracks developed (%)	Peeled off (%)	Partially broken down (%)	Comp. broken down (%)	In good codtion (%)	Maint. work needed (%)
Roof	32.8	12.6	8.9					45.5	55.3
Floors				13.8	22.3			63.7	36.1
Walls				27.8	10.8	6.3		55.1	44.9
Window						39.1	5.1	55.8	44.2
Doors						28.7	2.4	69.1	31.1
Toilets	4.2					39.1	19.8	36.7	63.1
Electric facilities						47.2	5.8	46.8	63
Paint	No painting 2.9	Worn out Paint 40.1	Dirty 11.9					45.1	54.9

Note The table titles are; Elements, leaking, Rusty, Partly ripped off, Cracks developed, Peeled off, Partially broken down, Completely broken down, In good condition, Maintenance work needed

doors, while 69.1% are in good condition. With 69.1% of the offices having their doors in good condition this means that the university has a little problem as regards maintenance of doors and this is because occupants repair their doors when broken, however, 31.1% of the offices need to have their doors maintained.

(vii) Electrical Installations: 47.2% of the offices in different faculties have partially functioning electrical installations, 5.8% have completely broken down electrical installations, while only 46.8% of the offices have their electrical installations still in good condition. This means that 53% of the offices have their electrical installations in bad condition and needs urgent maintenance.

(viii) Toilets: 4.2% of the offices in different faculties in the university have leaking toilet facilities, 39.1% have partially broken down toilet facilities, 19.8% have completely broken down toilet facilities, while only 36.7% of the offices still have their toilet facilities in good condition. This means that 63.1% of the offices need to have their toilet facilities urgently maintained.

The write up below discusses the general statistical condition of faculty classrooms in the University of Nigeria, Nsukka campus, which is represented in Table 2.

(i) Roof: 18.8% of the classrooms have leaking roof, 18.2% have rusty roof, 16.5% have partly ripped off roof. Only 46.5% of the classrooms still have their roofs in good condition. This means that 53.5% of the classrooms need to have their roofs maintained urgently.

(ii) Floor: 22.9% of the classrooms have cracked floor, 13.6% have peeled off floor, while 63.5% still have their floor in good condition. This means that 36.5% of the classrooms need to have their floor maintained.

(iii) Wall: 9.2% of the classrooms have partially broken down walls, 8.8% have cracked walls, 7.3% have peeled off walls, 8.3% have bent walls and 66.4% are in good condition. This means that 66.4% of the classrooms have their walls in good condition, while 33.6% of the classrooms need to have their walls urgently maintained.

(iv) Paint: 3.9% of the classrooms have no painting, 32.9% have worn out painting, 9.7% have dirty painting and only 53.2% have their painting still in good condition. This means that 46.5% of the classrooms in the university need re-painting.

(v) Windows: According to the survey conducted 8.2% of the classrooms in the university have completely broken windows, 36.7% have partially brown down windows, while 54.8% have

Table 2 Represents the general statistical condition of faculty classrooms in the University of Nigeria, Nsukka campus

Elements	Leak (%)	Rusty (%)	Partly R/off (%)	Cracks developed (%)	Peeled off (%)	Partially broken down (%)	Comp. broken down (%)	In good codition (%)	Maint. work needed (%)
Roof	18.8	18.2	16.5					46.5	53.5
Floors				22.9	13.6			63.5	36.5
Walls				8.8	7.3	9.2	8.3	66.4	33.6
Windows						36.7	8.2	54.8	44.9
Doors						25	5.1	69.7	30.1
Toilets	2.3					17.7	32.1	47.7	52.1
Sewage	5.7					18	17.9	58.2	41.6
System									
Electrical facilities						50.8	11.6	37.3	62.4
Paint	No Painting 3.9	Worn out Paint 32.9	Dirty 9.7					53.2	46.5

Note The table titles are; Elements, leaking, Rusty, Partly ripped off, Cracks developed, Peeled off, Partially broken down, Completely broken down, In good condition, Maintenance work needed

their windows still in good condition. This means that 44.9% of the classrooms have bad windows and are in need of maintenance.

(vi) Doors: 5.1% of the classrooms in the University have their doors completely broken down, 25% have partially broken down doors, while 69.7% are in good condition. With 69.7% of the classrooms having their doors in good condition this means that the university has little problem as regards to maintenance of doors, however, 30.1% of the classrooms need to have their doors maintained.

(vii) Electrical Installations: 50.8% of the classrooms have partially functioning electrical installations, 11.6% have completely broken down electrical installations, while only 37.3% of the classrooms have their electrical installations still in good condition. This means that 62.4% of the classrooms have their electrical installations in bad condition and needs urgent maintenance.

(viii) Toilets: 2.3% of the classrooms in the university have leaking toilet facilities, 17.7% have partially broken down toilet facilities, 32.1% have completely broken down toilet facilities, while only 47.7% of the classrooms still have their toilet facilities in good condition. This means that 52.1% of the classrooms need to have their toilet facilities urgently maintained.

6 Conclusions and Recommendations

This study has shown that infrastructural maintenance is a big problem in most government-owned public institutions in Nigeria. Most of these institutions rely on corrective maintenance which in most cases is not the best form of maintenance practice, the best infrastructural maintenance practice remains the preventive maintenance which involves carrying out maintenance practices to prevent unseen future maintenance problems which might occur. Due to inadequate funding of public institutions by the government, maintenance of infrastructure remains a big problem because funds are not budgeted for maintenance. Due to the lack of proper maintenance, the buildings within the university are fast losing its durability, economic value and are not sustainable, in other to fix these buildings it will cost the university a huge sum of money than it would have cost if a proper maintenance plan/schedule had been adopted. From the results above, it is observed that the faculty buildings, offices and classrooms within the University of Nigeria, Nsukka campus, needed above 40% maintenance work which implies that most of them are dire need of maintenance work.

Therefore it is recommended that

- A holistic maintenance model should be followed in line with international best practices in advanced countries.

- The university should develop and follow a preventive maintenance policy by employing the services of a good maintenance/management company to maintain and manage the university infrastructure, while the works services department serves a supervisory body.
- In line with the trending fourth industrial revolution, it is recommended that the university should introduce the use of one-stop shop maintenance services using information and communication technology (ICT).
- Special soft wares should be developed which can be used to keep records of building projects starting from the design, as-built, till the end of the project, this can help to identify maintenance problems easily.

The above recommendations if implemented will reduce maintenance problems faced by the university.

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Temporary Homes in Disaster Hit Areas

Taylor Wimberly, Salman Azhar, Malik Khalfan, Irfan Ulhaq, and Tayyab Maqsood

Abstract

Temporary housing plays a critical role in post-disaster recovery efforts but due to their unsustainability, cultural inadequacies, and being expensive they are not seen as a suitable resolution. Thus, due to the need for an integrated and more responsive strategy has become evident to better utilize the recovery and relief resources. The aim of this research is to explore the use of temporary housing in post-disaster situations by addressing both physical and psychosocial safety/health issues and potential solutions to improve the implementation of temporary housing. Furthermore, this research determines re-use and recycle, potential of temporary housing units after occupancy in post-recovery areas. This research also tries to identify how deconstruction is utilized and the benefits in post-disaster situations and determine the role and effectiveness of community participation during the post-disaster recovery situations. In the first part, this paper introduces the topic, then delivers the state of the art literature survey. This paper also justifies the chosen methodology followed by discussion and conclusion.

Keywords

Temporary homes • Post-disaster situation • Issues and criticism of temporary housing

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1 Introduction

Natural disasters seem to occur more frequently in today's world. Perhaps this can be attributed to the global connectivity provided by the internet where news and information about events are readily accessible to the global populace rather than constrained to the affected region. In addition to the apparent frequency of events, the world population continues to grow which increases the likelihood of natural disaster affecting more people. In order to combat this, emergency management agencies have designed relief and reconstruction programs to rebuild areas that are destroyed.

Often, use of temporary housing after large-scale disasters has been criticized due to unsustainability and cultural inadequacies (Félix et al. 2013), Also, for being overly expensive, lacking in timely response effort after the disaster, and held responsible for undesired impacts on urban environments (Johnson 2007). Agencies, such as the Federal Emergency Management Agency (FEMA) and the Mid-American Earthquake Center (MAE Center), within the United States, utilized Disaster Impact Software to enable emergency planners to estimate potential displacement to people after a natural disaster, however, these systems lack the ability to quantify and provide actionable solutions to address the temporary housing need (El-Anwar et al. 2009).

Following the 1999 earthquake disaster in Duzce, Turkey, the post-disaster region suffered from a variety of issues (Arslan 2007). The need for integrated management became evident, during the recovery and relief effort, in order for emergency planners to effectively utilize resources (Arslan 2007). Optimally, temporary housing would form a sustainable community capable of maintaining itself socially, economically, and environmentally over time (Arslan 2007). For this to be viable, temporary housing must be constructed out of materials that are re-usable and which are derived from materials which required reduced energy to make (Arslan 2007).

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2 Literature Review

Disasters result in the devastations of the houses and require urgent or temporary housing solutions for homeless families. Temporary housing is a broad concept; it ranges from large-scale temporary buildings, built by the government after a disaster, to hotels, apartments, friends or family, and all places where displaced families or individuals could live temporarily (Hui 2012). Temporary housing plays a critical role in post-disaster recovery efforts since they provide shelter and solace, allowing the victims to begin recovering and continuing with their lives (Félix et al. 2013). The reconstruction process of permanent housing can take considerable time, often several years to complete (Félix et al. 2013). This time gap between full post-disaster recovery and reconstruction is bridged by temporary housing programs (Félix et al. 2013). Temporary buildings could range from modular prefabricated building, to warm tents or self-built shelters, and may or may not have an integrated supply chain to deliver these solutions. However, due to their impartialities families are unable to resume daily life and activities. Furthermore, the rapid decay of temporary shelters places a high emphasis on the importance of temporary housing (Félix et al. 2013).

The use of temporary housing after large-scale disasters has often been criticized due to unsustainability and cultural inadequacies (Félix et al. 2013). Problems in sustainability are expressed in two ways: cost and environmental issues. Often, the temporary housing solutions were not produced in the region where the disaster occurred, thus remains expensive due to high material and transportation costs. Cultural inadequacy plays a role in the inadequacy problem of temporary housing (Félix et al. 2013). Often, the response for meeting the sudden demand for large quantities of temporary housing units have been solutions which employ standardization, technologically oriented, and reasonably cost-effective. However, due to the cultural misfits, the standard solution is not feasible because it ignores the real needs of the user, variation in cultural values and housing form, variation in family size, etc. (Félix et al. 2013). Moreover, temporary housing programs have also been reported as health hazards due to the presence of several forms of contamination (El-Anwar et al. 2009).

In response to large-scale natural disasters, emergency management agencies attempt to provide adequate temporary housing solutions needed to provide shelter and space for displaced persons. Agencies such as the Federal Emergency Management Agency (FEMA) and the Mid-American Earthquake Center (MAE Center), within the United States, utilized Disaster Impact Software to enable the emergency planner to estimate potential displacement to people and families after a natural disaster. Various impact assessment software systems have been developed to aid and support decision-makers during disaster preparedness and recovery efforts (El-Anwar et al. 2009). Systems such as Mid-America Earthquake Center system (MAEviz) and Hazards United States-Multi-hazard (HAZUS-MA) enable planners to estimate the damage to housing in the disaster area and estimate the displacement of families in the aftermath of potential disasters. Although these systems are useful, they lack features necessary for optimizing temporary housing arrangements, which can benefit from and build on capabilities of these systems in estimating the post-disaster displacement of families, and identify the optimal temporary housing plans to meet the specific disaster and cultural needs (El-Anwar et al. 2009).

Systems such as these are being developed and certain components have been integrated with MAEviz to give decision-makers support in identifying optimal post-disaster temporary housing arrangements. These systems are designed to optimize tradeoffs among multiple objectives criteria such as minimizing negative socioeconomic impacts on the displaced families, maximizing public safety by minimizing the vulnerability of displaced families, minimizing the negative environmental impact of temporary housing on the host communities, and minimizing total public expenditures (El-Anwar et al. 2009). While these four objectives are very important, the system is designed to allow decision-makers at emergency management agencies to define other user-defined optimization objectives (El-Anwar et al. 2009).

The temporary housing automated system uses three separate models, a data collection model, and an automated optimization model, and an output analysis and visualization model (El-Anwar et al. 2009). The data collection model is designed to collect and store housing, location characteristics and displaced family data. The data should be collected and stored in the data model during the preparedness and response phase (El-Anwar et al. 2009). Emergency management agencies can then update important data on all available temporary housing alternatives, reduce the time and cost associated with collecting the data after a disaster, and anticipate potential shortages in temporary housing at any location (El-Anwar et al. 2009). The collected data enables decision-makers to develop configurations to achieve their objectives (El-Anwar et al. 2009). Finally, the output analysis and visualization model allows decision-makers to analyze generated tradeoffs and their performances in achieving the temporary housing objectives; visualize the generated solutions and their corresponding configurations of temporary housing arrangements; and select the optimal temporary housing implementation plan that best serves the objectives of public (Fig. 1) (El-Anwar et al. 2009).

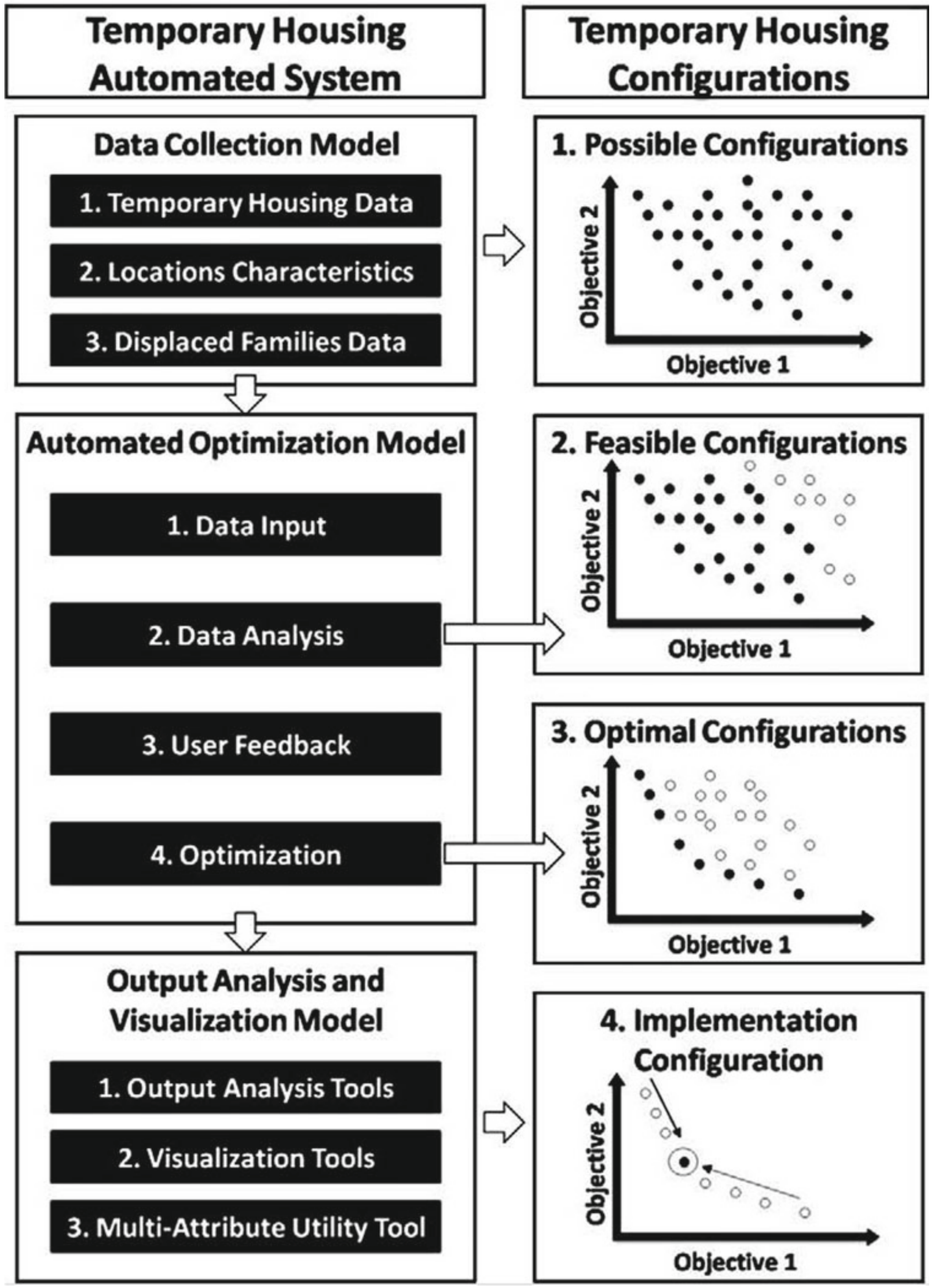

Fig. 1 Temporary housing model (El-Anwar et al. 2009)

2.1 Safety Management of the Temporary Community

Following natural disasters, construction of large-scale temporary housing projects are needed in order to assist with the disaster relief effort (Hui 2012). Hui (2012) described four distinct phases of post-disaster reconstruction: emergency shelter, temporary shelter, temporary housing, and permanent housing. Quite often, the terms “housing” and “shelter” are used interchangeably with little distinction, but these two terms are quite distinct and separate from each other (Hui 2012). In the United States, temporary building most often means prefabricated buildings and give refuge to displaced individuals and family after natural disasters (Hui 2012). Several factors affect the safety of the temporary communities, but given the nature of temporary housing communities, site safety and fire risk are most prevalent (Hui 2012). To increase site safety and reduce fire risk, the following recommendations were given (Hui 2012).

- Prepare for the post-disaster temporary housing ahead of schedule (Hui 2012).
- Pre-disaster preparedness is the most important prerequisite for being able to rapidly choose safe and suitable locations for temporary housing as well as determine the optimal temporary housing unit needed (Hui 2012).
- Diversity among post-disaster temporary housing by increasing the different types of temporary housing used (Hui 2012).
- In addition to timber-framed housing units and reinforced concrete structures, certain kind of hotels should be considered in the scope of temporary housing options (Hui 2012).
- Utilize enhanced management tools to ensure a stable transition after the disaster (Hui 2012).

2.2 The Psychological Effects of Temporary Housing

Prior to the 1997 earthquake in Marche, Italy, research had not focused on the impact of how temporary housing affected secondary stress factors (Caia et al. 2010). The psychological effect of disasters, earthquakes have been extensively studied by environmental psychologists, clinical psychologists, psychiatrists, and epidemiologists (Caia et al. 2010). Following a natural disaster, losing one's home contributes to the most important and primary stress factors with relocating to temporary housing becoming a highly relevant and secondary source of stress. People, whose homes were destroyed, suffered greater stress and psychological destabilization than those who home simply needed repair. Except for cases where the destruction is so considerable that relocation is unavoidable, it is considered by researchers, that keeping survivors in their original environments, is most preferable (Caia et al. 2010).

Two types of units were set up as temporary housing for the displaced families, i.e., mobile homes and wooden dachas (Caia et al. 2010). The mobile home is, made of metal roof containers, considered the typical prefabricated housing unit made available to victims of the natural disaster in Italy. The second type of temporary housing, the wooden dachas, is rarely used for earthquake victims, resembles a prefabricated weekend cottage. Two major distinctions separated the dachas from the containers, they were made of wood rather than metal, and their shape resembled regular houses in the sense they had pitched roofs and large windows typical of Italian single-family housing.

Types of temporary units also have psychological impacts on people. For example, those who lived in the dachas were found to be more attached and satisfied than the ones living in the temporary housing units (Caia et al. 2010). Comparatively, these individuals felt similar levels of psychological stress as measured against individuals who had returned to and lived in their original homes immediately following the disaster. These individuals also felt more dominated by the situation and exhibited more psychological stress symptoms. The attitudes toward their temporary home and the psychological wellbeing of the people who were housed in the containers were worse off than those living in the dachas (Caia et al. 2010). Natural disasters like this often cause psychological disorders such as post-traumatic stress and depression (Matsubayashi et al. 2013). For example, in 2011, survivors from tsunami strike in Japan often, suffer from physical, mental, and economic distress resulting in the increase of suicide rates in the post-disaster areas (Matsubayashi et al. 2013).

2.3 Post-Disaster Housing Reconstruction

Post-disaster reconstruction is one of the most evident ways for agencies, organizations, and governments to show that resources are being spent and aid is being delivered (Johnson 2007). In many cases, it is common to find temporary houses have been built faster or even ahead of other related infrastructure (Ingram et al. 2006). Unfortunately, underestimates in the reconstruction complexity, in post-disaster reconstruction is a technical problem of delivering quickly and cheaply the greatest number of houses. Often centralized project planning and management, which may be successful, suffers from lack of local participation in the rebuilding process.

The post-construction is not short of dilemmas. In 2004, Sri Lanka was struck by a tsunami. Days later, the government announced a "no reconstruction" buffer zone along the coastline and repair or reconstruction of homes within this zone was prohibited (Ingram 2006). Approximately 10 months later, the government revised the buffer zone policy citing land scarcity issues as the primary reason for reconsideration (Tafti and Tomlinson 2013). Although the idea of installing a buffer zone to protect against over-development, removing population from hazard-prone areas, and an effective way to preserve coastal ecosystems (Tafti and Tomlinson 2013). Forced relocation of families has resulted in unfavorable social conditions with economic, and cultural classes disrupt community networks, which are crucial for fostering adaptation and learning from a disaster. However, protection of the coastal environment is critical since coastal natural resources are fundamental components to livelihoods and security as physical protection from tsunamis, storms, and erosion (Tafti and Tomlinson 2013).

Although the right to adequate housing has been acknowledged as a basic human right by a wide range of international legal instruments and declarations, disaster responses have not adequately addressed the housing needs of the poor including low-income renters (Tafti and Tomlinson 2013). It is necessary to ensure low-income tenants have practical housing recovery option following a disaster. The issues get worse due to the attraction of new migrants to cities, putting more pressure on the rental housing market and further affecting rent prices (Denhart 2009). Thus far, direct assistance to tenants in the form of rent vouchers or allowances has been mainly used in high-income countries during recovery efforts following a natural disaster. This strategy has the potential to create an incentive for the development of the private sector rental market and can give households the independence to choose their recovery pathways (Denhart 2009).

2.4 Re-design, Re-use and Recycle of Temporary Houses

Applying the concept of re-use to temporary housing following a disaster appears beneficial to the overall recovery effort by presenting opportunities for accelerated reconstruction for the affected regions (Arslan 2007). Designing for the reuse and recycling of buildings and its materials acknowledges the lifecycle of buildings from material extracted from natural resources through materials recovered by recycling or reuse. The life cycle approach to design requires that ecological, social, and economic impacts be understood across the lifetime of the product, process, material, technology or service (Arslan 2007). Therefore, the impacts of these conflicting variables must be considered throughout the lifespan of the building from the site selection process, to design, construction, operation, and the eventual demolition (Arslan 2007).

Following the 1999 earthquake disaster in Duzce Turkey, the post-disaster region suffered from a range of issues such as economic, environmental, and social problems in addition to mass homelessness (Arslan 2007).

2.5 Deconstruction in Disaster Areas: Psychological, Environmental, Economic, and Social Impact

Currently, the most common way to deal with the destruction of urban environments following a natural disaster is to utilize large equipment for demolition, removal and deposit of debris in landfills. An alternative to this method is to employ “deconstruction” which utilized hand dismantling of buildings to extract the maximum salvage material to be reused for reconstruction (Denhart 2009). In 2005, the Gulf Coast was hit by three major tropical storms; Hurricane Dennis, Hurricane Katrina, and Hurricane Rita (Gaye 2005). These storms turned the Gulf Coast into a veritable wasteland with nearly $100 billion in damaged structures, including severe or total destruction of nearly 275,000 homes (Denhart 2009). The Federal Government responded to this disaster by demolishing homes and buildings where damage exceeded 51% of fair market value (Denhart 2009). On occasion, this demolition occurred without prior notice to the owner and sometimes inadvertently included demolition of houses that were undergoing renovation (Denhart 2009). This caused great stress and anxiety for many homeowners, especially to impoverished families whose broken home was the vast majority of their wealth, in wondering if their home would be next (Denhart 2009).

Mercy Corps, an International non-profit, humanitarian relief and development agency implemented a deconstruction program in New Orleans following the hurricanes of 2005 (Denhart 2009). This program offered building owners an alternative to demolition, allowing low-income property owners the ability to retake control of their property and salvage value form their homes (Denhart 2009). Mercy Corps’ main goal with the deconstruction program in New Orleans was to provide inexpensive building materials for low-income residents who wanted to return and rebuild their homes (Denhart 2009). Mercy Corps’ response to the disaster that devastated the Gulf Coast marked the first time the agency provided large-scale sustained disaster relief in the United States (Denhart 2009). Over 70% of the homes in New Orleans were either completely destroyed or severely damaged (Denhart 2009). The Louisiana Department of Environmental Quality estimated that 30 million cubic yards were scattered across New Orleans. Those who returned to the city were faced with high unemployment rates and a scarcity of construction materials for rebuilding (Denhart 2009). This was further complicated by inflated prices for materials that were available.

3 Methodology

This research focuses on qualitative data. Initial, the focus of research as aimed at collecting scholarly reports focusing on keywords such as temporary housing, disaster-hit areas, sustainability of temporary housing, re-use and recycle of temporary housing, and effects of temporary housing. Zotero, a Mozilla Firefox web bourse add-on tool was used to capture downloadable pdf files and capture the metadata for the file. During the initial collection phase, abstracts of articles were briefly read to determine whether the article could contain relevant data. Articles that seemed remotely related were captured using Zotero. After the initial collection phase, articles collected were read thoroughly to ensure relevance to the topic of this paper. Sources were organized based on similar contents with sources which did not contain relevant dataset aside (see Table 1). Following the initial data review, keywords (Katrina, post-disaster deconstruction, deconstruction vs. demolition) were added to the search to find new relevant material. During the secondary data collection phase, sources were carefully reviewed to ensure the content was relevant. Irrelevant data was not captured via Zotero. An extensive literature review was completed to provide background and relevance for discussion.

4 Discussion

It is clear that following a natural disaster the relief response needs to be quick and direct (El-Anwar et al. 2009). Emergency management agencies are often under intense pressure to respond quickly, and limit the burden of expense on the public (El-Anwar et al. 2009). This often drives the top-down view of the technically oriented solution (Ingram et al. 2006). Each disaster is uniquely different based on the type of disaster, area of effect and cultures present within the affected area, and in terms of local resource availability. In order to prepare and answer each disaster with a unique and individual solution pre-disaster planning for disaster preparedness and recovery efforts is paramount (El-Anwar et al. 2009). Preparing for disaster allows emergency agencies to fully understand the cultural, social, economic differences, and local resource availability within the country and give the best chance for crafting a timely, unique, and direct solution to respond to disasters.

Attitudes toward ones temporary home may play a role in psychological wellbeing following relocation from a natural disaster area (Caia et al. 2010). Testing confirmed the idea that attitudes toward one's temporary home are largely responsible for psychological wellbeing and for psychological stress symptoms such as anxiety, sadness, and guilt (Caia et al. 2010). Several studies support evidence that the risk factor for suicide increase after natural disasters in the same way that mental distress and economic hardships increase suicide risk factors (Matsubayashi et al. 2013). Earlier studies have found earthquake victims are 46% more likely to commit suicide than non-victims (Matsubayashi et al. 2013).

There are several options for re-using and recycling a temporary house after occupancy. Temporary houses and the housing site can be re-used in their existing place as future temporary houses for a future disaster (Arslan 2007). Following the recovery effort in Duzce, Turkey, temporary housing sites were re-used as construction offices and workmen dormitories. Finally, temporary housing units can be deconstructed with minimum material loss and energy (Arslan 2007). The deconstructed houses can then be sent to other disaster-affected areas for re-assembly and re-use, or they could be sent to other location for re-assembly and re-used with a different function (Arslan 2007).

Currently, there is a small but growing amount of literature contributing to on the environmental, economic, engineering, and technical aspect of deconstruction (Denhart 2009). The concepts and utilization of deconstruction are slowly beginning to make way through professional felids such as engineer, architecture, planning, and has gained slight attention from the non-scholarly research communities (Denhart 2009). There is much to learn and case studies have yet to determine the overall impact of deconstruction and how it plays into the temporary housing program of disaster relief efforts.

Studies have shown that deconstruction is competitive with machine demolition (Denhart 2009). This has been credited to the ability to re-use or re-sale building materials to recoup the large amount of labor expense associated with careful dismantling of a structure. Typical demolition requires one skill machine operator to demolish a building, but deconstruction offers entry-level jobs where workers can learn a valuable skill to for those interested in pursuing skilled work in construction specialities (Denhart 2009). There are issues with deconstruction relating to disaster areas that could impede its use (Denhart 2009). Often, the urgency for quickly removing damaged structures and difficulty in disposing of waste debris makes it difficult for deconstruction to compete with the efficiency of demolition (Denhart 2009). Instead of competing as an alternative to demolition, deconstruction should be focused on becoming an integrated part of building decommissioning, whether in disaster response efforts or in everyday business (Denhart 2009).

Recently Communication participation has been encouraged widely. Non-Government Organizations, policymakers, and scholars widely encourage community participation in reconstruction efforts, however, very little knowledge exists about how to apply the principles of community participation at the project level (Gaye 2005). Case studies for post-disaster reconstruction projects have shown, the ideal of community participation takes on a number of forms, and in the majority of cases does not really reach reconstruction in the field (Gaye 2005). This suggests there is a big gap between the theory of community participation and the practice (Gaye 2005). Studies have also shown when participation occurs at late stages there are frequent problems with either the project process or with the project outcomes (Gaye 2005). When engaged and participation is solicited and integrated into the upfront stages, studies show the community can have an important impact on the project with long-term advantages for the community and other stakeholders as well (Gaye 2005).

Table 1 Matrix of data collected and used in preparation for and in writing of this chapter

Research objective	Source type	Authors	Data collection stage		Applied data final	Data not used
			Initial	Secondary		
Objective 3: Re-use	Journal entry	Arslan (2007)	X		X	
Objective 3: Re-use	Journal entry	Arslan and Cosgun (2008)		X	X	
Did not apply	Journal entry	Bolin and Stanford (1991)	X			X
Objective 2: Psychological effects	Journal entry	Caia et al. (2010)	X		X	
Did not apply	University of California	Comerio (1998)	X			X
Objective 5: Role of community	Journal entry	Davidson et al. (2007)	X		X	
Objective 4: Deconstruction	Journal entry	Denhart (2009)		X	X	
Objective 4: Deconstruction	Journal entry	Denhart (2010)		X	X	
Objective 1: Issues and criticism	Journal entry	El-Anwar et al. (2009)		X	X	
Objective 2: Psychological effects	Government report	Farris (n.d.)	X		X	
Objective 1: Issues and criticism	Journal entry	Félix et al. (2013)	X			
Did not apply	Journal entry	Abulnour (n.d.)	X			X
Objective 2: Psychological effects	Journal entry	Hui (2012)	X		X	
Objective 1: Issues and criticism	Journal entry	Ingram et al. (2006)	X		X	
Objective 2: Psychological effects	Journal entry	Johnson (2007)			X	
Objective 1: Issues and criticism	Journal entry	Johnson and Lizarralde (2012)			X	
Did not apply	Journal entry	Levine et al. (2007)	X			X
Objective 2: Psychological effects	Journal entry	Matsubayashi et al. (2013)	X		X	
Did not apply	Journal entry	Nigg et al. (2006)	X			X
Did not apply	Journal entry	Olshansky (2006)	X			X
Did not apply	Journal entry	Shaw and Goda (2004)	X			X
Objective 1; Issues and criticism	Journal entry	Taheri and Tomlinson (2013)	X		X	
Did not apply	Journal entry	Yarnal (2007)	X			X

5 Conclusion

Temporary housing programs following large-scale natural disasters have been criticized for being unsustainable, culturally inadequate, and needing a technical solution. Pre-disaster planning for disaster preparedness and recovery allows emergency agencies to fully understand the cultural, social, economic differences, and local resource availability within the country and give the best chance for crafting a timely, unique, and direct solution to respond to disasters. This further helps to improve the psychological wellbeing and disregard post-traumatic stress and depression and suicidal rates. Deconstruction emphasizes a hierarchy of material use, takes less energy, and leaves a much smaller carbon footprint to use reclaimed materials than it does for demolition and disposal in landfills, creation of new building materials, or even to recycle materials for an alternative. Deconstruction has a positive effect on the psychological wellbeing as well, by reducing feelings of sadness and vulnerability and fostering feelings of empowerment and excitement about rebuilding and moving forward. Finally, community participation is key to successful reconstruction efforts. However, there is a clear disconnect between the theory of optimal community involvement and the implementation of the practice (Davidson et al. 2007). Early involvement of the communication can help the participants to recover from unforeseen problems and positive impact on the project with long-term advantages for the community and other stakeholders as well.

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Characteristics of Bidding for Engineering Services in Public Construction Projects

Khaled Hesham Hyari and Omar Hiary

Abstract

Engineering services to construction projects are essential to the proper delivery of construction projects. Engineering services include both design services before construction and engineering supervision during the construction phase of the projects. Procurement of engineering services for public construction projects is performed through competitive bidding. Several scholars investigated the bidding characteristics of contractors, while few or no research has addressed the bidding characteristics for engineering services. This paper presents an analysis of the bidding results of 450 invitations to bid for engineering services. The analysis revealed considerable differences in bidding between design bids and construction monitoring bids. Also, considerable differences in bidding characteristics exist between construction sectors that include: buildings, transportation, water and sanitary projects, and infrastructure projects. The performed analysis and the results obtained are expected to contribute to a better understanding of bidding behavior of engineering consultants for engineering services and the suitability of the competitive procurement approach to this kind of projects. Construction planners can evaluate these characteristics and consider other procurement approaches for projects that involved wide disparity in the received bids in competitive bidding. Selecting the proper procurement approach is expected to contribute to enhanced delivery of construction projects.

Keywords

Competitive bidding • Engineering design • Construction monitoring • Engineering supervision • Engineering supervision

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1 Introduction

Engineering services during both the design of construction projects and during the construction phase of projects (i.e., construction monitoring services) are vital services that have a huge impact on the success of construction projects. Despite such importance, procurement of engineering services received little attention in the literature compared with the procurement of construction services. A review of literature reveals that a number of publications have addressed design services however few or no research effort has tackled engineering services during the construction phase of projects (i.e., construction monitoring services).

Several publications addressed design fee in construction projects (Hyari et al. 2015; Shrestha and Mani 2012; Carr and Beyor 2005; Ling 2004; Hoxley 2000; Bubshait et al. 1998). Hyari et al. (2015) presented a conceptual cost estimating model for engineering services in public construction projects. The model was developed as a neural network model based on data from public construction projects in Jordan and estimates the cost of engineering services as a percentage of the estimated construction cost. Shrestha and Mani (2012) investigated the impact of design cost on the implementation of design–bid–build projects and concluded that higher design costs are linked with better construction performance in both time and cost (i.e., construction duration and cost overruns). Feldmann et al. (2008) investigated the attributes that affect the costs of engineering services procured for construction and rehabilitation projects within higher education facilities. The study utilized multiple regression analysis to study the relationships. Carr and

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Beyor (2005) studied the design fee schedules utilized by public construction agencies as indicators in design fee negotiations and recommended that design fee schedules should be updated regularly to match the rate of increase in construction costs. Carr and Beyor (2005) considered that fair compensation for design services require adjustment of design fee schedules with time.

Ling (2004) investigated the determination of design fees in design–build projects. Ling indicated the existence of conflicting perspectives in determining theses fess. Designers want higher fees to improve profitability and reduce risks. On the other hand, contractors look for lower design fees to improve their competitiveness. Ling (2004) noticed that owners support higher fees for design services to improve quality because design costs represent a very small portion of the overall cost of the project. Hoxley (2000) discussed the suitability of using competitive tendering for engineering services. The study was based on correlating the owner's perception of the quality of services received and the professional fees paid. The study concluded that competitive bidding for engineering and consultancy services does not affect the quality of the received professional services. Bubshait et al. (1998) investigated the impact of design fee on design quality and concluded that a decrease in design fee is generally associated with an increase in design deficiency.

Several publications addressed the bidding characteristics in public construction projects (Bedford 2009; Hong and Shum 2002; Drew et al. 2001; Skitmore et al. 2001; Sparks 1999). On the other hand, the review of literature indicates the lack of studies that focus on the bidding characteristics of engineering consultants while competing for engineering design and construction monitoring contracts. This paper presents an analysis of the bidding characteristics for engineering services in public construction projects. The following sections will present the bidding characteristics analyzed followed by the results of analyzing the bidding results of 450 projects that includes 4018 bids received from engineering consultants.

2 Bidding Characteristics

The analyzed bidding characteristics in this paper are (1) number of bidders; (2) bid spread; and (3) bidding variability (coefficient of variation). The following paragraphs provide a brief description of those characteristics.

1. Number of bidders: The construction industry is characterized as highly competitive industry because generally a number of contractors compete to win the contract, knowing that only one bidder will win the competition while the remaining bidders will lose the competition. The same applies to engineering services, and therefore, the number of bidders represents an indication of the level of competition in the project. A higher number of bidders puts an additional pressure on the bidders to reduce the submitted bid to increase the chance of winning the contract because each bidder wants to be the lowest bidder (Hyari 2016; Carr 2005). Different types of projects experience varying levels of competition as traditional projects normally experience higher competition than specialized projects and this should be reflected in the number of bidders in both cases.
2. Bid spread: Bid spread in construction bidding refers to the difference between the lowest bidder and the second lowest bidder is an important measure in competitive bidding. This difference is commonly named "Money left on the table" as it represents a foregone profit to the lowest bidder. Skimore et al. (2001) analyzed bid spread in competitive bidding and tried to correlate it with several variables that might have an impact on the spread including contract size value and number of bidders. Skitmore et al. (2001) concluded that analysis provides overwhelming evidence that supports the dominance of inherent variability in bidding. Runeson (1987) reported that as the number of bidders increases, the difference between the lowest bidder and the second lowest bidder decrease as a percentage of the estimated cost of the project.
3. Bidding Variability (coefficient of variation): Coefficient of variation measures the variability of bidding results. Engineering consultants are equally informed since they all get the same bidding documents, and they all supposed to do accurate cost estimating before submitting their bids since they have experience in this field. Therefore, this measure can represent either the bidders' willingness to reduce bid price to win the project or the accuracy of cost estimating and the consultants' evaluation of the work required and the risks associated with the needed work (Hyari 2016). This measure can be defined as the ratio of the standard deviation to the mean of received bids (Jayasena 2005). Higher values mean higher variability in submitted results

3 Results

The performed analysis is divided to four subsections that include: (1) descriptive analysis of the data utilized; (2) bid spread; (3) coefficient of variation; and (4) number of bidders.

(a) Descriptive analysis: The data includes the bid results of 450 tender announced by the Government Tenders Directorate in Jordan. The data includes 283 tenders for

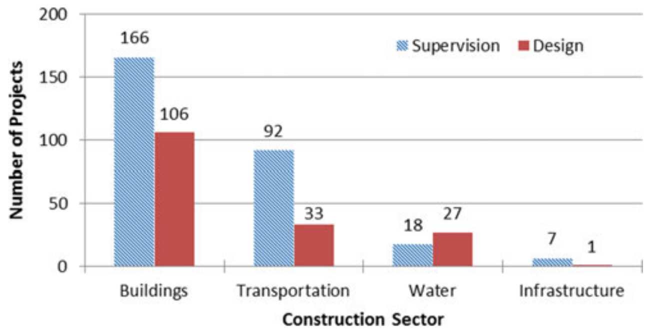

Fig. 1 Number of projects in each construction sector

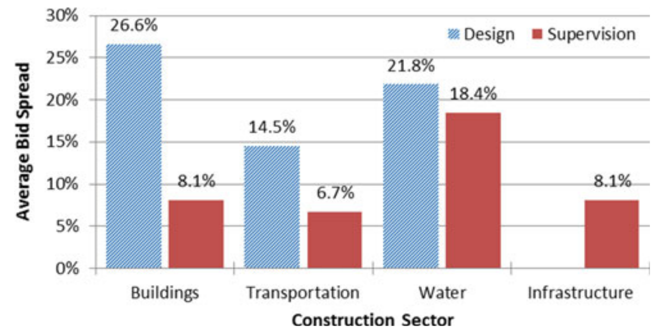

Fig. 2 Average bid spread for engineering services

providing engineering supervision during the construction phase of the projects and includes 167 tenders for design services. Figure 1 illustrates the number of projects according to the construction sector. The highest number of projects were in the building sector and includes 166 tenders for engineering supervision and 106 tenders for the design of buildings.

(b) Bid spread: The difference between the lowest bid received and the second lowest bid is important as it indicates the level of competition to win the bid and the quality of scope definition in the bidding documents prepared by the owner. Analysis of the bid results revealed a big difference in average bid spread between design bids and construction monitoring bids. Average bid spread was 23.7% for design bids, while average bid spread for engineering supervision bids was 8.3%. Figure 1 illustrates the average bid spread for engineering services according to the construction sector of the project. The results illustrate a big difference between design and engineering supervision bids for projects in the building sector. The highest average bid spread was for design bids for buildings (26.6%), while engineering supervision bids for buildings have an average bid spread of 8.1%. The results suggest that competitive bidding is not the best approach to procure design services for buildings. The results also indicate that design bids, in general, show higher bid spread compared to engineering supervision bids which indicate that scope of work for engineering supervision is well defined and cost can be accurately estimated in the bidding phase of the project.

(c) Coefficient of variation: Consultants' firms competing for engineering services' contracts are all experienced firms with proper qualifications that qualify them to bid for public construction projects. All firms bidding for a certain project are equally informed since they get the same bidding documents, however, received bids include varying bid amounts submitted by bidders. Such variability in bids is important as it reflects the accuracy of cost estimating and different perceptions of bidders in the evaluation of the risks envisioned in the project. Analysis of the data revealed also a wide difference in the average coefficient of variation between design bids and engineering supervision bids. The average coefficient of variation was 33.3% for design bids, while the average coefficient of variation for supervision bids was 16.3%. Figure 2 illustrates the average coefficient of variation for engineering services according to the construction sector of the project. Design bids in the building sector showed the highest bid variability with an average coefficient of variation of 38.3%, while construction monitoring bids for transportation projects showed the lowest bid variability with an average coefficient of variation of 13.2%. The widest difference between design bids and supervision bids exists in the building sector (38.3% vs. 17.9%). This again suggests that competitive bidding for design services in the buildings sector might not be the best approach. Direct negotiations or best value procurement must be investigated as an alternative approached for buildings design services (Fig. 3).

(d) Number of bidders: The construction industry is a highly competitive industry and a number of contractors compete to win one contract. The same applies to engineering services. The data was analyzed to study the number of bidders competing for projects in each construction sector. As illustrated in Fig. 4, the highest average number of bidders exists in the building sector in both design and engineering supervision with average number of bidders of 11.4 for building supervision projects, and an average of 9.7 for building design projects. This result reflects the high competition in the building sector. The design of transportation projects had the lowest average number of bidders (4.6) which reflects a decreased level of competition in this kind of projects that require higher engineering specialities, but at the same time, the fewer number of projects which limits providing design services in this category to big engineering firms.

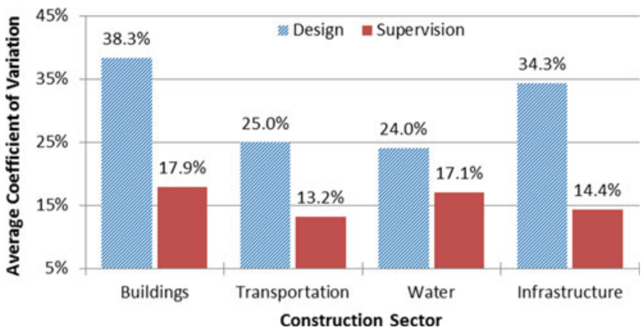

Fig. 3 Average coefficient of variation for engineering services

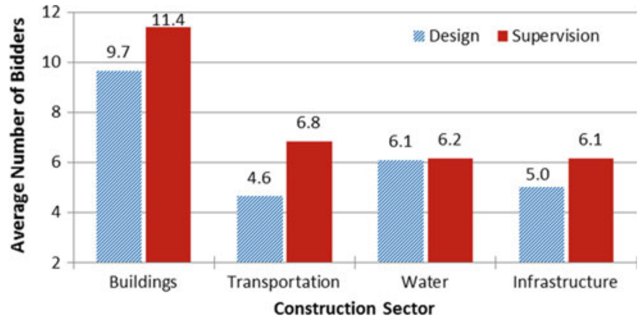

Fig. 4 Average number of bidders for engineering services

4 Conclusions

This paper presented an analysis of the bidding characteristics in engineering services bids for design and/or construction monitoring of public construction projects. The data used included 4018 bids submitted by engineering consultants on 450 bidding invitations. The analyzed data revealed considerable differences in the bidding characteristics between design bids and engineering supervision bids. Submitted bids for the design of buildings had the highest bid variability and the highest bid spread among design bids for other construction sectors. Also, design bids had the highest average number of bidders compared to other sectors. Submitted bids for engineering supervision of buildings during construction also had the highest bid variability, highest bid spread, and highest average number of bidders. The results suggest that competitive bidding might not be the best approach for the procurement of design services for building. The results presented should prove to be useful to owners and construction planners in planning procurement of engineering services for construction projects.

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Estimating the Productivity of the Bosnian–Herzegovinian Water Operators

Ivana Domljan and Vjekoslav Domljan

Abstract

This paper deals with the issue of productivity of municipal water operators in Bosnia Herzegovina (BIH). It demonstrates that Stochastic Frontier Analysis (SFA) could be a useful tool in assessing productivity and the relative efficiencies of water operators. The principal aim of this paper is to show that it is worth assessing the productivity improvements that could result from better use of inputs, primarily labor. In spite of severe scarcity of data for the BIH water sector, collected data allowed us to develop an SFA model with a set of inputs (number of connections, number of workers, electrical energy costs, and chemical costs) and outputs (water delivered) as required in the water sector empirical literature. The research could serve as a benchmark against which future quantitative analysis of water operators' productivity can be measured. It could additionally provide policymakers with comparable quantitative evidence on the functioning of water operators with the aim of regulating them more effectively and improving the performances of one of the most poorly functioning water sectors in Europe.

Keywords

Water operators • Productivity • Stochastic Frontier Analysis (SFA)

1 Introduction

In BIH, responsibility for water service provision is decentralized and rests within municipalities. There are about 130 municipal water companies in BIH serving the needs of a population of 3.0 million.

There is only one type of ownership and operating in BIH, i.e., there are only municipally owned water operators. As in the Communist time and as a legacy from that time, they operate as formally autonomous organizations, separated organizationally, administratively, and financially from the municipal authorities. However, since the transfer of responsibilities to operator level is not clear-cut, operators are capable of functioning as productive and efficient providers of services.

By being forced to follow social criteria (and consequently on practicing overemployment and facing depressed tariffs), they amass costs and delay the desperately needed investments on mains and other parts of infrastructure.

Due to the lack of financial resources for maintenance and investments and inefficient water management in most of the operators, percentages of water coverage and non-revenue water are unsatisfactory. More than 24 years after the Dayton Peace Agreement, access to water services has been unacceptably low or unreliable.

Non-revenue water levels in the Balkan countries are the highest in Europe indicating worn-out water pipe networks, weak rule of law, and poor water supply management (see Fig. 1).

Bearing in mind the current ranking of BIH, it would be useful to properly access the productivity of water operators to find out what is behind them in order to improve the relative position of the country by introducing proper policy and regulatory measures.

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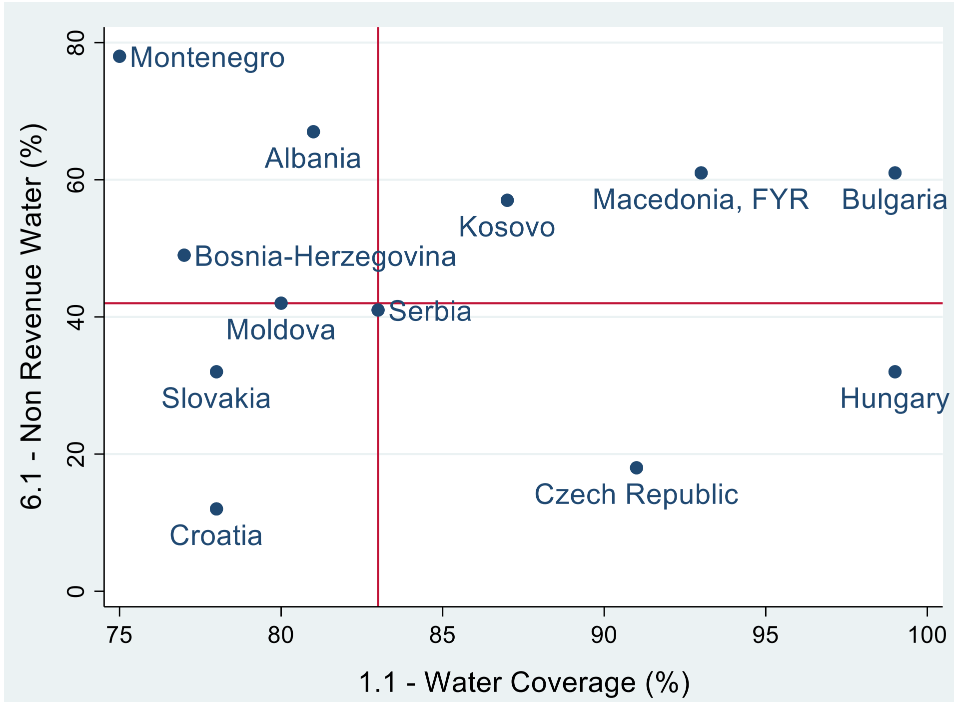
Fig. 1 Non-revenue water and water coverage; BIH and comparators, 2017



2 Materials and Methods

This paper focuses on the examination of how the productivity of operators has changed over time and decomposing it into its constituent parts. Such analysis can assist in examining the impact of regulation on the functioning of operators. Actually, it can contribute to the idea of how to simulate market functioning within a non-market sector by comparing performances of operators and finding out how productive and efficient they are over time.

We examine whether the change in productivity for a particular operator has been driven by improving its relative efficiency, by scale improvement, or by general technological improvement.

We consider a single-output production function, which, with panel data and output-oriented technical inefficiency, is written as:

$$\mathrm{y_{it}} = \mathrm{f}(\mathrm{x_{it}}, \mathrm{t})\exp(-\mathrm{u_{it}}) \tag{1}$$

where y_{it} is the output of the ith operator (i = 1, …, N) in period t (t = 1, …, T), f(.) is the production technology, x_{it} is a vector of J inputs, t is the time trend variable, and $u_{it} \geq 0$ is output-oriented technical inefficiency.

We simply focus on the rate of change of output and examine how much of it is driven by (i) rate of changes in inputs, (ii) changes in technology, and (iii) changes in efficiency.

If we start from (1) and differentiate it totally with respect to *t*, we get

$$\dot{y} = \sum_j \varepsilon_j \dot{x}_j + \mathrm{TC} + \mathrm{TEC} \tag{2}$$

where $\dot{y}$ is the rate of change of output, $\sum_j \varepsilon_j \dot{x}_j$ inputs growth, TC is the technical change $\left(\frac{\delta \ln(.)}{\delta t}\right)$, and TEC is the technical efficiency $\left(-\frac{\delta u}{\delta t}\right)$.

Equation (2) shows that output growth is driven by input growth that technical change (TC) will affect output positively if there is technical progress, and that technical efficiency (TEC) will affect output positively if technical efficiency improves over time (Colombi et al. 2014; Kumbhakar et al. 2014).

3 Results

The first step in our analysis is to estimate a Cobb–Douglas production function. From a statistical viewpoint, it yields a balanced panel of 21 operators but we estimated it as a pooled cross section (Domljan and Domljan 2011).

By dropping one by one the statistically insignificant variables while ensuring that the model passed a number of other diagnostic tests for the dataset, we got:

$$\mathrm{lwd} = 5.08 + 0.85\,\mathrm{lc} + 0.45\,\mathrm{lm} + 0.09\,\mathrm{le} - 0.06\,\mathrm{lch} - 0.03\,\mathrm{t} \quad (3)$$

The logarithmic specification is consistent with a standard multiplicative production function and enables the direct estimation of elasticities. The model appears to be a "good fit" with R^2 = 0.934. All the variables are statistically significant at 5% and they have their expected signs except for electricity costs. The sum of the coefficients on independent variables reflects, at a value of 1.3, the presence of scale economies (see Table 1).

The dependent variable in the regression model is the volume of water delivered (measured annually in m^3) (w d), and the independent variables are the number of connections (c), the yearly average number of employees (in the hours of work) (m), yearly electrical energy costs in BAM (e), and the yearly chemical costs (in BAM) (ch). In addition, a time variable (t) is included in the model.

In the second step, we estimated the productivity (see Table 2). This is achieved by running a stochastic frontier model (Kumbhakar et al. 2015).

In the third step, we estimated productivity change and related it to efficiency (see Table 3). In order to derive components of changes in productivity, we allow operators to be technically inefficient (Kumbhakar et al. 2015).

This demonstrates that output growth, of around 1%, has been driven by an increase in inputs of 3.3%, what is offset by a reduction in technical progress of 3.6% and technical efficiency of 0.8%.

Table 1 Regression

Variables	Model
lc	0.845*** (0.0658)
lm	0.451*** (0.0878)
le	−0.0644** (0.0315)
lch	0.0873*** (0.0135)
t	−0.0268** (0.0118)
Constant	5.075*** (0.404)
Observations	210
R-squared	0.934

Standard errors in parentheses
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table 2 SFA: productivity

Variables	Model
lc	0.844*** (0.0652)
lm	0.451*** (0.0866)
le	−0.0645** (0.0311)
lch	0.0874*** (0.0134)
t	−0.0352 (0.0339)
Constant	5.190*** (0.538)
Observations	210

Standard errors in parentheses
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table 3 SFA: productivity change

Variables	Results
dot_wd	0.009752
TC	−0.03525
input_driven	0.032642
TEC	−0.00806
expl_output	−0.01067
unexpl_output	0.020422
dot_wd	0.009752

4 Discussion

The IBNET's Apgar score of 4.8 for the BIH operators is "fairly low." It places them among the worst within the group of comparators countries (small Central and South East European countries).

The score is just below the median score of comparators countries (5.80) but even below the global median score (5.73) (see the Fig. 2 at which years in brackets state the latest data available for the respective country if data for 2017 is not available).

How much certain types of inputs contribute to such a "fairly low" position can be seen in the Table 4.

As Table 4 shows the labor costs of BIH operators amounts for 64% of total operational costs. Obviously, there is a mistake in the IBNET databases. To have a total of annual operational costs of 100%, the item *other costs* should be reduced to 26% of total costs, or alternatively, the item *labor costs* should be reduced to 36%.

BIH's total annual labor costs, expressed as a percentage of total annual operational costs, of 64% are pretty high in

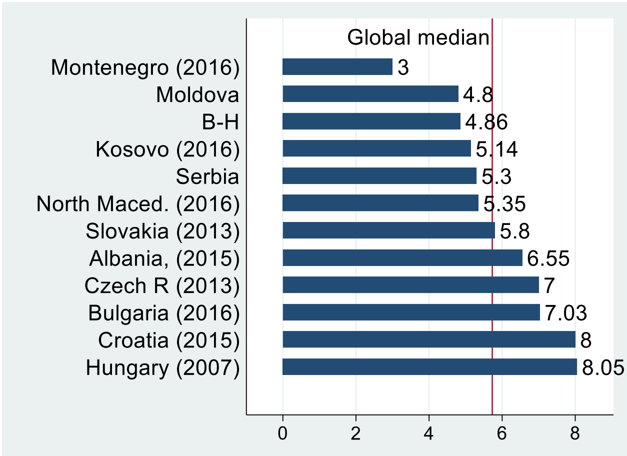


Fig. 2 Apgar score; BIH and comparators, 2017

comparison to both the comparators countries and the world since their respective median values are 40.5 and 36%. For instance, that size of the BIH operators' labor costs is in line with the labor costs of Camerun (77%), the Dominican Republic (71%), Jordan (65%), Papua New Guinea (64%), Argentina (64%), Kosovo (62%), and Ecuador (61%) (IBNET 2019).

Figure 3, showing staff productivity of operators, measured as the total number of staff members per 1000 connections (vertical axis) and per 1000 people served (horizontal axis), clearly demonstrates that by both indicators, BIH operators are overstaffed—global median of staff per 1000 connections is 5.12 and per 1000 persons served is 0.74, while BIH's respective medians are 7.24 and 1.97.

According to our dataset—which is not quite comparable with the IBNET dataset, since it relates to the period 2000–2009, and embraces 15% of total number of operators—ratios of respective costs, i.e., labor, electrical energy, chemicals, and other costs are 37.5, 10.2, 0.2, and 48.0%, respectively.

In addition, it was not possible to use the length of mains or network length, usually used in the production function as an indicator of capital, since data is missing or is not reliable in the case of many operators. Further, the number of operators was reduced to allow the dataset to establish balance panel data.

Regardless of these and other limitations, we did not expect that technical change would have a negative impact on productivity change. In our view, it could stem from the worsening methods in using inputs (disembodied technical change) or alternatively and less likely through the use of quality with worsening quality (embodied technical change) in the respective period. If the former case, it could be due to the replacing of people leaving the sector due to retirement, shifting to other domestic sectors or emigrating abroad with less skillful workers. In addition, there are broadly spread negative comments coming from associations of employers about the worsening quality of employees.

Globally, the water sector is generally characterized by slowly changing technology. In BIH, the R&D expenditure is at a very low level (around 0.15% of GDP) and top

Table 4 Inputs of water production; BIH and comparators countries, 2017

Countries	13.1 Labor costs	3.2 Electrical energy costs	100.13 Chemical costs	100.14 Other costs
BIH	64	9	1 (2016)	54 (2016)
Albania	41 (2015)	38 (2015)		
Bulgaria	37 (2015)	16 (2015)		
Croatia	39 (2015)	9 (2015)		
Czech R	13 (2013)	7 (2013)		
Hungary	42 (2007)	17 (2007)		
Kosovo	62 (2016)	21 (2016)		3 (2016)
North Macedonia	51 (2016)	8 (2016)		0 (2016)
Moldova	45 (2017)	26 (2017)		
Montenegro	39 (2016)	39 (2016)		
Serbia	48 (2017)	12 (2017)		
Slovakia	32 (2013)	8		
Median-comparators	40.5	16	–	1.5
Median-all countries	36	16	2	5

NB: Years for which the latest data available are stated in brackets
Source Adapted from IBNET (2019)

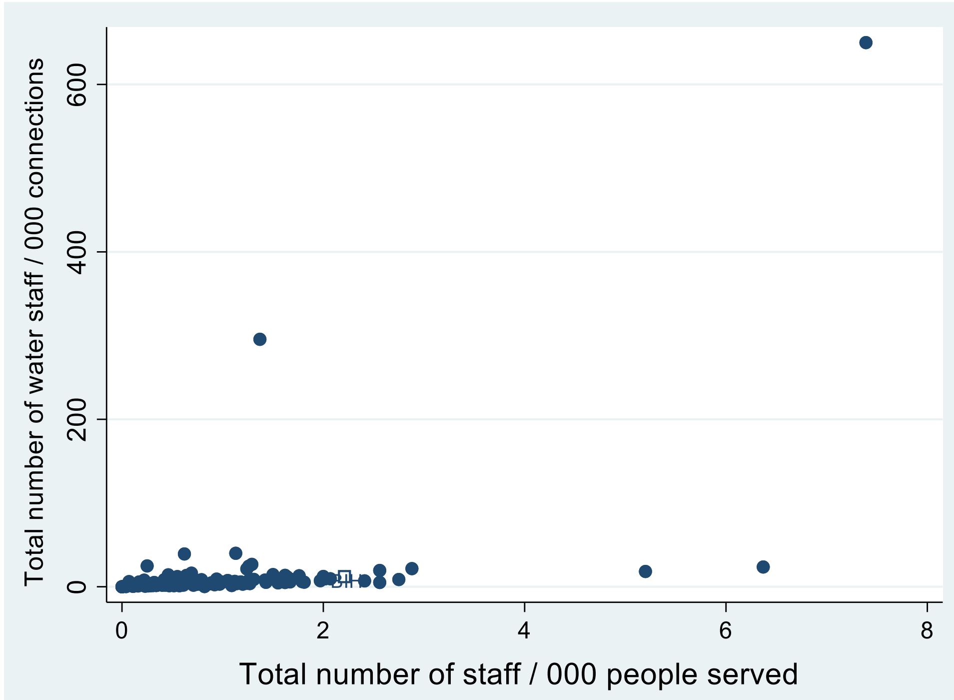


Fig. 3 Staff of water operators; BIH and world, 2017

managers are not appointed by professional but political criteria.

If prices of inputs were available, the estimation of the cost function and another stochastic frontier model would have been carried out, shedding more light on the issue of technical progress.

5 Conclusions

In this paper, we have examined how to estimate productivity and efficiency of Bosnian–Herzegovinian water operators.

In spite of their deficiencies, partial productivity indicators clearly state that BIH operators have weaker performances than their counterparts in comparators countries (small Central and South East European countries) not to mention other European countries.

The research demonstrated that BIH policymakers should focus on reforming the water system by introducing more economic criteria in their operating e.g. introducing benchmarking techniques with the purpose of stimulating the introduction of more innovative activities, particularly in the field of operational processes and organizational changes. Introducing private organizations, e.g., through public–private partnership could contribute to the improvement of the currently very weak sector. The IBNET's Apgar score demonstrates that clearly.

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Quality Assessment of Sandcrete Blocks Produced with River Sand in Ogun State, Nigeria

Babatunde Ogunbayo and Clinton Aigbavboa

Abstract

In the Nigerian construction industry, sandcrete block is an important building material, it is used in the construction of the building and other useful physical infrastructure. Many of the sandcrete blocks are produced at different locations and environment using different aggregate materials without resort to the minimum quality standard expected of the sandcrete block. It is on this bases that the study assessed the quality of sandcrete block produced with river sand in order to determine their compliance level to the standard expected of a sandcrete block in Nigeria. Eighteen sandcrete blocks of size 225 mm × 225 mm × 450 mm were gotten from three different production locations in Ifo, Ogun State Nigeria. Sieve analyses, bulk density, silt content, and the compressive test were carried out to determine the property quality of aggregate material (river sand) used for the production of the blocks and its strength. The result shows that the aggregate material used was of good quality suitable for the production of the sandcrete block. The result also shows that the average compressive strength of 1.16 N/mm^2 for sandcrete blocks from different production sites does not meet up with the minimum requirement for sandcrete block compressive strength as stipulated by NIS 2007 and ISO 848492-1994. The study revealed that the quality of the block produced is not affected by the quality of aggregate used but by poor quality control of aggregate and other materials used in the production of the blocks. It further revealed that the block quality is also affected by shoddy/improper curing of blocks produced. The study, therefore, concluded that regulatory and professional bodies should organize seminars for the local producers of sandcrete blocks on the best practice of producing quality blocks in meeting the required quality standard for construction work to avoid structural cracks and collapsing of building.

Keywords

Sandcrete block • Sieve analysis • Bulk density • Silt content • Compressive strength

1 Introduction

Quality is the characteristic and features expected of a product and its ability to meeting tacit needs (Williamson et al. 1996). Anosike (2011) Opined that quality is falling in line with specification on the totality of features required by a product. In Nigeria, persistent building collapses have led to the loss of properties and lives of its occupant which is due to the use of substandard building materials (Fakere et al. 2012; Oyekan and Kamiyo 2008). Ewa and Ukpata (2013) observed that the outward appearance of the most building is lost to cracks and other defects due to the poor sandcrete blocks quality used as walling units. The word sandcrete has not been assigned with any perfect definition, but it's as always been defined by most workers in a way that conforms to their own purpose (Abdullahi 2005). Sandcrete block is used for nearly 60% of building materials in Nigeria and other developing nations in Africa for building products. Oyetola and Abdullahi (2006) state that in order to minimize construction cost, the sandcrete blocks is widely used among West African populace, especially in Nigeria. Ajao et al. (2018a) observed that low amount of Ordinary Portland Cement (OPC) was used in the production of these blocks, which makes the quality of blocks inconsistency due to poor quality control of the materials used. Sandcrete blocks

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generally are moulded to different shape and sizes using composite material which includes cement, sand, and water (Barry 1999). Block as defined by BS6073-Part 2: (1981) is a heterogeneous building material with different unit sizes which its dimension should not exceed 650 mm and its length should be greater than its height. Conversely, Standard Organization of Nigeria (2007) define sandcrete blocks as the walling unit that exceeds the dimensions specified for brick when laid in its normal position. In Nigerian housing provision, over 90% of the building structure were constructed using sandcrete blocks and it is the most popular and commonest Mansory walling units (Baiden and Tuuli 2004). Among the constituent of producing a sandcrete block, cement is the most costly and important material to give suitable quality required by various producers. Commercial producers of these blocks reduce the quantity of cement needed in order to exploit profit and reduce cost (Okafor and Ewa 2012). The Standard Organization of Nigeria (2000) in assessing the quality of materials use in block production and to control the production process provides a reference document containing minimum requirements for different kinds of sandcrete block and their uses. The document state that the minimum compressive strength of sandcrete blocks should range between 2.5 N/mm^2 and 3.45 N/mm^2. Anosike and Oyebade (2011) and Baiden and Tuuli (2004) observed that inappropriate use of material for the production of these blocks has led to micro cracks on the building walls after construction. Ogunbayo et al. (2018a) state that component of the building needs a standard designed, that would be managed and controlled by government institutions and construction professionals. Anosike and Oyebade (2011) state that sandcrete block is usually a composition of (1:6) mix of cement and sand sprinkled with water and allowed to dry naturally. Users and producers of sandcrete blocks in most cases lack adequate quality information and engineering knowledge on the requirement of sandcrete blocks (Ewa and Ukpata 2013). Oyekan and Kamiyo (2008) observed that in many parts of Nigeria manufacturer have continued to produce sandcrete blocks without reference to building requirement or quality as specified by Standard Organisation of Nigeria (2000), This has made poor quality control of aggregate used in the production of sandcrete block production affect the strength of the blocks. The study of Abdullahi (2005) shown that the compressive strengths of commercial sandcrete blocks sampled in Minna, Nigeria were found to be between 0.11N/mm^2 and 0.75 N/mm^2 which does not meet the minimum strength as stipulated by NIS 87:2000. The result of the study of Ajao et al. (2018a; b) indicated that the compressive strength of sandcrete blocks manufacturers within three States; Lagos, Ondo and Oyo all in south western Nigeria ranged from 0.95 N/mm^2 to 1.33 N/mm^2, 0.79 N/mm^2 to 1.02 N/mm^2, and 0.77N/mm^2 to 1.14 N/mm^2. These values gotten from blocks suppliers within South Western Nigerian states were far behind the stipulated minimum standard for sandcrete blocks specified by Standard Organization of Nigeria (2000) of 2.5 N/mm^2 for individual block and 3.45 N/mm^2 for an average of five blocks. The finding of the study of Ewa and Ukpata (2013) revealed that the compressive strength of sandcrete blocks manufactured within the Calabar city after 28 day ranges from 0.23 to 0.58 N/mm^2, with an average compressive strength of 0.35 N/mm^2. These values fall below the minimum prescribed value for load-bearing sandcrete block specified by Standard Organization of Nigeria (2000) and IBC-I Council (2006). Moreover, block quality and its strength could be affected by a different factor such as poor quality control of aggregates, bad mix, improper curing among others. It is on these bases that this study investigates the property quality of river sand used in the production of sandcrete blocks in order to determine its effect on the strength parameter of the sandcrete block.

2 Methodology and Material

Three block-manufacturing sites were visited and six sandcrete blocks were selected randomly from each site. All the blocks selected were produced with vibrating moulding machine using a mix ratio of (1:10). The blocks were cured for 28 days and their compressive strengths determined in accordance with IBC-I (2006) strength testing of sandcrete block. The aggregate material (river sand) used in the production of the blocks were also collected and sieve analyses, bulk density, and silt content was carried out to determine the property quality of aggregate material in accordance with BS EN 933-1:1997. All the block manufacture make use of Dangote cement of (42.5R) which is produced in accordance with BS EN197-1: 2011 cement part 1. Water from the borehole was used in the production of the sampled sandcrete blocks in all the production sites. The safety procedure for the research was in line with the finding of Ogundipe et al. (2018).

3 Results

Based on the property analysis carried out on the fine aggregate used in the block production and the compressive strength test carried out on the block produced, the results are shown in Tables 1, 2, 3, and 4 and Figures 1, 2, 3, and 4.

Table 1 Sieve analysis of aggregate (river sand) used for sandcrete block in the production sites

S/N	Sieve sizes (mm)	% soil passing Production site	% soil passing Production site	% soil passing Production site
		M1	M2	M3
1	20	99.31	99.89	99.86
2	10	97.21	97.96	99.72
3	5.0	95.83	89.80	99.58
4	2.0	77.02	73.47	99.16
5	1.0	40.09	33.06	98.31
6	0.5	18.49	19.18	7.36
7	0.25	5.25	12.65	1.70
8	0.1	1.07	1.22	0
9	0.075	0	0	0
10	Pan	0	0	0

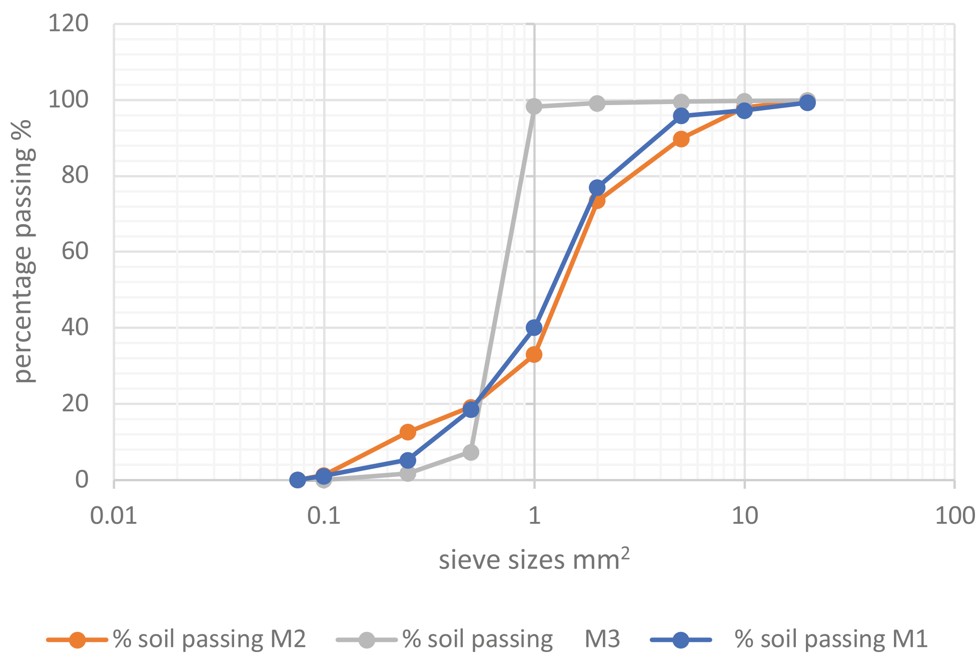

Fig. 1 Analysis of aggregate (river sand) used in block production sites

4 Discussion

The sieve analysis was carried out in accordance with BS EN 933-1: 1997. The particle size distribution is shown in Table 1 and Fig. 1. The result showed that the three Samples gotten from the production site of sandcrete blocks within the study area satisfied the particle size requirements of BS EN 933-1: 1997. The result is similar to Abdullahi (2005) and Ogunbayo et al. (2018b).

Similarly, bulk density analysis was carried out on sandcrete blocks sampled from the production sites. The result from Table 2 showed that production site M1 blocks as the lowest density value of 1985.2 kg/mm^3, followed by production site M2 with 1995 kg/mm^3, while the production site M3 has the highest density value of 2001.7. The result from the table 2 showed that bulk density values for individual sandcrete production sites meet required values 1920 kg/mm^3 for an individual block as stipulated by Standard Organisation of Nigeria (2000). The result from Fig. 2 also showed the average density value of 1994 kg/mm^3 for sandcrete block taken from all production sites. The results further showed that bulk density values for individual sandcrete production sites and the means for all sandcrete block production site meet required values of 2010 kg/mm^3 for means of two or more blocks as stipulated by NIS 87:2000. The result is similar to Ajao et al. (2018b).

Moreover, silt content analysis was carried out on aggregate (river sand) samples taken from sandcrete block production sites. The result from Table 3 showed that

Table 2 Analysis of bulk density for manufacturers block sampled

B Block production site	Dry weight (kg) Block size: 225mm × 225 mm × 450 mm	Bulk density kg/m^3 Block size: 225 mm × 225 mm × 450 mm	Mean Bulk Density kg/m^3
SITE M1			
BLK1	20.8	2047.6	
BLK2	19.8	1949.1	
BLK3	19.9	1958.9	1985.2
SITE M2			
BLK1	20.1	1978.9	
BLK 2	20.9	2057.4	1995.1
BLK3	19.8	1949.1	
SITE M3			
BLK1	20.3	1998.3	
BLK2	19.9	1958.9	2001.7
BLK3	20.6	2047.8	

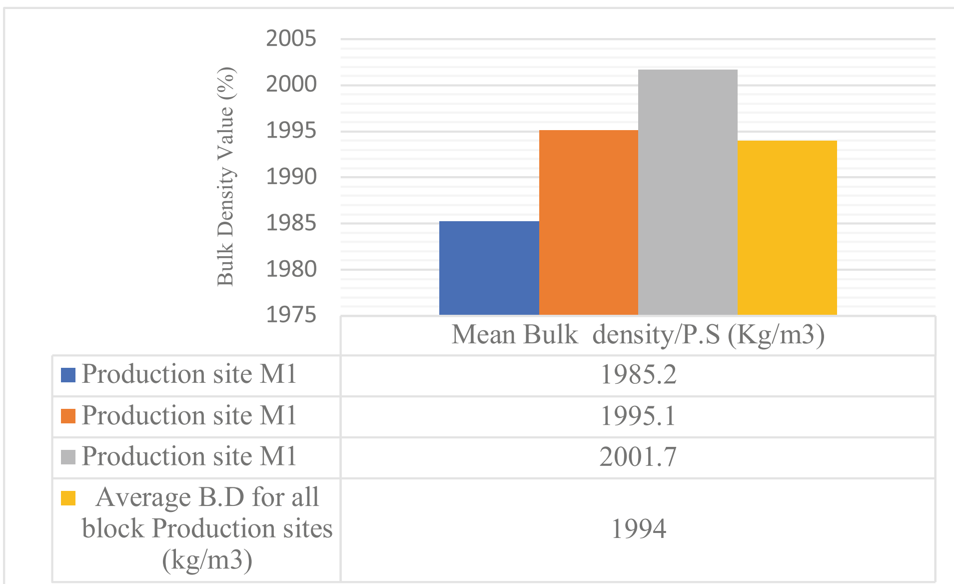

Fig. 2 Average bulk density for sandcrete blocks from all block production sites

aggregate from production site M2 as the lowest silt content of 2%, followed by production site M3 with 3% silt content, while the aggregate of production site M3 has the highest silt content of 3.7%. Also, the result from Fig. 3 showed average silt content of 3.13% for aggregates in all block production sites. The result showed that Fig. 3 showed that aggregate used by the production sites is suitable for sandcrete block production. The result is similar to Ojerinde et al. (2018) and Aginam et al. (2013).

Additionally, compressive strength test was carried out on sandcrete blocks taken from the three block production sites. The result from Table 4 showed that sandcrete block from production site M2 as the lowest compressive mean value of 0.99 N/mm^2, followed by production site M3 with 0.97 N/mm^{2,} while production site M1 has the highest compressive strength of 1.51 N/mm^2. The result from Fig. 4 also showed the average compressive strength value of 1.16 N/mm^2 for all block production sites sandcrete blocks sampled. And this value does not fall within the stipulated minimum strength for blocks by NIS 2007 and ISO 848492-1994. The result is similar to Ajao et al. (2018b), Anosike and Oyebade (2011), and Abdullahi (2005).

Table 3 Analysis of silt content for manufacturers block sampled

Sample	Production site M1			Production site M2			Production Site M3		
	A	B	C	A	B	C	A	B	C
River sand (ml)	100	100	100	100	100	100	100	100	100
Water (ml)	200	200	200	200	200	200	200	200	200
Vol. of R/S retained (ml)	96	93	94	97	94	96	96	97	95
Vol. of salt	1 teaspoon	1 teaspoon	1 teaspoon	1 teaspoon	1 teaspoon	1 teaspoon	1 teaspoon	1 teaspoon	1 tea spoon
Organic mat present (ml)	2	2	2	1	1	2	2	2	2
% silt content	2	5	4	2	4	2	2	1	3
Ave. silt (%)		3.7			2.7			3	

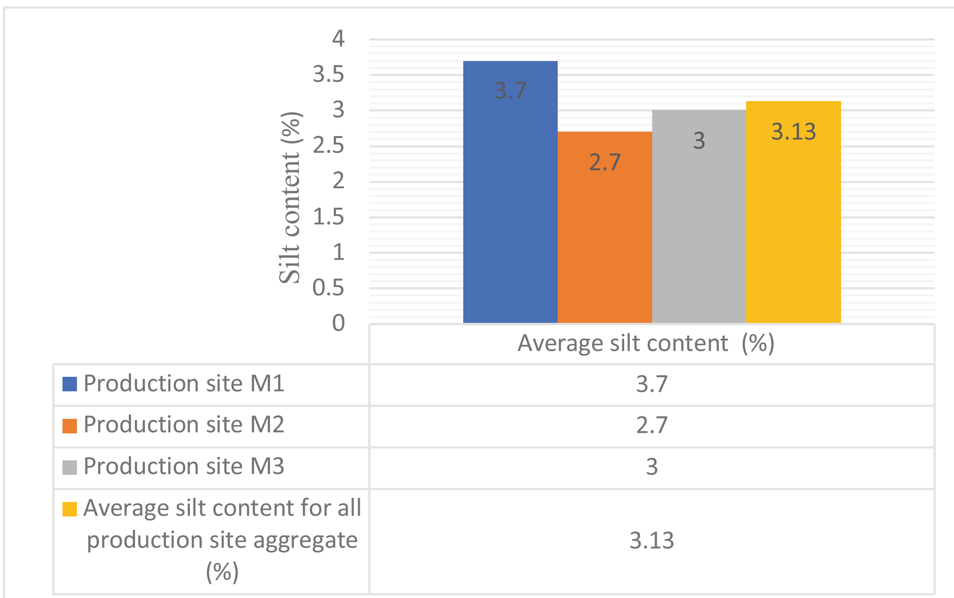

Fig. 3 Average silt content for river sand for all production sites

Table 4 Compressive strength of manufacturers blocks sampled

S/N	Site	Sandcrete block Size (mm)	Crushing strength (N/mm^2) of sampled blocks						C.S Mean (N/mm^2)
1	M1	225 × 225 × 450	1.33	1.44	0.89	1.0	1.22	1.03	1.51
2	M2	225 × 225 × 450	1.10	0.84	0.99	1.10	0.93	0.97	0.99
3	M3	225 × 225 × 450	0.99	1.10	0.88	1.11	0.77	1.02	0.97

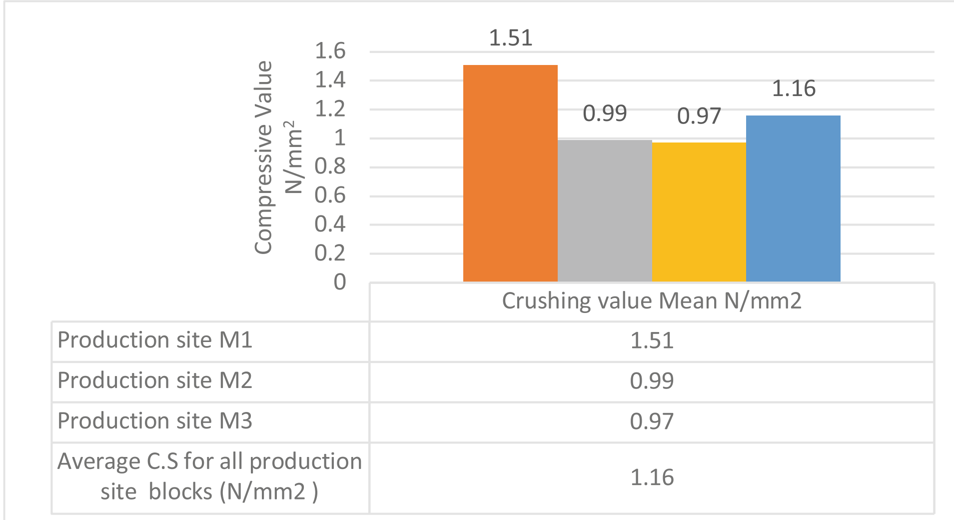

Fig. 4 Average compressive strength for manufacturers blocks sampled

5 Conclusions

The study investigates the quality of blocks produced using fine aggregate (river sand), cement, and water. From the result of the study, it can be deduced that aggregate material used in the production of the sandcrete blocks sampled falls within the specific requirement by EN933-1 2012 and is suitable for block production. The blocks produced with the aggregate have a bulk density that is in alignment with the required stipulated values by NIS 87:2007. The result shows that the aggregate contains an average silt content of 3%, which shows further that the aggregate is a good material for block production. The result of the study shows that blocks produced with the aggregates have a compressive strength mean of 1.51 N/mm^2 (M1), 0.99 N/mm^2 (M2), and 0.97 N/mm^2 and average compressive strength of 1.16 N/mm^2 for all block production sites which does not meet up with the minimum requirement for sandcrete block compressive strength as stipulated by NIS 2007 and ISO 848492-1994. The study revealed that the quality of the block produced is not affected by the quality of aggregate used but by poor quality control of aggregate and other materials used in its production. It further revealed that the block quality is also affected through improper curing of blocks produced. The study, therefore, concluded that regulatory and professional bodies should organize seminars for the local producers of sandcrete blocks on the best practice of producing quality blocks in meeting with the required quality standard expected of sandcrete block for construction purpose. This is of importance in avoiding structural cracks and collapsing of building structure and its attached components. Future research work can be carried out on compressive strength of solid and hollow sandcrete blocks produced manually using river sand. Furthermore, the comparative strength of sandcrete blocks produced with a machine and manual mould using river sand can be investigated.

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Experimental Investigation of Concrete Block Walls Compressive Strength Using a Non-destructive Test

Babatunde Ogunbayo and Clinton Aigbavboa

Abstract

The non-destructive test is an inexpensive measure of surface hardness that is used to determine the theoretical relationship between the strength of hardened concrete block walls and the rebound number of the hammer. This study analyzed the compressive strength of concrete block walls of a building using a non-destructive test. Data was collected using the impact method (Schmidt rebound hammer) on three sides of the building concrete block walls. The standard experimental procedure for impact method was followed and the analysis of the result were presented through tables and figure. The result shows that the rebound value (R) of the three sides for the concrete block walls were 17.21 N/mm^2 (CBW1), 15.01 N/mm^2 (CBW2) and 16.1 N/mm^2 (CBW3). The average compressive strength for all the CBW tested in relation to the R is 16.1 N/mm^2 which shows that the compressive strength of the concrete block walls is within the stipulated minimum compressive strength of 12.5 N/mm^2 for load-bearing concrete blockwork, using Ordinary Portland Cement and suitably graded fine and coarse aggregate in accordance to BSEN1971-1 2011. The study indicated that a non-destructive test using Schmidt rebound hammer is suitable for testing of the in-use building structures because it does not compromise the performance of component or structure being investigated and it's quality. The study concluded that the structure tested using the non-destructive test is safe and suitable for habitation.

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Keywords

Non-destructive • Concrete block wall • Rebound value • Compressive strength

1 Introduction

Concrete block is a standard size rectangular block multi-purpose building product that is mostly used as load-bearing and non-load-bearing walls of a building. It is used with other construction material like concrete columns, tie beam or when built with integral steel reinforcing. In Nigeria, the concrete block walls are used as freestanding walls and loading bearing structure because of its affordability and simplicity. Over 90% of masonry walling units of housing structure provided was constructed using concrete blocks. Its utility value comparing to its cost and its adaptability climatic factors make it a good material for building work (Omoregie 2012). This makes concrete blocks vital material in building construction work (Baiden and Tuuli 2004). In meeting the need of the building, concrete blocks can be produced through mechanical vibrating molding machine or manually process of production (Anosike and Oyebade 2012). However, in the production of concrete blocks, the durability and strength of the concrete block before and during usage is not considered. Although the standards organization of Nigeria has provided specifications for its production and usage. In many parts of the country, concrete blocks are produced devoid of reference to any requirement or its usage specifications (Ogunbayo et al. 2018a). Odeyemi et al. (2015) opined that concrete blocks strength increases with density in its hardened state. The concrete block as a load-bearing wall support other building as such its strength could be determined using a non-destructive test in accordance to an international standard such as Czech Standards Institute (2013) that stipulated minimum compressive strength of 12.5 N/mm^2 for load-bearing concrete block

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walls. The non-destructive test is majorly carried out on component of building structure without affecting the structure itself before, during, or after usage (Ogunbayo et al. 2018b). The non-destructive test is performed on a structure using an apparatus called the Schmidt rebound hammer, and the test does not compromise the envisioned performance of any component or structure being investigated and it's quality (Aydin and Saribiyik 2010). Yüksel (1995) opined that in determining the compressive strength of any part of a building structure, the non-destructive testing is ideal because of its easiness.

Although, using the non-destructive test to determine the concrete block strength is not expensive, there are standard processes that need to be followed to attain better results using the rebound hammer (Agunwamba and Adagba 2012). Conversely, Leshchinsky (1991) state that a non-destructive test causes less damage to building walls. Aydin and Saribiyik (2010) state that the result of a non-destructive test using a Schmidt rebound hammer dependent upon the type of surface finish and its preparation, the degree of saturation, carbonation, and temperature. The study of Amasaki (1991) further shows that result of Schmidt hammer test on concrete block walls is affected by so many factors which include aggregate type, mix ratio, type of hammer, testing area, honeycomb, and scaling and rough texture. Yilmaz (2009) observed that the use of the non-destructive test to determine the concrete block walls strength is affected by factors such as; type of aggregate use, area of testing, method of construction, direction of testing, and state of the surface to be tested. Nevertheless, Turgut (2004) opined that using the non-destructive test on concrete block walls is of no importance if its results are not meeting the expected result from part tested. This study investigates the compressive strength of concrete block walls in relation to the rebound value (R) using a non-destructive impact method (Schmidt rebound hammer).

2 Methods and Procedure

The experimental procedure for this research was carried out in accordance with the Czech Standards Institute (2013). The load-bearing concrete block walls to be tested were carefully selected and the tested points were prepared and smoothened using a grindstone. The rebound hammer was pushed against the test surface at a reasonable speed with a fixed amount of energy against the concrete block walls, positioned horizontally to and against the test surface and until an impact is initiated. 25 impacts values were recorded on each concrete walls tested. Minimum of 12 impact values were taken from values for each concrete block wall sampled. The average rebound value (ARV) for ten impacts which is the minimum values that can be taken for evaluation in accordance with ASTM C805-85 (1993) and BS1881 (1986) was calculated and the R value determined. The compressive strength for the concrete block walls sampled was analyzed in relation to the Rs. The study makes use of the following equipment, apparatus, and tools: Schmidt rebound Hammer, grinding stone, measuring tape in carrying out its experiment procedure. The safety procedure for the research was in line with the finding of Ogundipe et al. (2018).

3 Results

Based on the compressive strength of concrete block walls carried out in relation to the rebound value (R) using a non-destructive impact method (Schmidt rebound hammer), the results are shown in Tables 1, 2, 3 and Fig. 4.

4 Discussion

As shown in Table 1, the non-destructive test was carried out on CBW1 of 250 × 250 × 450 mm with plaster and screed of 25 mm thickness. The R value after impact were recorded taking at least 12 readings out of 25 impacts that was carried out on the tested concrete block wall. For accuracy, the lowest (15.45 N/mm^2) and the highest (19.55 N/mm^2) R values were deducted, and the ARV for the 10 R values was calculated. The result shows that the R for CBW1 is 17.2 N/mm^2.

As shown in Table 2, the non-destructive test carried out on CBW2 of 250 × 250 × 450 mm with plaster and screed of 25 mm thickness. The R values after impact were recorded taking at least 12 readings out of 25 impacts that were carried out on the tested concrete block wall. For accuracy, the lowest (14.45 N/mm^2) and the highest (17.87 N/mm^2) R values were deducted, and ARV for the 10 Rs was calculated. The result shows that the R for CBW2 is 15.01 N/mm^2.

As shown in Table 3, the non-destructive test carried out on CBW3 of 250 × 250 × 450 mm with plaster and screed of 25 mm thickness. The R values after impact were recorded taking at least 12 readings out of 25 impacts that were carried out on the tested concrete block wall. For accuracy, the lowest (13.45 N/mm^2) and the highest (18.45 N/mm^2) R values were deducted, and ARV for the 10 Rs was calculated. The result shows that the R for CBW3 is 16.29 N/mm^2.

The compressive strength result for the three load-bearing block walls in a specific relationship with the R value is shown in Fig. 1. The result showed compressive strengths of 17.21 N/mm^2 (CBW1), 15.01 N/mm^2 (CBW2), and 26.45 N/mm^2 (CBW3), and average compressive strength in

Table 1 Analysis of rebound value for the CBW 1

S/N	Sample (mm)	No of impacts	Rebound value (N/mm^2)	Deductions (N/mm^2)
1	Concrete block wall of 250 × 250 × 450 mm with plaster and screed of 25 mm thickness	1	15.75	15.75
		2	16.69	16.69
		3	15.45	Lowest value
		4	18.65	18.65
		5	16 85	16.85
		6	16.75	16.75
		7	18.45	18.45
		8	17.95	17.95
		9	16.35	16.35
		10	19.55	Highest value
		11	18.24	18.24
		12	16.23	16.23
			Total	171.91

Average rebound value (ARV) = $\frac{\text{Sum of the total value}}{\text{Number of Impact}}$

R = $\frac{171.91}{10}$ = 17.2 N/mm^2

Table 2 Analysis of rebound value for the CBW2

S/N	Sample (mm)	No of impacts	Rebound value (N/mm^2)	Deductions (N/mm^2)
2	Concrete block wall of 250 × 250 × 450 mm with plaster and screed of 25 mm thickness	1	14.55	14.55
		2	17.45	17.45
		3	14.45	Lowest value
		4	17.65	17.65
		5	16.85	16.85
		6	15.75	15.75
		7	17.45	17.45
		8	15.85	15.85
		9	17.15	17.15
		10	17.50	17.50
		11	16.78	16.78
		12	17.87	Highest value
			Total	150.13

Average rebound value (ARV) = $\frac{\text{Sum of the total value}}{\text{Number of Impacts}}$

R = $\frac{150.13}{10}$ = 15.01 N/mm^2

relation to the R value is 16.1 N/mm^2 for all CBW tested using the Schmidt rebound hammer.

The findings of this study agreed with British Standard Institute (2011) that stipulated that the minimum compressive strength of an existing load-bearing wall above the damp-proof course should be 12.5 N/mm^2 for load-bearing blockwork.

5 Conclusions

This study investigates the compressive strength of concrete block walls in relation to the R value using a non-destructive impact method (Schmidt rebound hammer). From the result of the study, the compressive strength values of the concrete

Table 3 Analysis of rebound value for the CBW3

S/N	Sample (mm)	No of impacts	Rebound value (N/mm^2)	Deductions (N/mm^2)
3	Concrete block wall of 250 × 250 × 450 mm with plaster and screed of 25 mm thickness	1	15.65	15.65
		2	15.95	15.95
		3	16.45	16.45
		4	15.45	15.45
		5	17.35	17.35
		6	15.85	15.85
		7	18.45	Highest value
		8	15.95	15.95
		9	13.45	Lowest value
		10	16.36	16.35
		11	17.03	17.03
		12	16.87	16.87
			Total	162.91

Average rebound value (ARV) = $\frac{\text{Sum of the total value}}{\text{Number of Impacts}}$

$R = \frac{162.92}{10} = 16.29\ N/mm^2$

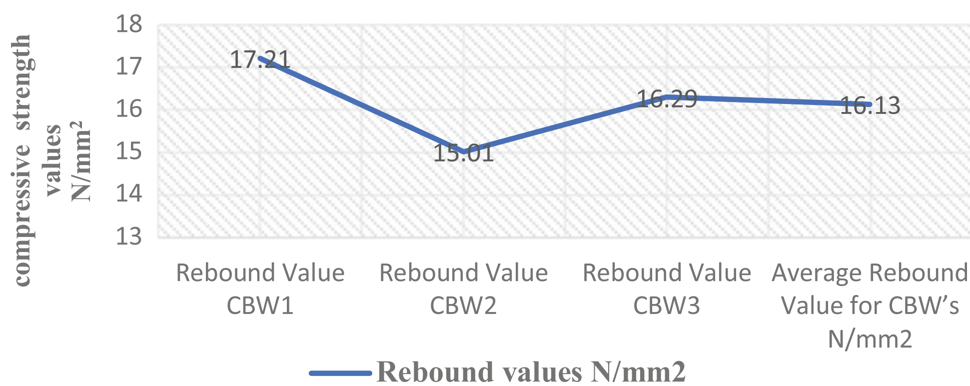

Fig. 1 Analysis of compressive strength for concrete block walls in relations to the Rebound values (R)

block walls tested in relation to the R value were 17.21 N/mm^2 (CBW1), 15.01 N/mm^2 (CBW2), and 16.29 N/mm^2 (CBW3). The average compressive strength for all the CBW tested in relation to the R value is 16.13 N/mm^2, which shows that the compressive strength of the concrete block walls is within the stipulated minimum compressive strength of 12.5 N/mm^2 for load-bearing concrete blockwork, using Ordinary Portland Cement (OPC) and suitably graded fine and coarse aggregate in accordance to BSI (2011). The study indicated that a non-destructive test using Schmidt rebound hammer is suitable for testing of building structures because it does not compromise the performance of component or structure being investigated and its quality. The study concluded that the structure tested using the non-destructive test is safe and suitable for habitation. The limitation of this research is that there is little existing literature on this study area. Future research work can be carried out on existing concrete floors and columns using the Schmidt rebound hammer.

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Reviewing Problem-Solving as a Key Employability Skill for Built Environment Graduates

John Aliu and Clinton Aigbavboa

Abstract

The benefits of possessing problem-solving skills cannot be over-emphasised. From fresh graduates to industry employees, this skill is pivotal in achieving one's goals as well as functioning effectively in the construction industry. Several researchers have suggested that industry employers value graduates who possess practical problem-solving competencies and can deliver timely and implementable solutions to arising industry problems. Hence, this paper focuses on the benefits of possessing problem-solving abilities and possible ways to foster them in higher education. This study was conducted via a review of relevant literature from peer-reviewed journals and conference articles from databases including EBSCO Host, ProQuest, SciVal, Springer, Taylor and Francis online, Emerald, among others. Notable findings from this study revealed that brainstorming, Root Cause Analysis, Cause and Effect Diagram, Pareto chart, Flowcharting and decision matrix are among some of the ways by which problem-solving skills are developed in higher education institutions (HEIs). The study also found that problem-solving skills could be developed among students by moving from teacher-centred approaches to student-centred approaches. These ranges from case-based teaching, discovery learning, problem-based to project-based learning among others. It is recommended that present-day HEIs engage built-environment students even more by integrating project-based activities into their curricula, to holistically prepare the next generation of industry professionals.

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Keywords

Problem-solving skills • Higher education • Student-centred approaches • Construction industry • Employability

1 Introduction

The present-day construction industry remains an integral part of the global economy and shapes the built-environment and quality of life for people around the world. It is a sector that has become dynamic, uncertain and continuously evolving and has increased the need for adequately skilled professionals such as architects, engineers, surveyors, town-planners among others to handle its activities (Aliu 2017). In meeting the needs of the construction industry, graduates are required to possess several non-academic skills and competencies apart from their academic knowledge. These skills include communication skills, leadership skills, time management skills, decision-making skills, teamwork skills, critical thinking skills, leadership skills, organisational skills, numeracy skills and problem-solving skills (OECD 2013). Hence, this study primarily focuses on problem-solving skill, which has become a critical requirement for industry employers in recent times.

The capacity to proffer solutions to arising problems has been identified as a desirable attribute of graduates across various studies. The study by Archer and Davison (2008) and Kilgour and Koslow (2009) describes problem-solving as the ability to be creative and practical in handling industry problems. The study by Wickramasinghe and Perera (2010) also listed problem-solving as one of the critical attributes to be possessed by graduates heading into the construction industry. They describe it as the ability to strive towards achieving positive results despite a steep path in identifying and analysing problems. Problem-solving is also identified as various ways of thinking outside the box, improving one's

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thinking skills and providing alternative solutions to arising industry problems (Conrad and Newberry 2012; Jackson and Chapman 2012; Ahn et al. 2012; Reid and Anderson 2012). The benefits of possessing problem-solving skill cannot be overstated. The current and incessant demands of the industry, coupled with an increasingly complex society have increased the need for higher education to develop critical thinking and problem-solving abilities among students (Yunus et al. 2006). The uncertain and continuously changing nature of the industry has prompted graduates to become more proactive in taking initiatives, acting responsibly and thinking critically on various ways to solve problems and proffer solutions. Against this backdrop, this paper examines the importance of possessing this skill and different ways that universities can develop this competency among students before they graduate.

2 What Does Problem-Solving Entail?

Several researchers and academia facilitators have adequately discussed what problem-solving entails. Problems are merely needs or goals that must be met (Ritzs et al. 1986). In a case where the path towards achieving that goal looks uncertain, the process of moving towards that goal despite the uncertainties is a perfect picture of what problem-solving entails (Martinez 2005). This explanation mirrors the definition posited by Charness (1998), Reiss and Törner (2007) and Voyer (2011), who all describe problem-solving as an activity that enables an individual to achieve a coherent process seeking solution even when not clear on how to reach the desired state.

D'Zurilla and Nezu (2001) and D'Zurilla et al. (2011) describe problem-solving as "*the self-directed cognitive-behavioural process by which a person attempts to identify or discover effective and adaptive solutions for specific problems encountered in everyday living*". This description supports their definition of 'problem' that describes it as any "*life situation or task that demands a response for adaptive functioning, but no effective response is immediately apparent or available to person or people confronted with the situation because of the presence of one or more obstacle*." The explanation by Metallidou (2009) describes problem-solving as a goal-oriented systematic approach that requires a mental capture of the problem and the adoption of strategies to achieve a desired goal or outcome. Several researchers have distilled problem-solving strategies into several steps. The four steps presented by Dewey (1910) includes locating and defining the problem, hinting at possible solutions, ascertaining the implications of the solution and result observations (Dewey 1910). Polya (1945) problem-solving strategy also involves four steps including understanding the problem, formulating a plan, executing the plan and reflecting on the process and results. A further six problem-solving steps were presented in Kneeland (1999) model. They include identifying the problem, gathering and accumulating pertinent facts, defining the problem, drawing up possible and alternative solutions, identification and selection of the best solution and execution of the solution. The first three steps highlight the problem definition phase, while the next three steps deal with the solution identification and implementation phase.

Problem-solving further involves several interdependent and interactive capacities and a wide range of human process and abilities as shown in Fig. 1. The diagram also illustrates various interchangeable concepts of problem-solving that include memory, intelligence, reasoning/logic, metacognition, motivation, learning, creativity and intuition.

As seen in Fig. 1, there is a strong correlation between problem-solving and several human processes and cognitive abilities. Several studies have suggested that students who possess a higher level of metacognitive competencies quickly master the art of problem-solving (Cornoldi et al. 2015; Safari and Meskini 2016). This is because the problem-solving process involves several operations that deals with planning, analysing, monitoring, organising and monitoring strategies in solving problems. These operations require one to employ creativity, reasoning, logic and memorising that constitute several elements of metacognition.

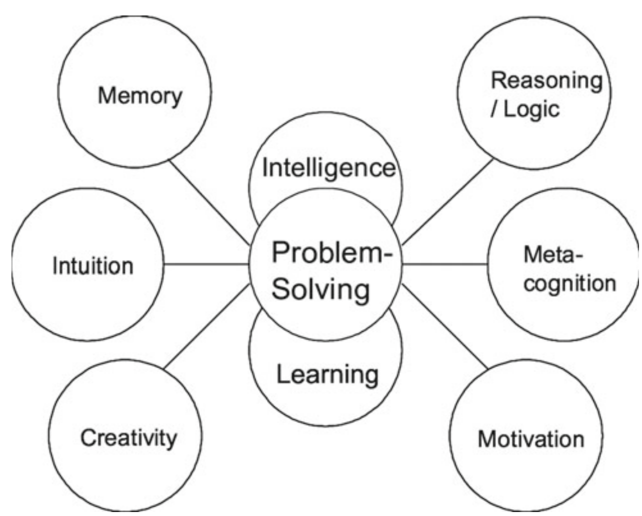

Fig. 1 Capacities relating to problem-solving (Adams and Turner 2008)

3 Problem-Solving Skill Tools in Higher Education

Over time, numerous researchers have proposed several techniques adopted by higher education in stimulating the critical thinking and problem-solving abilities of students. Egan et al. (2017) insist these proficiencies are critical competencies students have to develop to experience industry success after graduation.

One of the techniques used to develop these competencies is Brainstorming (BS). This technique involves the spontaneous exchange of ideas among team members to proffer solutions to practical problems, hence leading to increased productivity (Gogus 2012; Unin and Bearing 2016). Also known as a technique that stimulates the ability to generate ideas and creative solutions thoughtfully, brainstorming fosters the development of problem-solving competencies among students (Drapeau 2014; Schlee and Harich 2014; Michinov et al. 2015; Fu et al. 2015).

Another problem-solving technique is the deployment of the Root Cause Analysis (RCA). The objective of this method is to determine the fundamental cause of a setback, problem or incident (Okes 2019). Unlike other methods that address problematic symptoms, RCA advocates that problems can be resolved by addressing their root causes from the onset. Considered as an iterative process, RCA addresses the underlying causes of a problem to prevent the problem from reoccurring (Serrat 2017).

During a team-approach in problem-solving, establishing the relationships between the identified problem and its potential cause is valid through the adoption of a Cause and Effect Diagram.

Also known as a fishbone, educators visually display various potential causes for a particular problem that can stimulate innovative ideas among students. This method is suitable for group settings during brainstorming sessions in which there is limited quantitative data available for analysis. The fishbone also provides a platform for students to demystify issues thoroughly, resulting in a more robust solution (Coccia 2018; Shinde et al. 2018).

Furthermore, another problem-solving tool is the Pareto chart. Named after Vilfredo Pareto, the Pareto chart consist of bars and graphs depicting the contributing factors to the more significant problem. When adopted by educators, it provides students with the various grey areas that need full focus to achieve results. Pareto charts are utilised when the need to focus on the most significant problem out of several of them is required (Arnold 2015).

Flowcharting is another technique by which problem-solving skill can be fostered among students. Flowcharts are easy-to-understand maps or diagrams that illustrate the various sequential steps or stages in achieving a process. They provide students with the ability to understand the various processes, hence improving their organisational competencies, an attribute of problem-solving (Hooshyar et al. 2015, 2016).

Finally, when students face a conundrum of multiple choices and many variables, a decision matrix can provide pivotal pointers in making a best or final option or decision. This quantitative method is designed by arranging the alternatives decisions on the left-hand rows and the selection criteria on the column sections. The rows are rated and examined against the columns to arrive at the best or final option or decision (Shih et al. 2007; Proctor 2014).

4 Implications for Higher Education

From the above discussion, the process of displaying attributes and competencies in proffering solutions to arising industry problems and challenges can be regarded as a critical non-academic skill. Problem-solving skills refer to the ability of students to define the problem, think critically, display credibility and accuracy, reflect on ideas, be organised and efficient, exhibit flexibility, generate potential solutions, analyse results and apply solutions. Simply put, students with problem-solving skills tend to exhibit self-confidence and can think creatively and work independently. In developing these abilities, the traditional lecture room approaches are just not enough. By moving from a teacher-centred approach to a student-centred approach, these set of skills could be enhanced among students. These approaches range from case-based teaching, discovery learning, problem-based and project-based learning among others. When deployed and adopted by higher education educators, these student-centred approaches engage students in the learning process via exposure to real-life (real-world) projects. Apart from spicing up the learning process, these student-centred approaches provide students with multi-step problems to stimulate their creativity and critical thinking abilities, hence improving their problem-solving skills.

5 Lessons Learnt and Conclusion

The benefit of possessing problem-solving skills is a critical requirement for graduate success in the world of work. The current and incessant demands of the industry, coupled with an increasingly complex society have increased the need for higher education to develop thinking and problem-solving among students. As a collection of required skills, problem-solving is the ability to determine what problem exists and gaining critical insights to suggest possible solutions. It also deals with identifying realistic outcomes and alternative solutions in a given problematic situation. From the study, problem-solving skills involves several attributes. They include the ability to defining the problem, think through a plethora of ideas, emphasise credibility and accuracy, reflect on the thought-process, be organised and efficient, exhibit flexibility, generate potential solutions and analyse results. From this study, problem-solving skills are developed through various tools including brainstorming, Root Cause Analysis, Cause and Effect Diagram, Pareto chart, Flowcharting and decision matrix. Furthermore, students can be fully equipped with problem-solving skills if higher education establishes collaboration with the construction industry. The exposure to industrial equipment and access to up-to-date technical information further develops this repertoire of skills among built environment students.

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A Socio-cultural Perspective to BIM Adoption: A Case Study in South Africa

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Abstract

The implementation of BIM in construction organisations requires various strategic and change management processes. The effect of organisational culture, manifested through external survival issues, internal integration issues and underlying assumptions, on BIM adoption are absent in the literature. This paper aims to illustrate that a focus on these three level of cultural manifestation within AEC organisations could lead to improved analysis of BIM adoption. An architectural organisation based in South Africa is used as a case study. A mixed method of data collection was adopted to analyse BIM's manifestation in an architectural organisation's culture. Interviews were conducted with key members in the organisation, and survey data of 29 respondents was used to triangulate and develop consensus about the underlying assumptions relating to BIM. The results showed how each of the three levels of cultural manifestation is influencing BIM adoption. In particular, the findings revealed that leaders' perceptions greatly impact the adoption of BIM through the three levels of the organisational culture.

Keywords

Building information modelling • BIM • BIM diffusion • Cultural values • Behaviour • Organisational culture

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1 Introduction

The construction industry has remained innovatively static (NBS 2016), despite decades of exposure to its waste and inefficiencies (Egan 1998; Gallaher et al. 2004). The industry's fragmented nature is still challenged by the lack of collaborative project delivery systems and the limited adoption of interoperability standards and the scarce automation of project processes. Building Information Modelling (BIM) is proclaimed as the industry's panacea and is alleviating some of interdisciplinary inefficiencies within the construction industry. BIM is the current expression of digital innovation within the construction sector (Kassem et al. 2015). BIM adoption contributes: (1) reduced project lifecycle costs; (2) increased productivity, efficiency, infrastructure value, quality and sustainability; (3) effective communication and collaboration amongst project stakeholders (Arayici et al. 2011). Although governments and institutions around the world have started to strategise and mandate the use of BIM in construction projects (Kassem et al. 2015). This is not the case in other parts of the global construction market. For example, in South Africa, the demand for BIM in both the public and private sector is still very scarce. South African architectural organisations have very little guidance and skills to successfully adopt BIM processes and workflows. At this embryonic phase of BIM adoption within South Africa, it is important to investigate the socio-cultural effects of BIM adoption. According to Martins and Terblanche (2003), the culture of an organisation is considered as a driving factor of BIM adoption. In addition, various authors have called for a culture change in the industry to enhance the BIM diffusion and to meet sustainability targets (Deutsch 2011; Ajayi et al. 2016; Khosrowshahi and Arayici 2012; Rowlinson 2010). This paper investigates the inherent effect of BIM on organisational culture with the focus on the South African construction industry. The work is based on Schein's theories of organisational culture, with the implication that strategic focus on certain aspects of BIM might aid organisational cultures to adapt to the external environment.

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2 Building Information Modelling (BIM)

Since its inception in 2002, authors have initially described BIM as technology or "tool" (Campbell 2007; Zuppa et al. 2009; Barlish and Sullivan 2012), referring mainly to the software used on AEC projects. However, (Succar 2009) pragmatic definition of BIM as "*a set of technologies, processes and policies enabling multiple stakeholders to collaboratively design, construct and operate a facility in virtual space*" has acknowledged the increasing connotation of BIM. The most prevalent use of BIM relates to early design usages such as visualisation, 3D coordination, design authoring and analysis, whereas lifecycle uses such as maintenance scheduling and building system analysis are still limited (NBS 2016; Singh 2017).

South Africa has yet to develop BIM mandates on an institutional level (Chimhundu 2015; Kiprotich 2014). BIM adoption in South Africa has received very little traction in both the public and private sectors, thus lagging behind developed countries (Chimhundu 2015). South Africa widely accepts the UK's BIM maturity model as a standard approach to measuring the competence of BIM adoption (Mordue 2016). However, UK's and ISO 19650 standards, are mere guidelines in South Africa and is only partially followed due to differing construction processes and culture (Froise and Shakantu 2014).

In a study on BIM diffusion, Esmaeili (2018) found that the main influence behind BIM adoption can be attributed to how the construction industry places value on internal factors and imitation behaviour, rather than external factors. The external factors in a diffusion model refer to regulatory and empirical evidence by governments and institutions of the potential benefits of innovation, whilst imitative behaviour can be explained by the bandwagon effect in innovation diffusion. Consequently, the effect of BIM diffusion depends on the strength of the industry adopter's network (Kent 2000). Industry networks describe clusters of organisations that have developed recurring ties through projects, shared information and work closer together than other organisations within the industry (Ebers and Jarillo 1997). Due to the construction industry's notoriously conservative and fragmented nature (Arthur et al. 2017; Kiprotich 2014) and with very little previous inclusion of facilities management in construction processes, Kent's network theory reveals why survey findings show little BIM uptake in the full lifecycle of construction projects (Kent 2000). Cao et al. (2014) argue that the client/owner exerts social pressures on AEC professionals on a project level, leading to conformity pressures (Cao et al. 2014). This, therefore, supports the bandwagon theory because, despite the ambiguity about the profitability of BIM innovation, adopters are under social pressures to adopt BIM to avoid losing legitimacy in the industry (Esmaeili 2018). BIM implementation within AEC organisations wields the same imitation behaviour as on projects. Without detailed knowledge of BIM or its impact on organisational practices, organisations implement BIM technologies, acquire training, appoint BIM managers and process documentation based on social cues to ensure legitimacy in the industry (Cao et al. 2014). Various authors have found that the dissemination of BIM technology on traditional practices in organisations has led to adoption barriers (Babič and Rebolj 2016) such as resistance to change, unestablished contractual foundations, fragmentation and inertia, poor people management strategies, lack of buy-in from organisational and project stakeholders, unfavourable trust and risk behaviours and misperceptions on BIM (Liao and Ai Lin Teo 2018; Arthur et al. 2017; Arayici et al. 2011; Kassem et al. 2015). On an employee level, BIM adoption renders some deep-rooted workflows and behaviour dysfunctional, which violates identity and causes anxiety between individuals to lose group membership. Consequently, change causes an unlearning of sorts, which causes resistance to change (Schein 2006) or BIM wash. Therefore, Kent (2000) points out that an organisation's culture should be changed to create an environment for innovation learning rather than protecting old practices. Based on architectural organisations' position in the early design network, architects are in a predominant position to influence the speed and depth to which innovation is diffused through the industry. Once motives for behaviour are understood, organisations will be able to change towards adaption or even advance toward a competitive market.

3 Organisational BIM Culture

Numerous definitions of organisational culture exist; however, the most common lay term is "the way we do things around here" (Schneider et al. 1996). Organisational culture is manifested in the right way things are done, or how problems in the organisation are understood and resolved.

A culture is formed through the personal goals, beliefs, values and assumptions that the founder believes "how things should be". The founder's views are imposed on the peers and, as the founder's views and behaviour result in success, the behaviour is recognised as the "right way" and shared to new members of the group (Schein 2006). The view that top management is the architects of culture is common in academia (Martins and Terblanche 2003; Ashkanasy et al. 2011; Cameron and Quinn 2011). An organisation's culture is often viewed as unitary and unique, characterised by a stable set of meanings (Ashkanasy et al.

2011). However, this view can be challenged in two ways: (1) organisational culture is ultimately affected by its host culture; (2) each organisation comprises of various sub-cultures as members often group themselves in smaller societies relative to their needs.

Host cultures are the normative external cultures that the organisation establishes itself in (such as national cultures, industry culture and educational cultures) and forms the basis of initial assumptions which assist members to relate to one another. It is here that the impact of environmental changes, including technological advancements such as BIM, plays a big role in cultural changes in industries. On the other hand, internal cultures or sub-cultures are formed within an organisation where group members are often organised based on their location, designations, disciplines or projects. The level and circumstances of cohesion between the sub-cultures can define the strength and health of the organisation and its ability to change (Ashkanasy et al. 2011).

When political, societal and technological environments change, people's cultural values also change (Wu 2006). An organisation's ability to change and adapt to its environment is critical for survival in a competitive market. In order to understand the contributory and complementary role of external influences and the organisation's internal environment, this study adopts the Schein (2006) approach, according to which "a pattern of shared basic assumptions that a group learns as it solves its problems of external adaptation and internal integration, that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think and feel in relation to those problems" (Schein 2006). Hence, according to Schein (2006), the problem with deciphering culture in an organisation is to surface the group assumptions. Figure 1 presents three levels as defined by Schein, at which a culture can be analysed by; artefacts and creations, values and basic assumptions.

Artefacts: Artefacts are the visible elements of an organisation such as documents, the physical layout of the office, technology and visible audible behaviour patterns, etc. Artefacts are easily seen by an outside observer, but the cultural aspects thereof are hard to decipher.

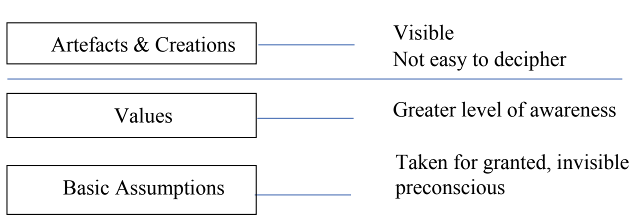

Fig. 1 Three levels of culture (Schein 2009, p. 21)

Values: Values govern behaviour, which is the next level of culture. It refers to the communal focus on what people say is the reason for their behaviour. Though, values do not uncover the underlying reasons for organisational members' behaviour.

Basic Assumptions: These taken-for-granted assumptions are unconscious to the group and are the reasons why members perceive and think a certain way. Basic assumptions are learned responses that originated as organisational values.

In analysing a culture, Schein (2006) suggests a structured qualitative approach in the following three areas of an organisation to uncover the three levels of the culture:

- **External survival issues** which can be analysed in the organisation:
  - Mission, strategy, goals.
  - Means: structure, systems, processes.
  - Measurement: error detection and correction systems.
- **Internal integration issues** found in:
  - Common language and concepts.
  - Group boundaries and identity.
  - The nature of authority and relationships.
  - Allocation of rewards and status.
- **Deeper underlying assumptions** in:
  - Human relationships to nature.
  - The nature of reality and truth.
  - The nature of human nature.
  - The nature of human relationships.
  - The nature of time and space.
  - The unknowable and uncontrollable.

Schein's (2006) model for analysing organisational culture is widely accepted (Schein 2006). Therefore, to form a framework for cultural analysis, Schein's three-level model is merged with the three levels of cultural manifestations to ensure the study uncovers the underlying assumptions surrounding BIM adoption as displayed in Table 1.

This merge reveals the areas of focus and influences to uncover the cultural values relative to BIM. Therefore, by adding a BIM overlay, the degrees of BIM abstraction within the organisational culture can be realised.

According to the above analysis, the reality of BIM manifestation within the organisation's culture can be achieved by the consensus of values between all members throughout the organisation and hence, this study aims to understand this phenomenon.

Once the reality of BIM in an organisation is revealed, recommendations can be made to further promote BIM adoption for competitive advantage in the industry and ultimately influence the wider industry network's BIM diffusion rate.

Table 1 BIM's cultural values research model

Analysis focus		Artefacts	Values	Basic assumption
External survival issues	Mission, strategy, goals	x	x	
	Means: structure, systems, processes	x	x	x
	Measurement: error detection, correction systems	x	x	
Internal integration issues	Group boundaries and identity		x	x
	Nature of authority and relationships		x	x
	Allocation of rewards and status	x	x	x
Deeper underlying assumptions	Human relationships to nature			x
	– Organisations' relationships to its environment			x
	– Nature of Human Nature and Activity Internally			x
	The nature of reality and truth			x
	– Nature of space and time			x
	The nature of human relationships			x
	The unknowable and uncontrollable	x	x	x

4 Methodological Steps

In order to answer to the research questions derived from the literature, this study will use mixed-method approach to collect data in three phases in correlation with Schein's three levels of culture, as displayed in Table 2.

The data collection phases, as guided by the Schein's methodology were addressed by using the following strategies:

a. **Interviews**: to achieve consensus among key members of the organisation in order to uncover the espoused values and basic assumptions by targeting the participants situated in key offices as mentioned in Table 3.
b. **Survey**: to gather a greater audience for consensus and to validate discussions of the interview by targeting randomly sampled 29 employees, among which 13 has previous experience in BIM.

Table 2 BIM's cultural values research model

Phase	Cultural level analysis	Data collection methodology
Phase 1	Artefacts	Observation, survey
Phase 2	Values, assumptions	Interviews
Phase 3	Basic assumption validation	Survey

The findings from the interviews and survey aids in measuring BIM's manifestation in an organisational culture, which is presented in the next section.

5 Results and Analysis

The aim of this section is to analyse BIM's manifestations within the organisation's external survival issues, internal integration issues and underlying assumptions. Only once a consensus among the key members of the organisation is reached (Schein 2006), the manifestation of BIM in the culture can be revealed. Therefore, findings of the interviews with key members of the organisation triangulated with the aid of survey data are summarised and compared in the following sub-sections:

Table 3 Interview participant details

Participant	Role in AO1	Discipline background
Owner	Managing director	Architect, 22 years' experience
Leader	Executive director	Architect, over 20 years' experience
BIM Manager 1	Associate BIM manager	Architectural technologist, 9 years' BIM experience
BIM Manager 2	BIM manager	Architectural technologist, 7 years' BIM experience

Table 4 BIM culture's external adaption functions

Schein's (2006) definitions	Summary of findings
Strategy	
Developing consensus on the primary task, core mission or manifest latent functions of the group	Key to the organisation's mission is efficiency. Consensus reached that 'BIM is a tool' to increase efficiency
Goals	
Developing consensus on goals, such goals being the concrete reflection of the core mission	The consensus on long-term goals are reached, however, not in short-term goals
Means for accomplishing goals	
Developing consensus on the means to be used in accomplishing the goals—for example, division of labour, organisational structure, etc.	Consensus reached on creation of BIM teams and roles, not on the wider transformation of the organisation's structure
Measuring performance	
Develop consensus on the criteria to be used in measuring how well the group is doing against its goals and targets, i.e. information and control systems	Consensus reached on the need to develop external and internal BIM performance measurement systems
Correction	
Developing consensus on remedial or repair strategies as needed when the group is not accomplishing its goals	Problems are corrected though BIM assistance and BIM training

5.1 External Survival Issues

The primary determinant of behaviour in an organisation, i.e. AO1 is the company's efficiency values encompassing its mission, goals, performance and correction. Therefore, this section aims to present the summarised findings; achieved by interviews and triangulated by survey data in comparison to Schein's definition of external adaption issues as displayed in Table 4 (Schein 2006).

The investigation revealed that there exists no concrete strategy document to articulate the mission, and staff members are referred to the AO1 practice manual to understand how "things work around here". However, BIM does not feature in this manual as the manual's development preceded BIM adoption. The findings reveal a widespread agreement among members of the group that the perception of 'BIM as a tool' can support the strategy and increase productivity goals in the organisation. However, due to the incipient and scattered nature of BIM implementation within the organisation, top management is not fully aware of BIM impact on efficiency and, in turn, there are unsure how to measure and where to benchmark their organisation performance. The BIM Managers did, however, identify their internal barrier for growth as "a lack of buy-in from top management". Their external barriers are similar to international adoption barriers discussed in the surveys (NBS 2016): "the consultants don't use BIM", "lack of client demand". However, the Owner later revealed that AO1 can influence their clients to appoint consultants that use BIM software. The lack of buy-in can be directly tied to the perception that BIM is just a tool, and changes in operations due to this "tool" will yield investment and loss of productivity, which ultimately goes against the organisation's mission of being efficient. Further, the consensus among the group suggests that the structure, error detection, measurement and correction systems were all built around the efficiency values of top management. BIM has been identified as the means to achieve efficiency. And despite the limited buy-in caused by its perceived adverse effect on productivity during implementation, the organisation's structure I is changing to accommodate BIM roles which is an indication of the influence and power that efficiency values have on this organisation.

5.2 Internal Integration Issues

For a group to accomplish tasks that allow them to adapt to their environment, they must develop and maintain internal relationships (Schein 2006). Therefore, for the adoption of BIM in an organisation's culture, internal integration is a significant concept which is the focus of this subsection is important. The summarised findings from the data collection phases in comparison to Schein's internal integration problems are displayed in Table 5.

From AO1 perspective, the summarised findings of internal integration illustrate that to be acknowledged in the group, one needs BIM knowledge and a willingness to conform to efficiency requirements. The BIM managers serve as a safety net if staff would like to engage in

Table 5 Internal integration factors

Schein (2006)	Summary of the findings
Boundaries	
Consensus on group boundaries and criteria for inclusion and exclusion. One of the most important areas of culture is the shared consensus on who is in and who is out and by what criteria one determines membership	Consensus was reached that BIM experience and BIM knowledge gives membership in the group, whereas a reluctance to adapt—despite correction measures—will exclude members
Power and status	
Consensus on criteria for the allocation of power and status—on how one gets, maintains and loses power	Consensus that staff members have full autonomy in processes until there are problems
Intimacy	
Consensus for the criteria for intimacy, friendship and love. The rules for peer relationships and the way openness are handled in the context of managing organisational tasks	Consensus on openness which reveals trust and risk-taking as espoused values, however, with inconsistencies
Rewards and punishments	
Consensus for the allocation of rewards and punishments. Every group must know what gets rewarded with property, status and power	No consensus was reached on the rewards of BIM

experimentation, and as a buffer between staff and management when there are problems. Except for efficiency, articulated espoused values in AO1 include openness, trust and risk-taking. Further, inconsistencies between what is said and what is observed are revealed in both the espoused values and reward systems.

It appears that even though BIM processes have crept into both the organisations' external survival problems and internal integration issues, BIM's manifestation is more visible in the external survival areas than in the internal integration. This might be due to the external social cues on BIM adoption, as discussed in the literature (Cao et al. 2014), while the internal integration is left to discover adoption for itself. Therefore, internal integration relies on the deeper assumptions of BIM to inform the processes of BIM manifestation.

5.3 Deeper Underlying Assumption

The assumptions developed during external adaption and internal integration reflect deeper assumptions about more abstract general issues, around which people need consensus (Schein 2006). Schein's internal integration problems in comparison to the perspective of AO1 is displayed in Table 6.

From the analysis, the assumption is drawn that even though AO1 strives to be the leaders in their industry, they are trapped in isolation BIM processes which hinder the achievement of their goal. However, the organisation pragmatically adjusts to their situation and has done so with BIM adoption. This organisation has a "doing" culture mainly focused on efficiency; however, their staff are key to that efficiency. Staff should develop their skills with the help of the BIM managers to be efficient. The Owner and Leaders' assumptions around BIM in AO1 includes:

- BIM is a practical tool to increase efficiency.
- BIM changes how AO1 operate but it does not define them.
- Higher BIM skills make one more valuable in a project team.
- AO1 perceives to be ahead of their competition.
- Staff must take initiative to grow.
- The BIM managers function as the safety net when things go wrong.
- The dynamics in the team affect efficiency.
- In there was a strong feeling that BIM is secondary to architecture, instead of being part of the architectural process.

Based on the agreed assumptions derived from the analysis, the BIM culture in AO1 could be summarised in the following points:

- The BIM culture is relatively new and not fully implemented in the entire company.
- The BIM culture drives efficiencies and profits in the organisation.
- The present BIM culture perceives itself as strong enough to endure any future changes in technology or BIM processes.

Table 6 Underlying assumptions (Schein 2006)

Schein's (2006) definitions	Summary of the findings
Organisation's relationship to its environment	We are technologically advanced in a South African architectural context
Nature of reality and truth	BIM is a tool for efficiency
Nature of time and space	Authoritarian style focused on openness
Nature of human nature, activity and relationships	We will give you the platform, take the lead and succeed

- The key strengths of the BIM culture are:
  - High degree of learning and skills development catered to all levels of staff.
  - The staff have full autonomy to experiment and to enhance their capabilities.
  - BIM managers buffer between the technical core and top management.
  - High degree of practical standards to achieve efficiency.
  - Status is gained from BIM knowledge and experience.
  - BIM forces collaboration and therefore colleagues trust each other.

6 Discussion and Conclusion

This research indicates that the Owner's perception that BIM is just a tool has greatly affected the scale of BIM adoption in the organisation. This organisation operates in line with its host culture which is currently siloed and fragmented, even though they have the power to break down the siloes through fully adopting BIM and its collaborative processes. However, this responsibility comes with great uncertainty which threatens the core mission of this organisation: its efficiency.

Aspects of BIM have been found in every cultural aspect within this organisation. However internal barriers are hindering the expansion of BIM abilities. The research uncovered that, due to the current organisations being profitable coupled with a significant focus on productivity, top management is unaware that current practices are inefficient. As a result, the BIM managers are faced with a lack of buy-in when it comes to changing processes. The predisposition that BIM is a tool separates BIM from architectural practices, also creates a barrier for BIM managers to adjust operational and cultural aspects such as:

- Changing the way staff are hired to grow technological diversity.
- Change operational documentation to inform new staff on how things are done.
- Enforce BIM practices through client's consultation and consultant collaboration on projects.
- Educate top management on BIM processes to enable them to drive the BIM strategy to achieve the organisational vision.

To address these concerns, BIM managers should develop a BIM strategy, clearly defining the goals for BIM and the processes to achieve those goals. The strategy should be created in conjunction with top management and other members of the organisation to ensure they buy into the strategy. Not only will management's assumptions be revealed and addressed, but the staff will feel empowered to take the lead in achieving BIM goals.

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Digital Asset Information Management for Transport Infrastructure: Framework and Implementation

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Abstract

Asset management is the systematic process of deploying, operating, maintaining, upgrading and disposing of built environment assets. Effective asset management requires the involvement of all levels of an organisation in planning, control and monitoring of asset performance that combines management, financial, economic and other activities and practices. This paper aims to propose and evaluate a framework for digital asset information management, including four elements—data exchange, classification system, location referencing and information requirement. This framework is validated through interviews with a road agency in Australia. It is expected that this framework is useful for road agencies to evaluate their current practices and take appropriate actions towards digital asset information management.

Keywords

Digital engineering • Asset management • Information management • Location referencing

1 Introduction

An infrastructure asset requires a large capital investment and then requires ongoing operation and maintenance, including improvement and removal of roads. The Australian Government spends more than AUD$7 billion every year on maintaining and renewing roads (Department of Infrastructure and Transport 2015). Maintenance of a road consists of routine maintenance, specific maintenance, restoration maintenance and pavement rehabilitation, all of which have a crucial influence on the related economic, social and environmental aspects. Asset management is the entire process of planning, programming and systematically monitoring an asset. Asset management decisions, such as data-supported decision-making, management systems, relationships between condition and performance, and trade-off and investment analysis are integral components of daily business that support the mission to meet the service requirements of assets.

In recent years, while Building Information Modelling (BIM) has become an important strategy in building, construction and infrastructure sectors to improve productivity and health and safety, the use of BIM for asset management has only been recognised recently in terms of its benefits of managing assets when using 3D models. BIM is an intelligent 3D model-based process to inform and communicate project decisions and communicate project decisions (Li et al. 2019). BIM is a term with three linked functions, including BIM, Building Information Model and Building Information Management (Li et al. 2017). BIM refers to the business process of generating and using building data in the lifecycle of buildings. Building Information Model refers to the digital representation of the physical and functional characteristics of a facility and Building Information Management is the process of utilising digital building information for effective sharing. BIM and asset information can work together to make informed decisions in areas such as bringing existing assets into BIM, developing new assets in BIM, operating and managing existing or new assets.

This paper, therefore, aims to develop a digital asset information management framework so that BIM or other digital engineering technologies can be utilised for effective asset management decisions.

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2 Digital Asset Information Management

A review of existing standards and current practices reveals the importance of the below four elements in digital asset information management.

2.1 Data Exchange

Digital asset information model is dependent on strong information and data exchange capabilities, allowing interoperability of information generated throughout the project lifecycle. Over the past few years, a few data exchange standards for transport infrastructure have been developed. Land and Infrastructure Conceptual Model Standard (LandInfra) is an Open Geospatial Consortium (OGC) standard which defines concepts for providing and understanding information about land and civil engineering infrastructure facilities (Gruler et al. 2016). The concepts in LandInfra are formally using case driven subset of LandXML functionality, but supported by a UML (Unified Modeling Language) diagrams. Additionally, the standard covers various subject areas defined by so-called Requirement Classes (RCs), which mandate what the subsequent encodings must support in order to claim conformance to LandInfra. Each requirement class (RC) in RCs has a corresponding Conformance Class which explains how the encoding is to be tested for conformance. In addition, the extension project of "IFC for Infrastructure" provides the data model for 3D and 2D alignment information mainly for spatial location of infrastructure assets and further being a baseline for projects like IFC-Bridge and IFC-Road (Benning 2017). For example, the main scope of the IFC Road project is to extend product data model of road facilities with earthwork enabling open data access based on IFC4 (ISO16739) schema in order to secure interoperability in delivering the as-built design model to government. The data schema of IFC-road includes spatial structure, physical structure, properties and earthwork model.

2.2 Asset Classification

In the field of asset management, hierarchical classification of transportation assets is normally used. For example, the Department of Transport in NSW, Australia adopts a four-level classification system, including asset discipline (Level 1; refers to asset disciplines together with the related asset classes, e.g. architecture and service, civil and structures, electrical, fleet, property, signalling and control, technology and telecommunications and track), asset class (Level 2; refers to asset classes and descriptions together with related asset functions for each asset class), asset function (Level 3; refers to asset functions and descriptions relevant for an asset class, such as Complexes, e.g. road carriageway, waterway, bus fleet depot, quarry and land; Entities e.g. building, footbridge, sea wall, jetty, bus and furry; Systems, e.g. air supply system and LV lighting system; and Products, e.g. air dryers and meters) and asset type (Level 4; refers to asset types and descriptions relevant for an asset function). On the other hand, Roads and Maritime Services in NSW adopts a six-level asset classification system, including asset group, asset class, asset function, asset type, asset component and asset sub-component. In addition, Austroads is undertaking an ambitious project to establish a harmonised road asset data standard for use in Australia and New Zealand. The Road Metadata Standard Project has been initiated in response to requests from stakeholders who increasingly need to share data with other road management agencies but are frustrated by the lack of common data standards (Austroads 2019a). This project is an ongoing project at the time of this study.

2.3 Location Referencing

Austroads investigate the potential to harmonise road location referencing and identify a feasible approach to harmonisation of road location referencing. It is discovered that when conducting a data collection survey on the network, it is important that the data is properly referenced and that location can be assigned repeatedly over time with a level of confidence. Without proper location referencing, users would have no way of discerning at what location the data was collected, severely limiting the use of the data. Generally, the location referencing methods adopted by Austroads member authorities can be separated into two major categories:

- Linear referencing defines a location in terms of distance and direction in reference to another location (e.g. 15 km east of location X). Linear referencing is limited to a start and end reference point and is directly related to its geographical location.
- Spatial referencing defines a location using a set of coordinates, which describes a location in two or three dimensions, calculated using a mathematical model of the earth, where all locations are referenced to the same point or against a datum.

Currently, most transportation authorities use linear referencing methods as their primary means of referencing locations within their network. These methods are simple to understand; however, they incur high installation and maintenance costs in order for them to be an effective referencing tool and they are a relative referencing tool because the physical markers used as reference points may change over time as the network is altered.

A move to spatial referencing as the main method of location referencing asset data is anticipated. Given the current issues and constraints associated with spatial location referencing, a new spatial approach to location referencing is likely to require some years to develop and to integrate as each member authority develops and acquires an accurate spatial representation of its centrelines. Over time this technology will become common among all member authorities, and new spatial referencing methods and systems may be adopted as a standard for field location referencing.

2.4 Information Requirement

To enable the owner to safely and effectively operate new assets and refurbished assets, asset information requirements need to be stated clearly before construction commences so as to define the responsibility of transferring the data between organisations.

Prior asset handover and asset acceptance phase, asset information requirements shall be collected and managed at the stage of plan and acquire. Providing and updating the following detailed asset information requirements facilitates assert handover, commissioning, operation and maintenance.

The below example shows the information requirement of an infrastructure asset's life cycle. At the commencement phase, asset information linked to requirements specification, feasibility, environmental, geotechnical reliability, availability, maintainability and safety (RAMS), system safety assurance plan and hazard log, shall be recorded and submitted. In the operation and maintenance stage, configuration data (i.e. asset status), condition data (including asset condition, assessment criteria and remaining life), operational data (including asset criticality and assessment criteria and asset utilisation and capacity), maintenance data (including maintenance activities data, preventive service schedule, work orders for maintenance activity, defects, work breakdown structures, etc.) and other financial data and documents should be recorded.

2.5 The Framework

A digital asset information model for transport infrastructure is therefore proposed based on the above review of literature and standards. The model includes the aforementioned four main modules (Fig. 1)

3 Case Study

VicRoads is the Victorian Government's central road agency. Its purpose is to deliver social, economic and environmental benefits to communities throughout Victoria by managing the Victorian arterial road network and its use as an integral part of the overall transport system.

The aim of this case study was to: (1) understand VicRoads' current road asset operation and maintenance processes; (2) understand VicRoads' current asset management tools or platforms including their functions, data inputs and outputs and underlying data schemas; and (3) benchmark VicRoads' road asset management practice in terms of digitalisation. Document reviews and internal interviews and workshops were conducted to help the team understand VicRoads' current asset management practices. Collected documents included VicRoads organisation chart, design and construction specifications, asset management documents, including, pavement, street lighting, intelligent traffic system and bridges, as well as road design publications and standards. Asset management tools and platforms used in VicRoads, including RAI (Road Asset Inventory) system, SCATS (Sydney Coordinated Adaptive Traffic System), STREAMS (an international award-winning Intelligent Transport System (ITS) that supports road authorities to help save lives, reduce congestion and make road networks safer), AMCS (Asset Monitoring and Control System), Connect (financial System, formerly known as PARMS) and RAS (Road Asset System) were also reviewed. Focus group study was conducted with the participants from five four departments within VicRoads, including asset management team, delivery team, network design services team and asset services team.

3.1 Current Practices

Asset Classification. In 2018, VicRoads developed a new Asset Hierarchy in order to meet the requirements of the new enterprise asset management system version (i.e. Ellipse 6.3) whilst still supporting the essential processes of existing Connect system (formerly known as PARMS-Program and Resource Management System). The new Asset Hierarchy contains three main types of sub-hierarchies: Road Asset Hierarchy, Structures Asset Hierarchy and Electrical/Communications Asset Hierarchy.

Figure 2 shows an example of the Road Asset Hierarchy. The new Hierarchy recognises the existing equipment classes in Connect and allows for the creation of additional records to support assets to be transferred from legacy systems. However, the new Asset Hierarchy can only be maintained, modified and extended by authorised asset

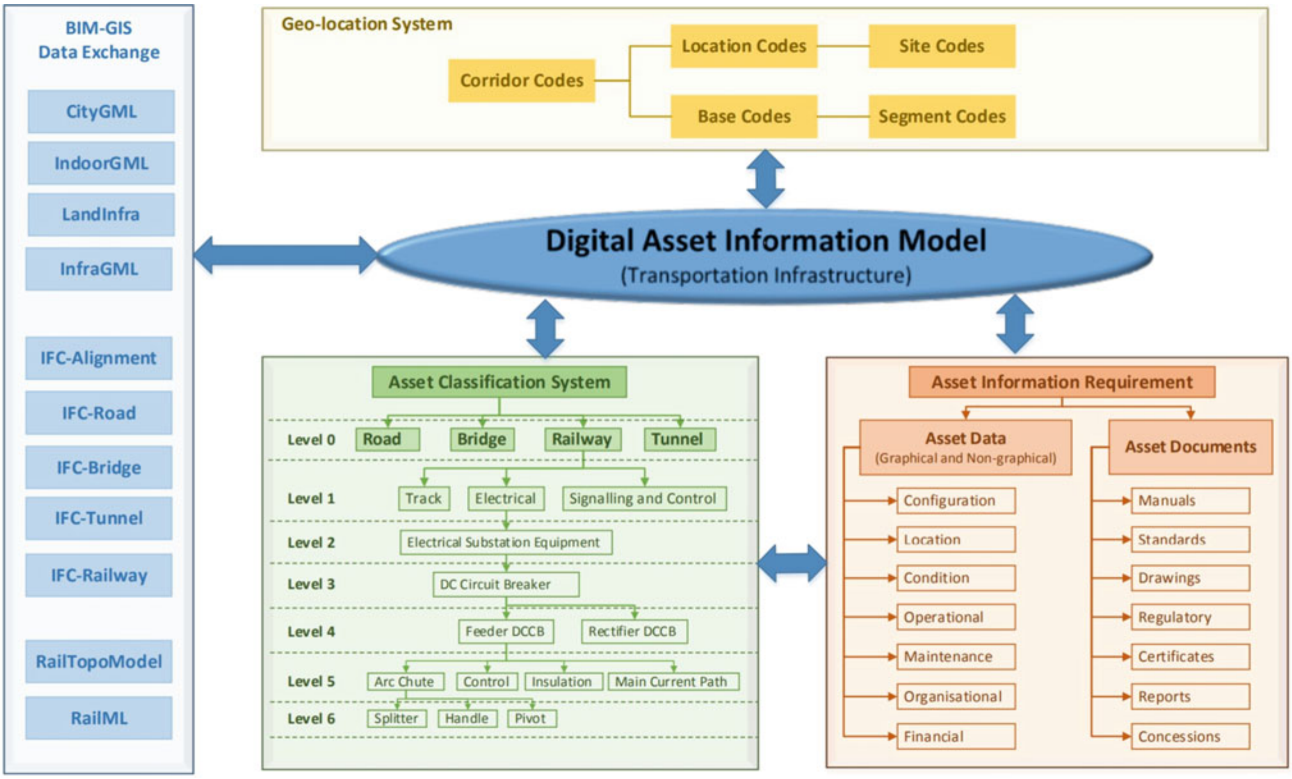

Fig. 1 The digital asset information management framework

managers using standard Connect user functions, which means it cannot be shared and used by other internal Asset Management Tools such as RAI, SCATS, STREAMS and AMCS. Indeed, each tool has its own asset hierarchy to support asset information storage. Therefore, VicRoads Asset Management team needs to maintain at least five different types of asset hierarchies. The lack of a unified Asset Hierarchy increases the difficulty and complexity of asset information capturing, updating and validation. In addition, automated asset data sharing and exchanging among the various asset management systems and platforms becomes impossible.

Location Referencing. Currently, the asset location referencing used is the VicRoads' Standard Road Referencing System (SRRS), which comprises a database model of the declared road network, defined by links joining physical reference markers and fixed features of known and measured locations. The location of any point on the network may then be defined by measured distances along with the link relative to a physical reference marker or fixed feature. The SRRS is a linear referencing method which can be communicated concisely via plaintext. However, a major limitation of linear referencing is that specifying points that are not on a linear feature is troublesome and error-prone, though not entirely impossible. In addition, for the use of linear referencing, the starting points and end points should be well defined, which can be difficult in some cases (Austroads 2019b). For example, if intersection points are used as starting and end points for roads, problems may be created for complex intersections.

Tools and Platforms. In VicRoads, six main systems and/or tools are currently utilised to support asset operation and maintenance: RAI, SCATS, STREAMS, AMCS, RAS and spreadsheets for structures and road assets. RAI is a powerful system, providing fast and efficient filtering and searching utilities, enabling staff members to easily locate asset records. RAI provides the ability for VicRoads to:

- record inventory information regarding electrical, communications, operating systems;
- associate incident and traffic management, and traffic control assets for the full lifecycle of the asset;
- record and track maintenance jobs for each asset;
- record and track jobs relating to faults for each asset and their rectification;
- allocate to, and notify contractors of, jobs for their attention; and
- produce various reports on assets and jobs.

SCATS is an adaptive urban traffic management system that synchronises traffic signals to optimise traffic flow across a whole city, region or corridor. STREAMS is an

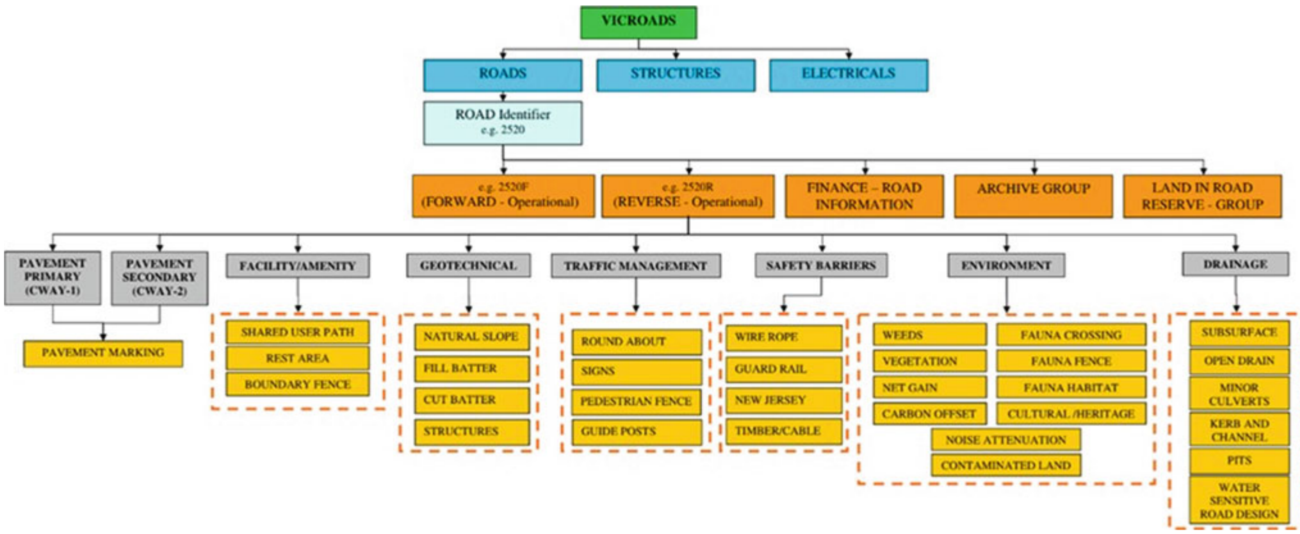

Fig. 2 Road asset hierarchy

international Intelligent Transport System (ITS) that supports road authorities to help save lives, reduce congestion and make road networks safer. It enables road authorities to manage their transport network holistically, rather than as a collection of separate components. AMCS is a smart street lighting management system that improves safety and security through improved visibility, saves money by consuming less electricity and has a positive impact on the environment due to the increased life expectancy of LED luminaires.

It should be noted that these four systems normally work independently. Although there are a few connections built between RAI and SCATS, data searching and sharing across these four systems are difficult and time-consuming. Currently, VicRoads is developing a new platform, vMap, to address this issue. vMap is a one-stop-shop for all spatial data. It contains information from a variety of different data sources around VicRoads including assets, road networks, strategic and planning data and road safety.

3.2 Recommendations

As a result of the benchmarking activity, three early recommendations are proposed to facilitate the transformation from VicRoads' current asset management practice towards the ideal DAIM paradigm.

Recommendation 1: Develop a unified asset classification/hierarchy system and apply it to all the internal asset management systems/platforms. The aim of the unified asset classification/hierarchy system is to provide a single point of reference for asset owners and operators. Four existing asset classification/hierarchy systems, developed by Transport for NSW, NSW Roads and Maritime Services, Austroads and One Network Road Classification (ONRC), can be used as a basis.

Recommendation 2: Move from a Linear Referencing System (i.e. 1D) to a Spatial Referencing System (i.e. 2D or 3D).

Given the limitations of the Linear Referencing System, Spatial Referencing Systems such as Geospatial Referencing Systems (2D) and Geometric Referencing Systems (2D or 3D) should be applied. The former one provides a way to describe locations on the earth's surface in real-world coordinates. This includes GIS as well as coordinate-based mapping systems. Searching and mapping are two key advantages of this referencing system. Most governments rely heavily on GIS applications for managing geographic data. These provide searching (proximity-based) and modelling abilities. The latter is based on digital models that provide coordinate geometry within local model coordinates. Typically, these include digital design (2D or 3D) and BIM models. Some model environments are stand-alone and, more recently, they may be geo-connected (placed in the real world). The family of geometric reference systems are those based on geometric models of infrastructure.

Recommendation 3: Apply BIM and other Digital Engineering technologies in future projects. Digital Engineering or BIM, is much more than developing static models. It can facilitate harnessing the true potential of the built environment industry and creating a platform for multiple applications by integrating digitisation and GIS (Song et al. 2017). In addition, as-built BIM models can accelerate the information handover phase and improve asset data quality in terms of accuracy, integrity and consistency. BIM processes are commonly adopted in either building or infrastructure projects. Other emerging technologies, such as laser survey techniques, have also been employed. Over the next decade, BIM and digital engineering technologies that combine internet of things, data analytics and optimisation will enable asset owners to make informed decisions in the asset planning and management areas.

4 Conclusions

A comprehensive review of digital asset management practices, including asset data exchange, asset classification, asset location referencing and asset information requirements is conducted and validated through a case study. The results suggest that asset management processes and outcomes over the facility lifecycle can be improved using the framework. At an organisational level, large companies are well advised to develop their own digital transformation strategies to facilitate digital asset information management.

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Challenges Affecting Leadership Development in the Construction Industry

Murendeni Liphadzi, Clinton Aigbavboa, Temidayo Osunsanmi, and Didibhuku Thwala

Abstract

The study adopts a data reduction method to examine the presence of any complex configuration among a set of variables on challenges affecting leadership development. A structured survey questionnaire was administered to 111 project managers and construction managers to extract the relevant data, and this produced a relatively high reply rate. After satisfying all the necessary tests of the reliability of the survey instrument, sample size suitability and population matrix, the data was subjected to principal component analysis, resulting in the classification of three new thematic leadership development challenges areas; and were explained in terms of leadership education and training; leadership succession challenge; political instability. These knowledge areas now form the basis for oblique leadership development training requirements in the context of the South African construction industry. The main contribution of the paper is manifested in the use of the principal component analysis, which has rigorously presented an understanding of the complex structure and the relationship between the various knowledge areas. The originality and value of the paper are embedded in the use of contextual task and conceptual knowledge to expound the three uncorrelated empirical utility of leadership development challenges.

Keywords

Construction challenges • Factor analysis • Project manager • Leadership development

1 Introduction

Leadership is a long-term process of influencing people toward fulfilling a mission and particular goals of a group or an organisation (Emad 2014). Leadership process sets goals and enhances commitment to organisational objectives. Studies have revealed that most of the obstacles facing the construction industry relating to leadership and the lack of leadership development. Appropriate leadership can create an organisational culture that is committed to quality, improves efficiency and productivity of teams, enhancing staff's satisfaction, advancing construction performance and finally, meeting personal and organisational goals (Day and Antonakis 2012). Moreover, it is essential to note that leadership development has emerged as an active field of theory building and research, providing a more scientific and evidence-based foundation to augment the long-standing practitioner interest in the topic (Day and Sin 2014). Also, the construction industry has to do with the coordination of different infrastructure duties; thus it is essential to note that all this has to managed and lead by a fitting leader. According to Mbande (2010), the development of any industry hinges on skills development. The structure of this article is as follows. Firstly, leadership development will be examined to summarise the phenomena and its theories that develop and to ascertain factors that play a role in developing successful leadership. Secondly, we will look into the challenges facing leadership development and delineate different factors whereby we will further present the results in line with the challenges affecting leadership development.

2 Leadership Development in the Construction Industry

If one word could describe the principle of construction management, it is responsibility. Thus, project managers are responsible for all that happens in a project. This does not

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mean that the project leader should or could do everything associated with the project. However, it does mean that they have the ultimate responsibility for the project (Liphadzi 2014). To chase success in today's construction industry, people will need to tackle workforce skills gaps, swiftly changing technology, demanding customers and unprecedented pressure on productivity. However, if they can, the opportunities are enormous. This is an industry that the 2016 Farmer Review indicated that it must "modernise or die", and effective leaders with a new outlook hold the secret to making that happen (John 2004). Leadership development focuses on a process of development that inherently involves multiple individuals within the construction industry (e.g. leaders and followers or among peers in a self-managed work team). The construction industry will be more successful if it develops leaders who have an understanding of skills, knowledge and characteristics needed of a project or construction manager (Moore 2006). The nature of leadership development is inherently multilevel and longitudinal (Emad 2014). Researchers such as Kotter (2001) have noted the importance of individual identity in developing leadership skills and expertise as part of the leader development process. Other researchers have examined issues of cognitive and metacognitive skills at the core of leadership potential (Khoza 2006). Bennis and Nanus (2007) noted that leadership development approaches are transitioning from the idea of teaching skills and competencies to teaching values and concepts. This means that leadership development programs must become more intimate and unique to individuals. Jarad (2012) recognised that there are nine critical drivers for leadership development which include; long-term drivers—developing future leaders, retaining staff, the growth of the company, equip staff for change and sustained professional development, and short-term drivers—strengthen teams, motivate staff, increased efficiency and increase competitiveness. Also, Jarad (2012) is of the view that construction organisations can develop leadership and management skills by developing a culture of teaching, mentoring, self-study and frequent job changes. There is the need for a shift in the way project managers function and lead projects, and it is essential for them to develop as leaders to successfully operate in the increasingly complex working environment of the construction industry (Bass and Avolio 2004). In the fast-changing construction industry, there is mounting pressure on project managers to do more with fewer people and less resources. Under such circumstances, the people-side of project management or leadership is vital. The next section articulates the challenges affecting leadership development.

3 Challenges Affecting Leadership Development in the Construction Industry

There are numerous challenges facing today's construction and project managers, some are new to the construction industry and some are old, but effective leadership should be one of the priority in overcoming this challenges (Liphadzi 2014). Businesses today face several challenges to operate proficiently and sustain competitive advantage, and it is often incumbent upon company leadership to provide the proper direction to help their teams navigate these challenges and adapt appropriately. Without a steady pipeline of skilled individuals with the knowledge, skills and experience to step into leadership roles or an effective process to identify high-potential employees and give them the needed training to be effective leaders, organisations will be unprepared to handle the changes and challenges of the future (Jarad 2012). Thus, it is vital for organisations to take serious attention to leadership development. While construction organisations recognise the need for effective leadership development, they face several significant challenges in their efforts to develop future leaders.

Cunningham and Rostron (2014) cited the following challenges affecting leadership development among organisations; balancing long-term and short-term business requirements, lack of opportunity, lack of a formal structure, Inconsistent buy-in across the organisation, lack of support from senior leadership, lack of self-confidence by managers, lack of accountability for the application of new skills and knowledge to the job. Furthermore, Curphy (2014) stated that there is a need to have context and relevance when planning for leadership development. Similarly, Todd Macey, president of Vital Learning, says the challenge to leadership development is the fact that organisations do not focus on outcomes or the returns of the development strategy. According to Glesson (2016), a lack of awareness of the leadership development programmes are accessible. Moreover, the process for being considered for a leadership role is often ad hoc and nontransparent. Leadership development practices are often fragmented and lack an overall strategy that is embedded within the organisations (Weiss and Molinaro, 2005). Likewise, Cunningham and Rostron (2014) stated that inadequate internal resources to deliver leadership development programmes was part of the challenge. In addition, the lack of alignment between business strategy and the leadership development strategy of the organisation. The essence of the challenge with leadership development is that organisations invest heavily in leadership development, but do not necessarily see a real or justifiable return on the investment. One of the main reasons for this is the methodology employed for leadership development (Jarad 2012). Curphy (2014) further simplified the challenges in leadership development as the evaluation problem, definition problem, the people problem and the content problem. In relation to the evaluation problem, he stated that it is vital for the LD programmes to be evaluated consistently, whereby the outcomes focus on the skills, behaviours, competencies and collaboration. Sadly, over the years, researchers have found that L&D programs for leadership development are missing the mark. In the 2016 State of Leadership Development report, 75% of respondents said more significant innovation was needed in learning techniques used in leadership development programs. Lastly, Glesson (2016) denoted that organisations no longer have a leadership challenge but a developmental challenge.

4 Methodology

The above literature review provides a systematic understanding of the recent developments in leadership development challenges. It allows the identification of context to leadership development knowledge areas and research. The review identified twelve (12) leadership development challenges (LDC) specific to the construction industry. Subsequently, a self-administered structured survey questionnaire was used to collect primary data from project managers and construction managers, the principal research question asked was as follows; what are the challenges facing leadership development in the South African construction industry? This study adopted a structured survey approach, whereby 111 project managers and construction managers where sampled to elicit relevant data on Leadership development challenges. Quantitative research makes use of statistical analysis, where findings are conclusive and descriptive (Yong and Pearce 2013) Statistical Package for Social Sciences (SPSS) computer software was used to conduct data analysis. Both descriptive analysis and EFA were conducted. More so, the study adopted a convenience sampling approach, which is also referred to as a non-random sampling method. The design is that of an exploratory factor analysis called principal components analysis (PCA). Used in order to gain a purer understanding of the traits, PCA is applied to reduce the proposed dimensions into smaller factors. Yong and Pearce (2013) affirm that the main drive for factor analysis is to reduce data based on shared variance so that patterns and relationships can be easily read and comprehended. Factor analysis reduces a large number of variables to a manageable size (Tucker and MacCallum 1997). Moreover, the analytical tool adopted was aimed to explore the inherent characteristics and relationships between these 12 variables identified. Justification for looking at the LDC variables at this stage is that these variables are firmly rooted in the theoretical literature of leadership development, but it is not clear which of the variables would measure the same underlying effect. In the survey, respondents were asked to rank the relative significance of the 12 LDC variables, respectively.

5 Data Analysis

5.1 Factor Analysis (Principal Component Analysis)

According to Field (2005), Badu (2009), factor analysis is useful for finding clusters of related variables and thus ideal for reducing a large number of variables into a more easily understood framework. Factor analysis addressed some pertinent issues relating to the appropriate sample size for undertaking and establishing the reliability of factors analysis (Field 2005). Data were subjected to the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy which recorded a substantial value of 0.671. KMO and Bartlett's measure is used to measure sampling adequacy in the use of factor analysis (Badu et al. 2009). The KMO statistic varies between 0 and 1 the value of zero indicates that the sum of partial correlations is large relative to the sum of correlations, indicating dispersion of pattern of the correlations and therefore factor analysis is likely to be inappropriate (Gorsuch 1983). A value close to 1.00 indicates that patterns of correlation are relatively compact and so factor analysis should yield distinctive and reliable factors (Badu et al. 2009). However, the literature suggests that the KMO value should be greater than 0.50 if the sample size is adequate (Child 1990; Field 2005). Subsequently, as presented in Table 1, the KMO measure of this study obtained a high value of 0.671 suggesting the adequacy of the sample size for the factor analysis. The Bartlett's test of Sphericity was also significant suggesting that the population was not an identity matrix.

After fulfilling all the necessary tests of the reliability of the survey instrument, sample size adequacy and population matrix, the data were subjected to factor analysis using principal component analysis (PCA), with varimax rotation. Earlier to principal component analysis, the communalities involved were first established. Communality illustrates the total amount original variable shares with all other variables included in the analysis and is very useful in deciding which variables to extract finally. The average communality of the variables after extraction was above 0.60. The standard rule about communality values is that; extraction values (eigenvalues) of more than 0.50 at the initial iteration indicates that the variable is significant and should be included in the data for further analysis or otherwise removed (Badu et al. 2009).

Table 1 KMO and Bartlett's Test

Kaiser–Meyer–Olkin Measure of Sampling Adequacy			671
Bartlett's Test of Sphericity		Approx. Chi-Square	240.046
	Df		66
	Sig		000

The eigenvalue and factor loadings were set at common high values of 1.00 and 0.50 respectively (Field 2005). Utilising the latent root criterion on the number of principal components to be extracted suggests that three components should be extracted as their respective eigenvalues are greater than one.

As demonstrated in Table 2 and supported by the scree plot in Fig. 1, three (3) components with eigenvalues greater than 1.0 were extracted using the factor loading of 0.50 as the cut-off point. The total variance revealed by each component extracted is as follows: The first principal component (component 1) accounted for 25.35% of the total variance while the second principal (component 2) component, explained 12.94% of the remaining variation not explained by the first component. Component 3 accounted for 10.33%. The cumulative proportion of variance criterion, which says that the extracted components should collectively explain at least 45% of the variation, shows that the three extracted components cumulatively explained 48.63% of the variation in the data set. Scores are numbers that express the influence of an eigenvector on a specific sample.

The ability to interpret of results PCA can be enhanced through rotation (Field 2005). The rotated factor solution is displayed by default and is essential for interpreting the final rotated analysis. Rotation suggests the behaviour of the variables under extreme conditions and maximises the loading of each variable on one of the extracted factors while minimising the loading on all other factors and it is best to factor output solutions for interpreting factor analysis. Table 3 presents the results of the rotated component matrix of the PCA. The next stage involved the analysis of the presence of any complex structure among the variables. A complex structure is said to be present when a variable has a factor or component loading higher than 0.50 on more than one component. Loadings reveal the influence of each original variable within the component. A check on Table 2 shows that all three components had more than one variable loading on them, thus resulting in the keeping of all the three components. What remains is the interpretation of the three principal components extracted. It is instructive to note that the original 12 variables have been summarised into three new uncorrelated variables.

6 Discussions

Based on the analytical examination of the inherent relationships among the variables under each component, the following interpretation was deduced to represent the principal dimensions of the components. For instance, component 1 was labelled leadership education and training challenges; component 2 was labelled leadership succession challenge and component 3 was themed political instability challenge. These names were derived based on their

Table 2 Rotated component matrix

Component	Total	% of variance	Cumulative %	Total	%variance	Cumulative %	Total	% variance	Cumulative %
1	3.042	25.352	25.352	3.042	25.352	25.352	2.202	18.348	18.348
2	1.553	12.942	38.294	1.553	12.942	38.294	2.028	16.903	35.251
3	1.240	10.336	48.631	1.240	10.336	48.631	1.605	13.379	48.631
4	1.111	9.256	57.887						
5	0.992	8.270	66.157						
6	0.922	7.687	73.844						
7	0.687	5.725	79.569						
8	0.624	5.201	84.770						
9	0.602	5.013	89.784						
10	0.473	3.943	93.727						
11	0.414	3.450	97.176						
12	0.339	2.824	100.000						

Fig. 1 Scree Plot

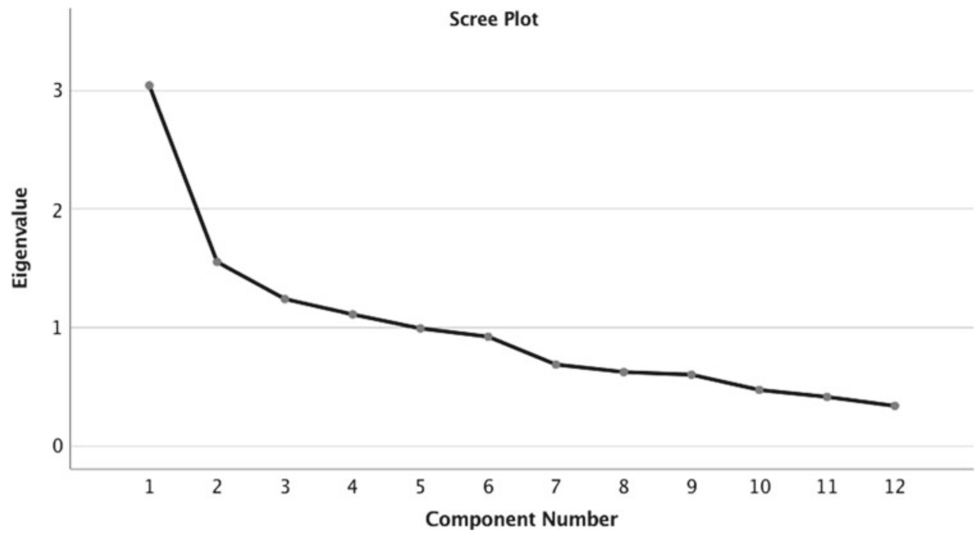

Table 3 Rotated component matrix

	1	2	3
Lack of skills	0.789		
Lack of training	0.763		
Inexperience	0.688		
Ineffective organisational culture	0.602		
Lack of opportunity		0.720	
Lack of incentives		0.676	
Lack of self-confidence		0.627	
Diversity in society			
Unstable political environment			0.654
Racial divide in the workplace			0.569
Autocratic management			0.551
Educational background			

Extraction method: Principal component analysis. Rotation method: Varimax with Kaiser normalisation.

interrelated characteristics and combination of variables with high factor loadings.

6.1 Component 1: Leadership Education and Training

The first principal component (PC1) in Table 2 reported high factor loadings for the variables lack of skills (0.789, 78%) and lack of training (0.763, 76%). The numbers in brackets indicate the respective factor loadings, which assume the relative importance of the variable in the data set of the component. The component accounted for 25.3% of the variance explained as shown in Fig. 2. This finding supports the proposition of (Emad 2014), that there should be structured programmes that train managers. Also, Gomez (2018) stated that there is a lack of leadership programme awareness within the construction industry.

6.2 Component 2: Leadership Succession Challenge

The second principal component (PC2) in Table 2 reported high factor loadings for the variables lack of opportunity (0.720, 72%) and lack of self-confidence (0.627, 62%). The numbers in brackets indicate the respective factor loadings, which assume the related importance of the variable in the dataset of the component. Research by (Jarad 2012) emphasises that it is essential for the current leaders to give way and prepare future leaders. This finding further supports work by Glesson (2016), who stated that we currently have a succession developmental challenge within organisations.

6.3 Component 3: Political Instability Challenge

The third principal component (PC3) in Table 2 reported high factor loadings for the variables unstable political environment (0.654, 65%) and racial divide in the workplace (0.569, 56%). The numbers in brackets indicate the respective factor loadings, which appropriates the relative importance of the variable in the dataset of the suitable appointed component. This finding supports the suggestion by (Jarad 2012) and Ofori (2016), they asserted that willingness within organisations is of importance to developing leaders within a construction firm. Subsequently, it is vital for organisations to have a plan for all their employees to be able to overcome the leadership development challenge in the construction industry.

7 Conclusion Implications and Recommendations

As illustrated in the literature many studies show the need for leadership development, but there is less attention on how to grow existing managers within the construction industry. Therefore, there are not many studies in the area of developing leadership in the construction industry. Construction industry stakeholders need proper strategies to prepare future leaders who are capable of taking control and also influence. From the 12 LDC variables, the study reduced the variables to three challenging component areas forming the basis for lateral leadership development requirements in the context of the South African construction industry. Contribution of the paper to the body of knowledge is manifested in the use of the principal component analysis, which has rigorously provided understanding into the complex structure and the relationship between the various knowledge areas. The originality and value of the paper are embedded in the use of contextual-task conceptual knowledge to expound the three uncorrelated practical utility of leadership development challenges. Besides demonstrating the challenges affecting leadership development in the construction industry, this study also has the effort to launch possible methods that can be implemented when designing a leadership development framework for the construction industry' organisation, which is a need in developing current managers and employees. Implementing leadership education and training programmes for leadership development in the South African construction industry is recommended; thus, built environment education and training providers should provide leadership development methods which are flexible and integrative. Therefore, future research can develop and evaluate leadership frameworks, moreover assess the return on investment of the appraised leadership development programmes and models.

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Enhancing the Visualization of Problems Tracking and Management Integrated BIM Technology for General Contractor in Construction

Yu-Cheng Lin and Ya-Ting Hsu

Abstract

Recently, BIM (Building Information Modeling) technologies are utilized for general contractors in various applications of construction management. The applications of BIM technologies become the most critical and useful tool for construction management during the construction phase. Despite many articles and much discussion in practice and academic literature, there is a lack of systematic approaches to enhance identified BIM-based problems illustration and tracking management for effective construction management. With the utilization of the API (Application Programming Interface) and web-based system development for BIM-based problems illustration and tracking management, this research proposes a new and practical methodology to apply BIM-based problems tracking and management. Using API and web-based system development, this study proposes a BIM-based tracking and management of identified problems for general contractors. Furthermore, the proposed system can enhance the effectiveness of BIM-based tracking and management of identified problems integrated BIM technologies. The proposed system is then applied in a selected case study of a building project in Taiwan to verify our proposed methodology and demonstrate the effectiveness in practice. Finally, this study summarizes the advantages, limitations, and suggestions for further BIM-based tracking and management of problems in construction management.

Keywords

Building information modeling • BIM • Construction management • General contractor • System development

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1 Introduction

When the application of BIM models are adopted in the construction project, the amount of BIM models will be increased and necessary to be communicated and managed effectively. Many problems occur at the jobsite during the construction phase, all the tracking and management of identified problems are a very important consideration for successful construction management. Effectively tracking and management of identified problems between project participants of the general contractor can improve construction management during the construction phase, thereby eliminating unnecessary mistakes and reworks. Conventional communication methods include face-to-face meetings, telephone communication, and virtual design and construction (VDC). However, a typical problem encountered during conventional communication is that discussions may not be effectively tracked and shared with others. During the construction phase, on-site engineers and BIM engineers typically communicate and respond BIM-related identified problem and problems thorough paper-based document or e-mail way. In order to assist involved on-site engineers, BIM engineers, and BIM managers in communicating and responding discussion information special related to BIM models, the primary objective of this study is to facilitate the visualization of tracking and management for identified problems among project participants of the general contractor during the construction phase. Identifying, tracking, controlling, and managing identified problems are critical tasks in construction management. This study develops the BIM-based tracking and management for identified problems (BTMP) system for engineers to enhance sharing and tracking of tracking and management for identified problems efficiency. Notably, this study integrates a novel web-based communicating platform and the 3D BIM approach to communicate and manage BIM-based tracking and management for identified problems in a 3D BIM environment. The identified problems, which typically

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involve project engineers from different fields, often has numerous issue problems. The issue information and status of identified problems regarding the change or updated from on-site engineers' feedback is generally not transmitted effectively to related engineers or manager, or effectively exchanged among on-site engineers. Moreover, on-site engineers frequently change their own work and rarely feedback updated information of BIM model. BIM-based tracking and management for identified problems are currently not widely applied in the construction industry because no appropriate platforms exist that assist project participants in communicating and managing BIM-related identified problems during the construction phase. By utilizing the BTMP system, on-site engineers and BIM engineers can obtain records of previous and current discussion regarding BIM models in a given project and manage BIM-based identified problems. Furthermore, Jobsite engineers and managers can track and access the most recent BIM-based tracking and management for identified problems during the construction phase. All responses from jobsite engineers and managers can be updated rapidly and made available to on-site engineers via the web-based environment for BIM-based construction management.

2 Literature Review

BIM is a digital tool that supports continual updating and sharing of project design information (Gould and Joyce 2008). BIM digitally contains precise geometry and relevant data needed to support the design, procurement, fabrication, and construction activities to describe 3D object-oriented CAD (Eastman et al. 2011). BIM is a revolutionary technology and process that has quickly transformed the way buildings are conceived, designed, constructed and operated (Hardin 2009). Furthermore, there are previous researches regarding the system development integrated BIM technology in construction. Choi et al. (2014) developed an automated system that designers and owners can check the evacuation regulation compliance of BIM data (Choi et al. 2014). Oh et al. (2015). presented an integrated design system for the improvement of BIM-based collaborative design (Oh et al. 2015). Bortolini (2019) developed a logistics planning and control model for site assembly of ETO prefabricated building systems using BIM 4D modeling (Bortolini et al. 2019) Li et al. (2018). designed an Internet of Things (IoT)-enabled platform integrated IoT and BIM for prefabricated public housing projects in Hong Kong (Li et al. 2018).

Despite many articles and system developments in academic and practice literature, there is a lack of systematic approaches to BIM-based tracking and management for identified problems in the 3D visual environment. To solve this problem, this study BIM-based tracking and management for identified problems (BTMP) system for engineers to enhance sharing and tracking of tracking and management for identified problems efficiency. Notably, this study integrates a novel web-based communicating platform and the 3D BIM approach to communicate and manage BIM-based tracking and management for identified problems virtually.

3 System Developments

Figure 1 shows the concept framework of BTMP System. The BTMP system is based on the Microsoft Windows Server 2008 operating system with an Internet Information Server (IIS) as the webserver. The BTMP system consists of three different user areas—project engineers, BIM manager, BIM engineer. Access to the BTMP system is controlled by passwords. In this study, BIM is used as an information model in the BTMP system. One purpose is to utilize BIM models as the visualization tool of identified problem issues. The BIM models are applied in the BTMP system to link and relate to identified problem issue information (such as identified problem issue descriptions and identified problem issue location). Autodesk Revit Architecture and Revit MEP were used to create the 3D BIM models. Identified problem issue information integration with the BIM components in the 3D BIM models was achieved using the Autodesk Revit application programming interface (API) and Microsoft Visual Basic.Net (VB.Net) programming language. Visual 3D-based identified problem issue maps were developed in Autodesk Revit Architecture and Revit MEP by programming in VB.Net and using Revit API. The BTMP system was developed to integrate acquired data from different software programs and all identified problem issue information, such that BIM files can be exported to an ODBC database for connection with the BTMP system. This following section demonstrates the implementation of functionalities in the BTMP system.

3.1 Authority Management Functionality Module

The authority management module is an access control mechanism preventing unauthorized users from entering the system or retrieving sensitive related information. The BTMP system requires all project participants to register. There are four types of users in this study. They are system administrator, BIM engineers, BIM managers, and project participants (on-site engineers).

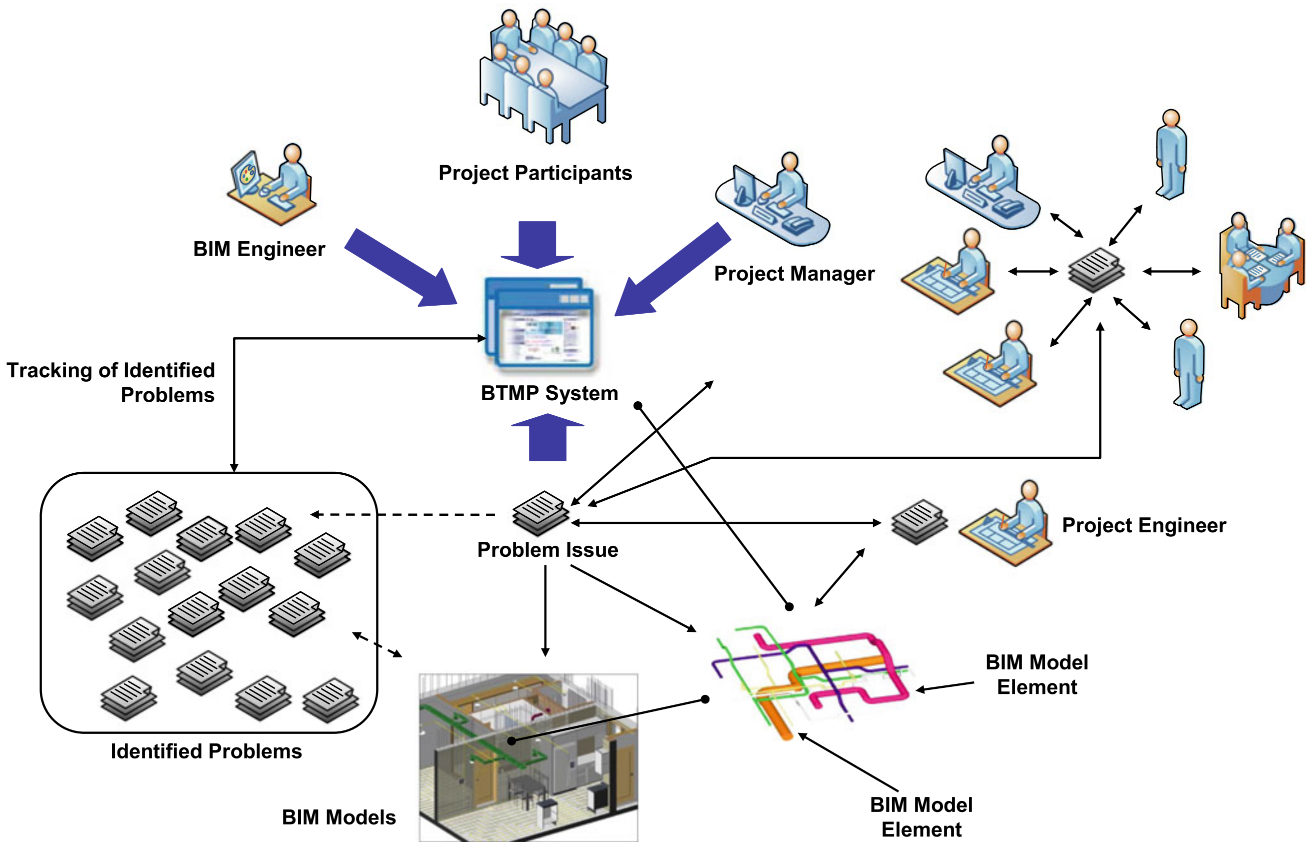


Fig. 1 Concept framework of BTMP System

3.2 Identified Problem Edition Functionality Module

This identified problem edition module is to let users edit-related BIM-based identified problem information associated with related perspective BIM information (or attached files). Furthermore, the information includes the proposer name, related responded participants and contact mail information. Users associated with specific issues can post questions, responses, and comments, thereby generating a permanent record of discussions regarding specific issues.

3.3 Identified Problem Alert Functionality Module

This module helps all project participants set up an alert service for monitoring and managing identified problem events via e-mail. Importantly, dates related to the notification of identified problem issue information are recorded systematically. Furthermore, this module provides convenient access and a push-based function to help engineers respond to situations before identified problem events are tracked and others respond.

3.4 Identified Problem Document Functionality Module

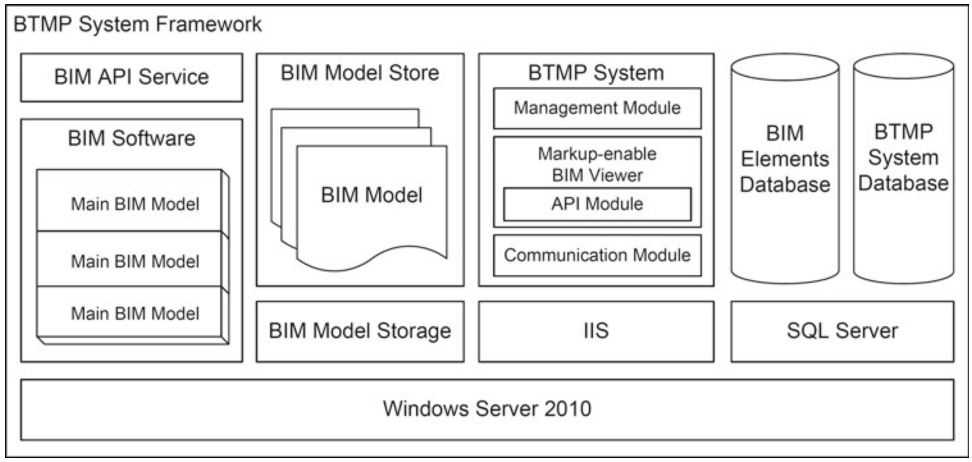
The identified problem document management module allows users to download identified problem-related electronic documents from the BTMP system.

Additionally, the module provides identified problem issue document edition management for identified problem issue tracking. Table 1 illustrates the description of each color for the BIM-assisted visualization for problem management status usage. Furthermore, Fig. 2 shows the framework of BTMP System.

4 Discussion

The case study includes a contractor with over 20 years in developing office buildings experience in Taiwan. During the construction phase, the projects generally include a general contractor, two subcontractors, and seven suppliers. The general contractor aims to improve construction management work and thus, encourages all stakeholders to use the BTMP system to manage their respective identified problem and consequently, improve construction

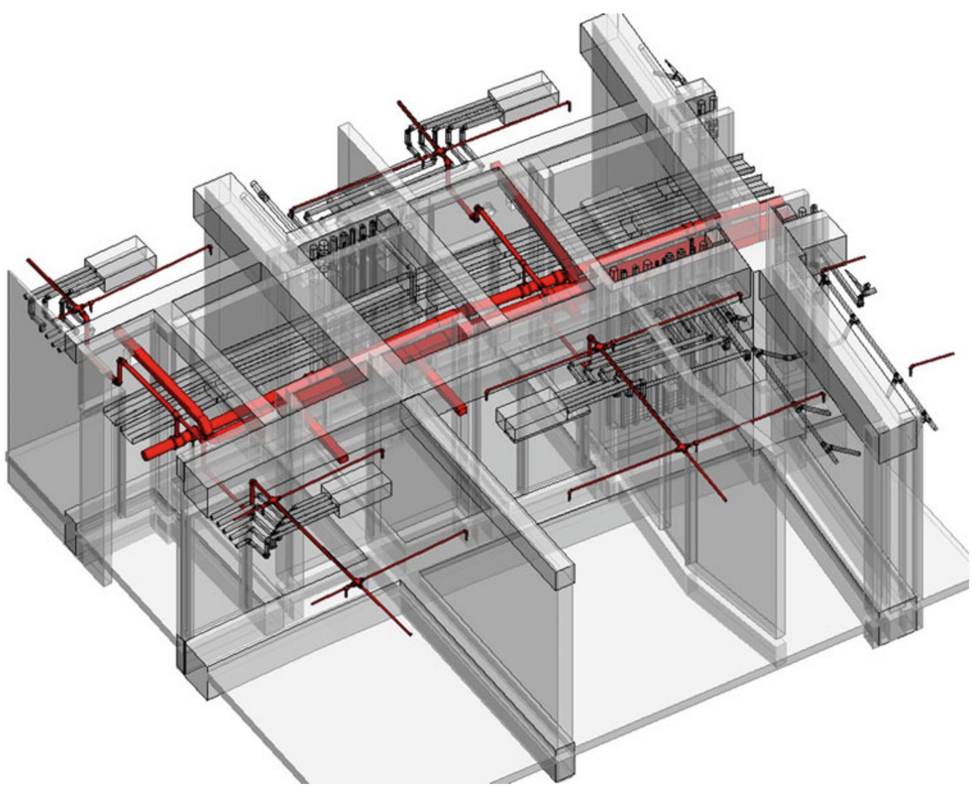
Fig. 2 Development framework of BTMP System



management and the efficiency of identified problems management work. Figures 3 and 4 present the use of the BTMP system to track and manage MEP pipe system problems of the case study.

The following are illustrated major advantages and disadvantages based on the case study. User feedback indicated that the primary advantages to using the BTMP system were as follows: (1) Track and manage identified problems effectively; (2) Illustrate different status of identified problems through 3D BIM models visually; and, (3) understand the current status of all identified problems in the project. User feedback indicated that the primary barriers to using the BTMP system were as follows: (1) insufficient updated information related to various identified problem issues of BIM models; and (2) substantial amounts of time and assistance needed for BIM engineers to modify and update BIM model information. In the case study, overcoming the resistance of project engineers in using the system during their work was important. Overcoming this resistance has been regarded as one of the major prerequisites for the successful implementation of a BTMP system. If resistance to use BTMP cannot be overcome, then the use of the system will be likely to end with its use by system development division, which may have been driving the system implementation.

Fig. 3 MEP Pipe system install problem (pending status) in the case study



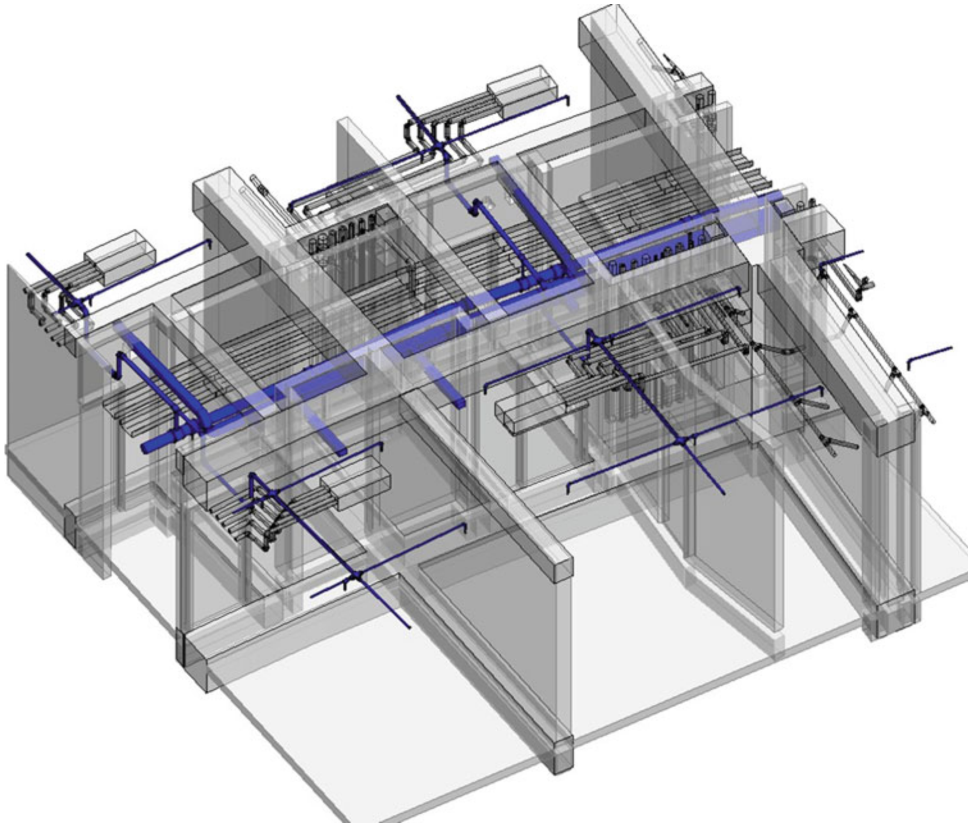


Fig. 4 MEP Pipe system install problem (completion status) in the case study

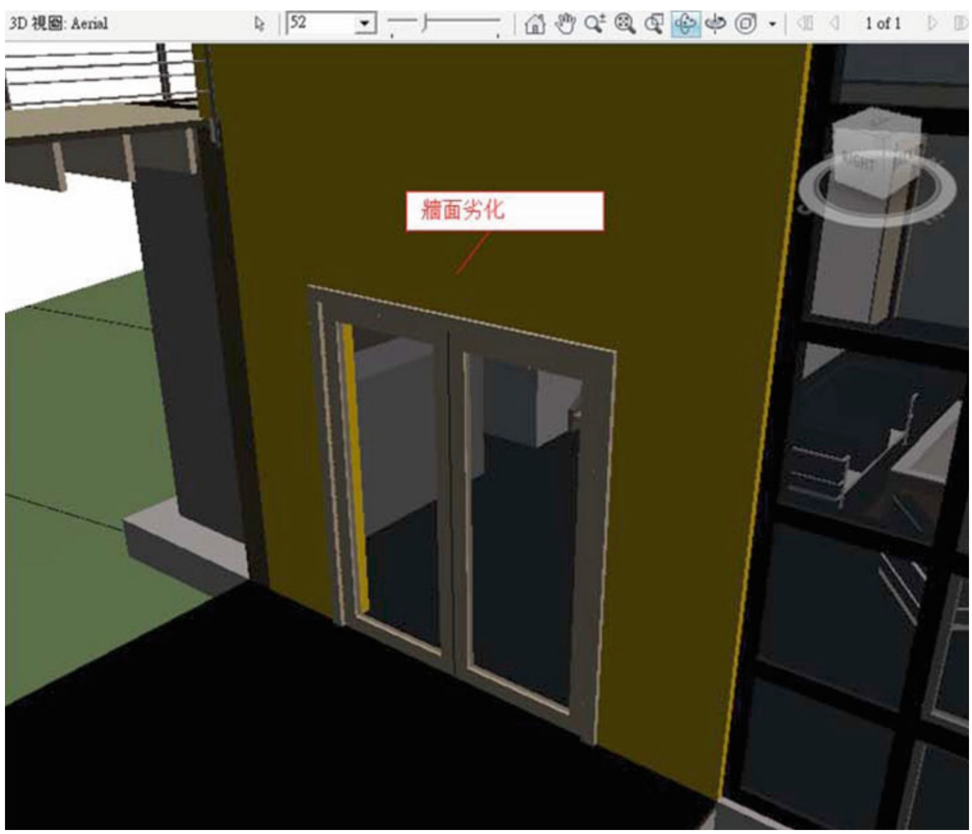


Fig. 5 The system interface of the BTMP system using in the case study

Table 1 Description of each color of status usage in the BIM-assisted visualization

Color of status Usage	Description
Blue color	To index identified problem regarding pending status
Yellow color	To index identified problem regarding in-progress status
Blue color	To index identified problem regarding completion status

If the whole BIM model is presented directly to the page on the BTMP system, it will affect the smoothness and effectiveness of the system operation. Therefore, the whole model is necessary to split into parts of the BIM model based on the user requirement to review BIM models effectively. Figure 5 presents the system interface of the BTMP system using in the case study.

5 Conclusions

The application of BTMP integrated with the BIM approach for building projects during the construction phase is proposed in the study. This study proposes the novel web-based BTMP system for manager, jobsite engineers, and BIM engineers as a BTMP platform integrated with BIM models through the web browser. The web-based BTMP system enhances tracking and management for identified problems effectively through 3D BIM environment. The BTMP system provides insight into factors impacting IC activities, which in turn assists projects participants and BIM engineers to improve BIM-related communication and management performance. The tracking and management for identified problems by the BTMP system allows projects engineers and jobsite engineers to view 3D BIM models and identified problems in the 3D BIM environment.

The BTMP system updates the latest information of identified problems models automatically synchronized to the BIM elements database. All required information in the BIM models automatically synchronized to the BIM elements database based on required information for BTMP by the API development. The BTMP system will retain existing data and update only the changed data after synchronization if the exported information already exists in the BIM elements database. The main characteristic of the BTMP system is to provide topic description while communicating with components that are relevant to 3D BIM model and associated 3D view for project engineers to quickly understand problems associated with BIM models through the web browser. The proposed solution can reduce the cognitive differences of tracking and management for identified problems among project engineers and managers. When issues problems all related to component selection, making the issue topics and BIM models relevant, effective integration of the course of the discussion in the BIM model to improve the status of the tracking and management for identified problems.

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Challenges of Conducting Market Research During Project Appraisals of Real Estate Investment

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Abstract

Real estate investments are known for requiring huge capital outlay thereby making prospective investors interested in understanding the risk and possible return from their investment. The risk and return attributed to the investments can only be revealed through conducting project appraisals. Unfortunately, the project appraisals of real estate investment are tainted with numerous inaccuracies and discrepancies. These inaccuracies have been attributed to poor market research conducted by estate surveyors and valuers. Therefore, this study appraises the challenges of conducting market research during project appraisal of real estate investment. The study adopted convenience sampling for administering the questionnaire to estate surveyors and Valuers in Lagos metropolis. A total of 56 questionnaires were obtained from the professionals out of 70 that were distributed. The data were analysed with statistical package for social science (SPSS version 20), using, mean score and Kruskal–Wallis test. The study discovered that the challenges faced by the estate surveyor in conducting market research are pressure from their clients to deliver the appraisal report and difficulty in sourcing information. The study recommends that a data bank should be created to facilitate the ease of information sourcing. The study contributes to improving the quality of project appraisal in the country.

Keywords

Estate surveyor • Market research • Project appraisals • Property investor

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1 Introduction

Real estate investment requires enormous capital outlay thereby making prospective investors interested in the risk and return accrued to their investment (MacGregor et al. 2018). The risk and return of an investment can only be ascertained through conducting project appraisal (Gambo et al. 2012). Hyari and Kandil (2009) described Project Appraisals (PAs) as the process involved with the assessment of real estate investment before committing resources into the investment. Similarly Fanning (2005), provided a detailed opinion regarding PAs and described it as the collective procedures that provide a detailed risk and return associated with an investment. This implies that PAs are usually conducted before the commencement of a project therefore making it significant for a potential investor. Regardless of its significant Johansson and Kriström (2015) believed PAs has been a source of confusion for real estate investors. The confusion originates from the following; poor definition of the stages involved in appraisal and lack of documentary evidence after carrying out the appraisal. On the other hand, examined Gambo, et al. (2012) discovered that PAs is becoming less effective in our dynamic and unstable economic system within the country. The reduced effectiveness is experienced in a development project that was judge viable by surveyors in their appraisals have turned out to be unviable Oloyede, et al. (2011). Asserted that the poor effectiveness of project appraisals has resulted in professionals been regarded as incompetent and the client neglecting their professional advice. Adebimpe and Bashir (2018) reported that poor effectiveness of appraisals report could be associated with negligent of the surveyor (professional) in conducting proper market research Ogbuefi (2002). Described market research as a procedure that evaluates the market condition to determine the type of real estate investment that should be introduced into the market. Nnamdi, et al. (2018) noted that market research is a pre-requisite for effective project appraisal MacGregor, et al.

S. M. Ahmed et al. (eds.), *Collaboration and Integration in Construction, Engineering, Management and Technology*, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-030-48465-1_72

(2018). Asserted that market research will ensure effective project appraisal because it will show supply and demand analysis of the investment. Fanning (2005) further stressed the advantage of market research in ensuring accurate project appraisal because market research has two primary functions. First market research provides the data input to identify the highest and best use of a property in terms of property use, market support and market participants. While the second function is it provides data input and identify the key factors that are measured by applying the three approaches to value. Despite the advantage of market research in ensuring accurate PAs Gambo, et al. (2012), affirmed that estate surveyors rarely adapt market research in Nigeria. Also, when they conduct market research, it is only done for 2 days which should be a continuous process as discovered by (Greer and Kolbe 2003). Against this background, this study examines the challenges faced by estate surveyors in conducting market research for PAs with a view of determining the reasons estate surveyors do not apply market research for project appraisals.

2 Review on Market Research

Greer and Kolbe (2013) asserted that market research is used to identify potential demand for a property while taking into consideration the future and means of satisfying them. Gambo, et al. (2002) described market research as a procedure that evaluates the market condition to determine what product or type of real estate investment that should be introduced into the market. The investment should also be capable of competing effectively with existing development rather than merely duplicating what already exists in the market.

Fanning (2005) stipulated that the reason for carrying out market research is to introduce a development that will effectively contend or complement the existing development rather than merely duplicating them. This implies that market analysis aims to introduce a product that will fill any gap that exists in the market in terms of quality or quantity. MacGregor, et al. (2018) asserted that four factors could be used to achieve this function effectively. These factors are illustrated in Fig. 1.

2.1 Stages of Market Analysis

Fanning (2005) identifies the stages of market analysis which is highlighted below.

2.1.1 Data collection; in this case, the proposed development will be oriented towards the study of the site and quality of the access routes to it, past or presents and future population levels within the market area, the social characteristics of the population, capital income level and size of existing and proposed competition to the budget under study.

2.1.2 Data analysis; this is done to understand the current and likely future condition in the market fully. It is broken down into the area and consumer research.

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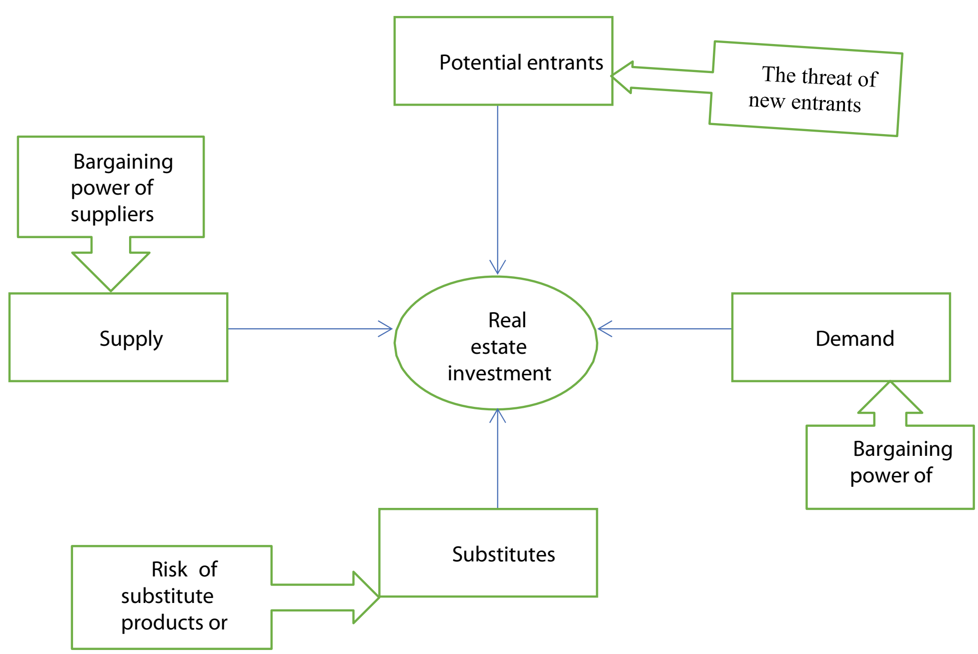

Fig. 1 Factors that ensure market analysis achieved is the desired function. *Source* (MacGregor et al. 2018)

2.1.4 Analysis of the effect of introducing the new budget into the market, thus modifying the present competitive structure.

2.1.5 Developments of conclusions and recommendations based on the preceding.

2.2 Purpose for Carrying Out Market Research

Market studies are conducted to cover the following property development and investment scenario and situations that are highlighted below (Wong et al. 2017).

2.2.1 In the first scenario a site in search of use: the analyst must determine whether there is appropriate support for use and if so delineate the market that supports that use. In this case, the analytic process begins by identifying the productive attributes of the site. It is followed by identification of the productive property capacity the real estate services it can supply and the market of potential users.

2.2.2 The second scenario concerns: a use in search of the site. In this scenario, it begins with an investigation of the broader market to identify the types of services or facilities the market is seeking. If the inquiry is focused on use, the analysis begins by addressing demand, e.g. basic and general demographics. This type of assignment begins with supply and demand analysis then proceeds to productivity analysis which addresses the physical, legal and locational attributes of the site. The market analysis and productivity analysis are then incorporated into the appraisal process.

2.2.3 Real estate as an alternative investment: the focus of the analysis is to identify whether the levels of return and risk associated with the real estate are appropriate given the requirements of the investors. The decision-making models used by the investors are identified to establish the parameters of the problem. Measures of return and risk are linked to standards of market performance and opportunity cost.

2.3 Challenges of Market Research

Gambo, et al. (2012) identify some challenges of market research which are highlighted below:

- Pressure from the client to deliver the appraisal on time
- Difficulty in sourcing for information.
- Not enough resources for an effective marketing plan implementation
- Budgetary constraints to hire the right marketing team members
- Keeping up with marketing trends and strategies
- Rapid technological change
- Heterogeneous and fragmenting markets
- Changes in the economy
- Inability to address the risk profile
- The problem of forecasting future cost and benefits
- Not sure of what direction to go or how to begin.

3 Methodology

The population of the study includes registered Estate Surveying and Valuation firms in Lagos Metropolis. It was reasoned out that research of this type conducted in Lagos would be a true reflection of Estate Surveying and Valuation practice in Nigeria. This is because Lagos serves as the commercial hub of the country thereby attracting numerous real estate investment. The real estate investment within the state further attracts Estate Surveyors and Valuers into the state. The valuers are often charged with the responsibility for conducting project appraisals within the state. However, before preparing a project appraisal market research is usually conducted (Nnamdi et al. 2018).

Estate surveyors are often confronted with numerous challenges during the process of conducting market research. Thus, the aim of this article was centred on appraising the challenges of conducting market research by estate surveyors. The objectives were achieved through the adoption of quantitative research that supports the design of questionnaire. The questionnaire was divided into four sections. The first section examines the personal information of the respondents. The second and third appraised the duration for conducting market research and the sources of information during market research. The last section examined the challenges of doing market research using a five-point Likert scale from strongly agree to disagree. The questionnaire was further administered to the respondents.

The respondents were selected through convenience sampling technique. The sampling technique was used because it ensures easy access for data collection. Data for the study were obtained through field survey using a structured questionnaire. A total of 56 questionnaires were collected from the professionals out of 70 that were distributed. The obtained questionnaire was further scrutinised for errors, omissions and consistencies and all were found to be consistent and thus analysed. Statistical Package for Social Sciences (SPSS) was used to analyse the data gathered. Descriptive statistics such as frequency and mean score were used for data presentation. Also, Kruskal–Wallis test a non-parametric was used to test the hypothesis.

4 Results and Discussion

4.1 Market Research

This section appraises the duration for conducting market research and the response is presented in Table 1. The table shows that almost half (46.4) of the respondents conduct market research for 2 days, 26.9% carry out market research for 1 day and 35% conduct market research for 3–5 days. The table reveals that few (13.5%) carry out market research continuously. However,

The findings from this study coincide with the work done by Gambo, et al. (2018) that discovered that estate surveyors rarely adapt market research in Nigeria. Also, when they conduct market research, it is only done for 2 days. It can be deduced from these study findings regarding market research that it is still a growing phenomenon within the study area as it yet to be conducted continuously as indicated by (Greer and Kolbe 2003).

4.2 Purpose for Conducting Market Research

Table 2 shows that they are three main reasons for conducting market research which are as follows: To convince the financier about the project viability, To determine the highest and best use and to determine the marketability of the project, followed by to determine project feasibility and convince the client of a good job.

4.3 Challenges of Conducting Market Research

The respondents were asked to rate the challenges faced when conducting market research and their outcome is presented in Table 3. Their response was ranked with the aid of a five-point Likert scale from 1 representing strongly disagree to 5 denoted by strongly agree. The table shows that pressure from the client to deliver the appraisal on time is the major challenge faced by surveyors in conducting market research. This finding relates to the study conducted by (Nnamdi et al. 2018) but the focus of their study was on the residential and commercial performance of a property. They discovered that pressure from the client to deliver on time affects property performance. Table 3 shows other factors that affect market research in order of hierarchy are difficulty in sourcing information and not enough resources for an effective marketing plan implementation, while problems of forecasting and not sure of what direction to go was ranked as less important.

4.4 Significant Difference for Challenges Confronting Professionals Conducting Market Research

Kruskal–Wallis test was used to test the hypothesis stating that there is no significant difference among the professional working experience and the challenges in doing market research. The aim of the hypothesis was to determine if the

Table 1 Duration for conducting market research

Duration for conducting market research	Frequency	Per cent (%)
1 day	15	26.9
2 days	26	46.4
3–5 days	13	23.2
Continuous	2	3.5
Total	**56**	**100**

Table 2 Purpose of conducting market research

	%	Rank
To convince financier on the project viability	89.2	1
To determine the Hhghest and best use	88.3	2
To determine the marketability of the project	85.2	3
To determine project feasibility	81.1	4
To convince client of a good job	62.2	5

Table 3 Challenges of conducting market research

	Mean	Rank
Pressure from client to deliver the appraisal on time	4.00	1
Difficulty in sourcing information	3.57	2
Not enough resources for an effective marketing plan implementation	3.57	3
Budgetary constraints to hire the right marketing team members	3.27	4
Keeping up with marketing trends and strategies	3.22	5
Rapid technological change	3.00	6
Heterogeneous and fragmenting markets	2.92	7
Changes in the economy	2.78	8
Inability to address the risk profile	2.57	9
Problem of forecasting future cost and benefits	2.46	10
Not sure of what direction to go or even how to begin	2.35	11

Table 4 Kruskal–Wallis test for difference among the professional working experience and challenges of conducting market

Research	Challenges for conducting market research
Chi-square	49.671
Df	6
Asymp.Sig	0.000

challenges confronting estate surveyors conducting market research is a function of their working experience. The Kruskal–Wallis test is provided in Table 4. The working experience of the respondents was used as a grouping factor or differentiating factor, while the challenges for conducting market research was used as an independent variable.

Grouping factor: Working experience.

The table shows that there is a significant difference among the professionals working experience and the challenges for conducting market research. This implies that the challenges confronting estate surveyors and valuers during market research are a function of their working experience.

5 Conclusion and Recommendation

Project appraisal is crucial at this time when there is an emphasis on investment performance in many parts of the world, and this is even more important in Nigeria where the economy is going into recession. Thus, it creates the need for careful consideration in the course of the investment decision-making process. An efficient project appraisal requires thorough market research which takes into account the underlying conditions of the market. This study examines the challenges of market research for project appraisals in Lagos metropolis. The study finds out that most of the respondents carry out market research for 2 days, 35% conduct market research for 3–5 days and few carry out market research continuously. The majority of the information relied upon for market research by estate surveyors is sourced from phone calls to their colleagues. They are three main purposes for conducting market research which are to convince the financier about the project viability, to determine the highest and best use and to determine the marketability of the project. Pressure from the client to deliver the appraisal on time is the major challenge faced by surveyors in conducting market research, followed by difficulty in sourcing information and not enough resources for an effective marketing plan implementation.

Conclusively, estate surveyors are willing to carry out market research but do not do so because of the pressure on the client to deliver their appraisals on time and as a result of this they conduct market research for just 2 days which should have been a continuous process. It was also discovered that estate surveyors face challenges with the market research process, especially when establishing the condition of the market. The study recommends that the body in charge of regulating and controlling the affairs of Estate Surveyors and Valuers (NIESV) in the country should create a data bank that can easily be accessible. Also, the estate surveyor should take due diligence when preparing appraisal reports. The study as well recommends that market research should be introduced into the school curriculum, as this will help develop the mind of the surveyors on the importance of market research.

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Road Infrastructure Project Success: Understanding the Role of Stakeholder Management in a Rural Setting

Joy Okwuchi Chizitere Oguzie, Ifeanyi Cosmas Nwakanma, Achimba Chibueze Ogbonna, and Augustine Ikenna Udunwa

Abstract

This paper analyzed the effects of stakeholder management(SM) on rural road construction projects using as a case study. Increasing road construction projects failure and abandonment and the impact on the citizens' wellbeing in two administrative areas were the motivation behind this research. Several authorities support the position of a relationship between stakeholder identification and management and rate of success of road construction projects. The main research instruments used was a standardized questionnaire based on Likert five-point scale. The data collected from the respondents in the field were subjected to Analysis of Variance (ANOVA) and F-Test. The result showed that there is a significant relationship between failure and abandonment of road construction projects and the management of stakeholders. Proper project stakeholder identification has a significant contribution to the implementation of successful rural road construction projects.

Keywords

Construction • Imo • Insurgency • Stakeholders • Road

1 Introduction

Road construction projects provide most countries' fixed assets and major stimulus to an improved and functional economy and hence qualify as infrastructure to the extent that they belong to the group of "basic structures and facilities that are essential to the generation of economic growth and development in modern economies" (2015). Like all projects, road construction projects involve varying, differing, conflicting, and sometimes competing stakeholders' interest, objectives, backgrounds, responsibility, and authority such that can change over the course of the project life cycle. Examples of such responsibility and authority may range from occasional contributions in surveys and focus groups to full project sponsorship, which includes providing financial and political support (European Union Review 2015).

The European network for rural development in its EU review 2019 described 'stakeholder involvement' as implying allowing the beneficiaries or project host to have a say in the decisions that affect their lives and an opportunity to give their opinion when development projects like road construction are being contemplated (European Union Review 2015). According to (Atiibo 2012), defined a stakeholder as a person or group of persons directly or indirectly affected by a project, as well as those who may have interests in a project and/or the ability to influence its outcome, either positively or negatively. These may include locally affected communities or individuals and their formal and informal representatives, national or local government authorities, politicians, religious leaders, civil society organizations and groups with special interests, the academic community, or other businesses (Andrea 2013). One 'primary challenge' and 'critical task' (Aapaoja and Haapasalo 2014) and important requirement of a good project manager and is the ability to coordinate the diverse interests and sentiments of these stakeholders from the initial phase through to final implementation (Neil 2011; David and Mike 2015).

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Stakeholders can have an adverse impact on the project objectives and identifying them is a continuous process that can be difficult but helpful in achieving success within the project scope. These stakeholders should be classified according to their interest, influence, and involvement in the project. A project can be successful in its entirety when the construction organization is able to effectively manage all human and non-human resources; this is done to deliver a facility that satisfies and exceeds the needs of the client at the time it is required and within considerable budget range (Muhammad 2014). To date, the concepts of cost, time, quality, and scope are viewed as important success metrics, especially in the context of value "exactitude, and equality" (Davis 2018; Ogbonna 2007). One way to meet and exceed the needs of clients is by their involvement (Muhammad 2014).

This paper focuses on the following:

1. Establishing the type of relationship between stakeholder management and causes of success or failure of road construction projects in rural communities in a developing country case.
2. Establishing inference from the relationship to guide future direction and possible future research.
3. The other parts of this paper are given as section II which is a short review of related literature, section III is the materials and methods, section IV addresses the results, discussions are in section V, while section VI is the conclusion and future research direction.

2 Related Works

The concept of stakeholder management as a function of project success abound in the literature (European Union Review 2015; Retfalvi 2014; Osumgborogwu 2016). In (Jepsen and Eskerod 2008), the term's origin was traced to Freeman's 1984 work and sees it as the individual or group that has an interest or some aspects of right or ownership in the project, can contribute in the form of knowledge or support or can impact or be impacted by the project." For example, (Retfalvi 2014) proposed that for improved stakeholder management, the project manager must integrate project risk management principles and project management leadership. A very important factor according to (Retfalvi 2014) is the identification of what constitutes project management leadership such as core leadership skills, risk-smart attitude, accountability-based behavior, and project manager expertise. (Muhammad 2014) stated that stakeholder management is a significant component in managing a firm as well as a project. In any project, and especially in construction projects, many different and sometimes discrepant interests must be considered. It is argued that meeting stakeholders' expectations and needs will favor the prospects of successful projects while failing to do so can cause projects to fail. Also, a project that does not successfully manage its stakeholders is assumed to have failed even if it meets the criteria of time, cost and quality. These critical factors pose a challenge to project managers as opined by (Jepsen and Eskerod 2008). Hence, (Liang et al. 2017) attempt to understand the influence of stakeholders on projects using a social network analysis approach.

In (Yang et al. 2011), it was indicated that because of the uncertain and complex nature of construction, it is important that a proper stakeholder analysis and engagement process is carried out to successfully manage the process. Stakeholder analysis is seen as ranging from identification, categorization, to assessment based on relevant influences and relationships. Stakeholder analysis identifies all primary and secondary stakeholders who have a vested interest in the issues with which the project or policy is concerned. The goal of stakeholder analysis is to develop a strategic view of the human and institutional landscape, and the relationships between the different stakeholders and the issues about most they care. In the same vein, are the facts of non-"homogeneity of stakeholder groups," their project complexity impact (Floricel and Piperca 2016) and 'complexity' itself being positively correlated with project uncertainty and risk (Nguyen et al. 2018) and failure (Spangenberg et al. 2018). In the same vein, (2012) explained that conducting a stakeholder analysis helps project managers to attempt to paint a picture of the stakeholder environment which will be used to make decisions about the management of stakeholders in the project. Stakeholder analysis should be a continuous process that spans throughout the process of a project life cycle to retain effectiveness and this should be done alongside stakeholder engagement which requires managerial skills and effective communication (Rowlinson and Cheung 2008). Therefore, stakeholder analysis can be said to mean the process of identifying all the persons, groups and institutions who may have an interest in a project and taking steps to manage their interests and expectations so that the project runs as smoothly as possible.

Justifying the need for stakeholder engagement, (Atiibo 2012) stated that different stakeholders will want different outcomes from projects. A vital part of stakeholder management is managing these competing expectations from the initial phase through to final implementation. Stakeholder priorities tend to change during the project life cycle and as such compounds, the challenge; managing stakeholders represents a major political challenge to project managers which if not properly handled will increase the incidence of failed and abandoned road construction projects in the state.

Following (Fukubayashia and Kimurab 2014), the importance of stakeholder engagement was further demonstrated through the ‘do-nou’ concept of rural roads development. It may be adduced thus that the Federal Government of Nigeria also appreciated the importance of rural road construction. In (2017), a 2010 world bank report on the rural access roads and mobility projects in Nigeria (phase 2) revealed a huge procurement plan by the federal and state governments.

Despite the review above, several states in Nigeria are still far from enjoying the quality and improved roads including the Imo state used as a case study. This paper thus is an attempt to add to the bank of literature on the subject matter of enhancement of rural roads infrastructure through proper stakeholder engagement.

3 Materials and Methods

The fieldwork was carried out in Owerri West and Owerri Municipal local government areas of Imo State Nigeria through the use of structured questionnaires designed to get the level of involvement of the affected communities where rural roads were either awarded or in the process of construction. Using a convenient sampling, questionnaires were administered to 100 respondents in two local government areas in Imo State:

Owerri West and Owerri Municipal, respectively, in Imo State Nigeria. Owerri is the capital of Imo state and accounts for most of the construction projects carried out in the last 8 years. Owerri Municipal is the seat of the government house, while Owerri West is a major local government linking Imo state to Rivers state a very important state in Nigeria due to its oil and gas exploration activities. The sampling technique thus is both convenient (since the researcher’s location is same Owerri) and purposive (since they were chosen deliberately due to the reasons above). However, during questionnaire distribution, random sampling of respondents was adopted as no choice of the respondent was premeditated during the field exercise.

The feature and spread of the respondents were analyzed using the simple percentage technique. This is done by quantifying the views and opinions of the respondents and normalizing it in percentage. The test of hypothesis and discussion of results were done after data were subjected to analysis of variance (ANOVA) and F-Test using statistical package for social science (SPSS) software version 19. Although 100 questionnaires were distributed, only 80 copies were returned correctly filled; 30 had an inconsistent response and were rejected, while 20 copies were not returned. The returned and correctly filled were 50 and used for this analysis.

The summary of the demography of the respondents showed 56% have experience of over 10 years. These were considered stakeholders since they reflect all interest groups either participating, interested or affected by the rural road projects in the area under coverage.

4 Results

This section was treated using research questions. The section presents the response and the deductions from them. The first question was to find out if material usage and quality of material used was responsible for the abandonment and failure of projects in Imo state. The responses as in Table 1.

Table 1 reveals that over 50% agreed to the assertion that indeed material quality and material usage was responsible for the failure and or abandonment of rural road projects in Nigeria. The ANOVA results can be seen in Table 2

Decision rule: Reject H_o if P-value < 0.05 or $F_{CAL} > F_{TAB}$ Otherwise accept.

Since the F-sig. change is less than 0.05, the researchers rejected null hypothesis (H_o) and accepted the (H_a) alternative: The impact of road deterioration and constant accidents are significant on the material used and the quality of road construction projects in Imo State. Notice that in Table 2, p-value is 0.019. Table 3 is used to test the second hypothesis which was to test the relationship between stakeholder management and success or failure of a rural road construction project.

Decision rule: Reject H_o if P-value < 0.05 or $F_{CAL} > F_{TAB}$ Otherwise accept.

Here, the null hypothesis was rejected since F-Significant value was 0.009 which is less than 0.05. The implication is accepting the alternative which states that there is a significant relationship between rural road construction projects failure and poor stakeholder management. The value 0.009 in Table 3 is less than 0.05. Table 4 was used to test the third hypothesis which was to test project stakeholder identification.

Decision rule: Reject H_o if P-value < 0.05 or $F_{CAL} > F_{TAB}$ Otherwise accept.

Since the F-Sig. value is 0.019 and is less than 0.05, the null hypothesis is rejected, and alternative is accepted stating that Project stakeholder identification has a significant contribution on the implementation of successful road construction projects in Imo State.

5 Discussion

Please The following are the findings of the study:

1. The deterioration and failure of road construction in Imo state are significantly related to poor stakeholder engagement.

Table 1 Response to question one

Measurement scale	Respondents	Percentage (%)
Strongly disagree	2	4
Disagree	6	12
Neutral	5	10
Agree	12	24
Strongly agree	25	50
Total	**50**	**100**

Table 2 ANOVA

	Sum of Squares	df	Mean Square	F	Sig
Between Groups	60.400	4	15.100	4.512	0.019
Within Groups	150.600	45	3.347		
Total	211.000	50			

Table 3 ANOVA

	Sum of Squares	df	Mean Square	F	Sig
Between Groups	62.200	4	15.500	5.416	0.009
Within Groups	128.800	45	2.862		
Total	191.000	50			

Table 4 ANOVA

	Sum of Squares	df	Mean Square	F	Sig
Between Groups	60.400	4	15.100	4.512	0.019
Within Groups	150.600	45	3.347		
Total	211.000	50			

2. There exists a relationship between the quality of materials used and the accident rate in Imo state showing that poor or little quality materials used in rural road construction are seen by stakeholders as responsible for accidents along the Owerri West in particular. This location is important because it links the state to the oil region through Port Harcourt road.
3. Identifying the relevant stakeholders in a rural project has a significant relationship with the success or failure of the project.

The above results agree with the works of other researchers, and more importantly, that of (Diugwu et al. 2015) who suggested that one way to reduce the number of poor or abandoned projects in Nigeria is to integrate good project management principles during planning, robust monitoring and evaluation procedure. Evaluation presupposes review, and this is where stakeholder engagement cannot be ignored.

6 Conclusions

The conclusion reached from the results of this paper is that stakeholder identification and management significantly affect the success of road infrastructure projects in rural areas using Imo state as a case study (see Tables 3 and 4). It is a future research direction to repeat this same analysis in more than one project and locations. It is also worthy of research if the interpretations across diverse locations. This will serve as a comparative analysis of the respondents' diverse view about stakeholder management for effective project delivery.

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Current Sources of Financing Power Infrastructure in Developing Countries: Principal Component Analysis Approach

Emmanuel Oikelomen Ayorinde, Ngcobo Ntebo, and Kasenge Mathe

Abstract

Infrastructure plays a dominant role in structuring and positioning every nation's economy and social development. Infrastructure financing is the blueprint in achieving infrastructure development in developing and developed countries. This research project determines the current sources of financing infrastructure in developing countries. The study adopted a quantitative research approach with data gathered from the respondents within power infrastructure development in the region. The findings revealed current sources of financing power infrastructure in developing countries to be commercial bank loans, public finance, private finance, power utility fees, public–private partnership, and foreign direct investment. These were seen as current sources of financing power infrastructure in developing countries. Having established that no society can develop without adequate investment in the power infrastructure sector, there is a call for adequate investment in the power infrastructure to foster and re-integrate developing countries in the path of economic development and global relevance. If the central government can direct adequate finance and harness the current sources available to develop power infrastructure in their society, it will ultimately lead to enormous economic growth and social development in the region. This research project will contribute to the development of public infrastructure in developing countries, which will directly influence the development of power infrastructure in the region for the purpose of economic relevance and improvement of lives in the society.

Keywords

Economic growth • Developing countries • Power infrastructure financing • Power infrastructure development • Social development

1 Introduction

Power infrastructure development is imperative for all nations' socio-economic growth and Gross Domestic Product (GDP) expansion (2018). The demand for electricity has doubled the supply rate in the world in recent times. This has led to the development of new or the rehabilitation of aging power infrastructure facilities (Bazilian et al. 2012). In the developing countries, a large amount of $5 trillion in needed for power infrastructure projects to meet the need of the regions by the year 2030, with over $2 trillion to be spent on new power infrastructure projects (Brew-Hammond and Kemausuor 2009). The gap in financing in the energy sector has hindered the region's economic development (Gujba et al. 2012).

1.1 Power Financing Sources

Power infrastructure financing is done using Development Financial Institutions (DFI), these are special local and international development banks, different from the regional development banks, tasked with the motive of assisting the private sector in the financing of power infrastructure development in Ghana. Climate finance (CF), is used in financing power infrastructure as a result of improved policies put in place by the central government to achieve clean energy that promotes sustainable development, and by so doing, attracting extra incentives in the financing of power infrastructure development in developing countries (Schwerhoff and Sy 2017). Bank loans from commercial banks are

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capital acquired by private investors for the purpose of financing power infrastructure projects in developing economy. Regional Development banks have also been used in financing power infrastructure in the region, this enables countries in developing economy to have quick access to capital in financing power infrastructure (Owusu-Manu et al. 2015). Green bonds are special concession for the financing of climate change projects like reducing the greenhouse gas emission (GHG), thereby promoting sustainable development by the deployment of renewable energy sources. In addition, the studies define concessional loans, as loans gotten from Africa Development Bank (ADB) by the government of a country is needed for the development of power infrastructure (Pachauri et al. 2012).

Furthermore, capital from international donors given as grants or aids by the World Bank or the United Nations (UN) is used in funding power infrastructure projects in the developing countries. Also, ADB is set up with the main purpose of allocating funding to governments of different countries in Africa with the aim of developing their power infrastructure. Public–private partnerships are also a means of financing power infrastructure and is done by collaboration between the government and the private investors in the financing of power infrastructure in the region. Private finance plays a key role in financing power infrastructure in developing economy. The capital is obtained from private investors investing in the power sector of the country as a way of improving the sector (Owusu-Manu et al. 2015). Public finance is the traditional means of financing infrastructure by the government in allocating a certain amount from the annual budget in financing the power infrastructure of the nation. Insurance companies is another means or mechanism of financing power infrastructure in developing economy obtaining finance from insurance companies (Schwerhoff and Sy 2017). Equity financing is a mechanism advisable for private investors in the power sector to utilize because of the rise in interest rates from commercial bank loans. Pension fund is a major source of long-term capital obtained by the government for financing power infrastructure projects in the region (Ahadzie et al. 2008).

2 Methodology

The method used in this study was a quantitative research approach with the motive of achieving the aim of the study, which is the challenges facing power infrastructure financing in Nigeria. Quantitative methods relate to positivism and factual data (Burns and Grove 1993). The questionnaire was developed from a wide review of the literature and is not part of any existing survey instrument. Practicing power infrastructure professionals in the power sector of Nigeria were engaged in the collection of the primary data on the sources of financing power infrastructure in developing economy. The Likert scale (strongly agree = 5, agree = 4, neutral = 3, disagree = 4, strongly disagree = 5) Mean item score (MIS) was used to present the research findings from the Likert scale in a decreasing order.

Exploratory factor analysis (EFA) is one of the two types of factor analysis (FA) and is often deployed during the initial stage of research by researchers in order to collate information about the interrelationships within a set of variables (Pallant 2011). The EFA of the results were obtained to confirm the validity and reliability of the sources of financing power infrastructure in developing economy, with the highest likelihood having an eigenvalue of more than 1, together with the varimax rotation, EFA was used specifically for this study. SPSS software version 21.0 was used to conduct the EFA for this research. The descriptive results show the rankings of all the factors from the first to last according to the variables, with the table representing the individual variables' mean score as well as the standard deviation of the variables (Pallant 2010).

2.1 Data Analysis

Two descriptive statistics were carried out, which are in the form of mean item score and factor analysis. The ranking of the variables was done with mean item score; likewise, factor analysis was carried out to outline the variables measuring same underlying effects (Ledwaba 2012).

2.2 Mean Item Score

The mean ranking of the variables presented depicts the individual views reached by the respondents. The result of the test is shown in the table below. The mean table represented below also include the standard deviation of the variables.

2.3 Results from Exploratory Factor Analysis

The EFA results on the current sources of power infrastructure financing in developing economy are depicted in Tables 1, 2, 3, 4 and Fig. 1. Out of the total of 17 variables outlined, about 7 (Pachauri et al. 2012) variables were missing, they are the following: 'public–private partnership' (CFS1), 'pension funds' (CFS2), 'private finance' (CFS5), 'land use taxes' (CFS6), 'public finance (government

Table 1 Current sources of power infrastructure financing

Current power financing sources	Mean	Standard deviation	Rank
Commercial bank loans	4.76	0.526	1
Public finance (government budget)	4.61	0.835	2
Private finance	4.16	1.158	3
Power utility fees	4.05	1.0110	4
Public–private partnership	3.36	1.360	5
Foreign direct investment	3.33	1.239	6
World Bank grants	2.32	1.298	7
Nigeria Bank of Industry (BOI)	2.18	1.111	8
Sales of state-owned assets	2.17	1.147	9
Development charges	2.10	1.152	10
International aid	1.99	1.201	11
African Development Bank funds	1.97	1.172	12
User charges fees	1.95	1.213	13
Green bonds	1.86	1.085	14
Insurance companies	1.54	0.765	15
Land use taxes	1.54	0.703	16
Pension funds	1.39	0.651	17

Table 2 KMO and Bartlett's test

Kaiser–Meyer measure of sampling adequacy		**0.904**
Bartlett's test of sphericity	Approx. chi-square	**592.069**
	df	**45**
	Sig	**0.000**

Table 3 Rotated factor matrix

Factor matrix	Factors	
	1	2
User charges fees	0.777	
International aid	0.744	
Foreign direct investments	0.731	
Development charges	0.703	
Nigerian Bank of Industry (BOI)	0.660	
World Bank grants	0.637	
African Development Bank (ADB)	0.600	
Sales of state-owned assets		0.838
Green bonds		0.831
Insurance company		0.564

budget)' (CFS14), 'power utility fees' (CFS16), and 'commercial bank loans' (CFS17). The following are the ten variables identified with the potential of financing power infrastructure in the developing economy.

2.4 Factor Analysis

Factor analysis is vital in breaking down numbers of large variables and breaking them into more simple clusters for better interpretations (Ahadzie et al. 2008). Tables 2–4 and Fig. 1 below show Kaizer–Meyer–Olkin (KMO), the measure of sampling adequacy attained a high score of 0.748. The Bartlett test of sphericity also was important, this suggests that the matrix of population is not identical. In addition, the Cronbach alpha that measures internal consistency is 0.904, thus suggests that the reliability of the instrument used by the researcher in the research is quite good.

The data was regulated with principal component analysis (with varimax rotation). The eigenvalue has a high value of more than 1. As represented in Table 3 and Fig. 1, the factor loading extracted were ten components with the eigenvalue between 0.5 and 1 (also see Fig. 1 scree plot). For the total variance (see Table 4), as explained by each component extracted, component 1 (51.257), component 2 (11.101). Therefore, the result from the principal component analysis (PCA) and the factors extracted amounted to 62.358% of the total cumulative variance.

Extraction method: Principal component analysis.

The principal axis factoring used showed that two (2) were present with an eigenvalue greater than 1 as represented in Table 4 above. Owing to the careful observation of the inherent connections among each of the variables under each factor, the following assessments were made: Factor 1 was described as taxation and grants mechanisms and factor 2 was described as public financing incentives. The term used in describing these factors was obtained as a result of closely observing the variables within each of the factors. The two factors extracted and their constituent indicators are explained below, together with a comprehensive description of how the two factors were described in the factor section.

3 Discussion of Result

3.1 Factor 1: Taxation and Grants Mechanisms

As shown in Table 3 above, the two extracted power infrastructure financing sources for factor 1 were user charges fees (77.7%), international aid (74.4%), foreign

Table 4 Total variance explained

	Initial eigenvalues			Extraction sums of squared loadings			Rotated sums of squared loadings		
Factors	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	**5.126**	51.257	51.257	5.126	51.257	51.257	3.608	36.075	36.075
2	**1.110**	11.101	62.358	1.110	11.101	62.358	2.628	26.283	62.358
3	.704	7.039	69.396						
4	.656	6.565	75.961						
5	.556	5.564	81.526						
6	.461	4.613	86.139						
7	.417	4.171	90.310						
8	.359	3.586	93.896						
9	.317	3.165	97.061						
10	.294	2.939	100.000						

Extraction method: Principal component analysis

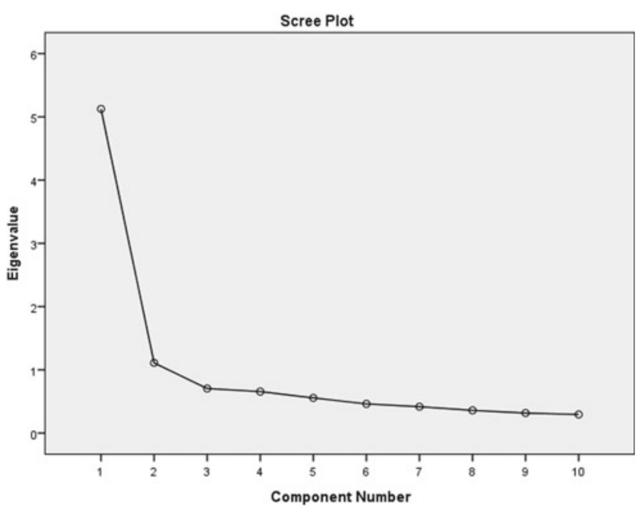

Fig. 1 Scree plot for factor analysis

direct investment (73.1%), development charges (70.3%), Bank of Industry (66.0%), World Bank grants (63.7%), and the African Development Bank (60.0%). The number in the parenthesis shows the individual factor loadings. The definition of these variables is also explained in Table 1. This cluster accounted for 62.358% of the variance.

3.2 Factor 2: Public Financing Incentives

As shown in Table 3 above, the three (3) extracted sources of financing power infrastructure for factor 2 were sales of state-owned assets (83.8%), green bonds (83.1%), and insurance companies (56.4%). The numbers in the parenthesis show the individual loadings. The definitions of these variables are also explained in Table 1 above. This cluster accounted for 11.101% of the variance.

4 Implications of Findings

The theoretical literature review is in agreement with the empirical findings of this research study. This is clear in the empirical study, which reveals that the current sources of financing power infrastructure in developing countries are from commercial bank loans, public financing (budgeting), private finance, and power utility funds. Therefore, it is imperative for developing countries to adopt other sources of financing power infrastructure for economic and social relevance. This is because according to the existing literature, for power infrastructure to be financed successfully, there is a need for adopting innovative means of financing power infrastructure other than the traditional means of budgeting. Commercial bank loans and private finance are not enough for sustainably financing power infrastructure so there is a great need for different sources to be adopted such as user charges, green bonds, development charges, World Bank grants, and sales of state-owned assets for a sustainable and well-developed power sector in developing countries.

5 Conclusion

Results from the literature review established that currently, financing power infrastructure in Nigeria is done by public finance, i.e., government budget, and public–private partnerships. However, literature has further shown that other mechanisms such as foreign direct investment can be used in financing power infrastructure in Nigeria. Results from the findings of the secondary data, i.e., questionnaire survey indicate that there are five main sources currently used in financing power infrastructure in Nigeria, namely commercial bank loans, public finance (government budget), private finance, power utility fees, and public–private partnerships. It can be said conclusively that this research objective for this study has been answered.

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Automation in Museum Construction and Operation

Amina Hammodat, Fadia Ajjan, Faris Zakieh, and Salwa Beheiry

Abstract

The conventional method in construction has many limitations and therefore needs modification. Not only is this method inefficient, but it is also harmful to the environment due to its high energy consumption. Therefore, there is a rising need for automation in construction. This need is accentuated in specific structures, such as museums, that are more creatively designed and have more specific maintenance and operation requirements. The purpose of this paper is to create a tool kit for automating the design, construction, and operation of museums while considering sustainability measures. The main methodology is research on the application of Building Information Modeling (BIM), robotics, and 3D printing during the design and construction stages, and examination of the integration of the Internet of Things (IOT) and indoor air quality management into the operation stage. The results are workable guidelines for the automated museum. The tool kit is beneficial as it will save time and cost and increase the efficiency of operation. It will also increase awareness of the necessity of new job opportunities for labor within the technology sector.

Keywords

Automation • Sustainable construction • Museum construction • 3D printing • Robotics • Internet of things • Indoor air quality

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1 Introduction

The construction sector accounts for approximately half of the total investment of a nation (Bock 2015). The prosperity of a nation's economy is therefore directly linked to the prosperity of its construction sector. However, studies indicate that the productivity of the construction industry has recently declined (Bock 2015). Hence, in an effort to increase productivity and efficiency, boost sustainability, improve working conditions, and support architectural creativity, automation in construction has become a primary focus of innovators in the industry.

Museums are highly particular institutions and hence, normally, have unique designs, structurally and architecturally. Some of the world's most respected constructed facilities are museums. Such examples include the Phaeno Science Center in Germany, New Museum in New York, and the Literature Museum in Marbach. Like any unique construction endeavor, museums require intensive planning. Accordingly, the designers must look at these projects holistically. Cost, environmental impact, time, and indoor air quality are examples of the aspects that require special consideration (Schittich 2009). It follows that the rising need for faster, more efficient, and sustainable construction triggers the interest in automated techniques in the construction of buildings in general, and museums in particular.

1.1 Background

Museums are highly specific structures in terms of the design requirements for their internal environment. This is due to the structures' dual functionality as centers for the preservation of historic artifacts and as educational facilities with a varying influx of visitors. To maintain the function of preservation, internal environmental factors such as humidity, temperature, and pollution must be continuously monitored and controlled (Ault 2000). A failure to do so could

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result in material expansion or shrinkage, mechanical failure, or texture damage in the artifacts (Ault 2000). The control of these factors can be achieved efficiently by the use of automation systems such as Building Information Modeling (BIM) during the construction of the structure and the integration of automated heating, ventilation, and air conditioning (HVAC) elements, while the structure is in use. Furthermore, museums must ensure the comfort and safety of their visitors. This is easily attainable through the application of process models to control the indoor air quality and through the utilization of BIM in risk management. The requirement for an efficient risk-management system is further accentuated by the historical value of the artifacts. As illustrated in (Cheng et al. 2017), BIM can be used to detect, control, and manage disaster risks by transmitting real-time information on the status of the building and predicting the optimal rescue and control route (Cheng et al. 2017).

1.2 Literature Review

1.2.1 The Need for Automation in Construction

Makarand Hastak compares the conventional construction method with the new automated one in his paper: *Advanced automation or conventional construction process?* He evaluates whether automation in construction is feasible or not based on five main criteria. These criteria include the following: need-based criteria, technological criteria, economic criteria, project-specific criteria, and safety/risk criteria. Each of these criteria branch into sub-criteria that are also taken into consideration when evaluating the automated model (Hastak 1998).

1.2.2 Feasibility

Turek et al. discuss the interaction between robots and humans. The authors mention the intelligent building (IB) concept, which utilizes mobile robots while also reducing the amount of energy needed in construction. Furthermore, they propose having a bridge between the human-centric view of a building and the robot-centric one. In order to achieve this, three main goals are presented: Mapping, Localization, and Path Planning. This model uses humans' knowledge, along with existing data to recognize the different elements of a building. This is very important when communicating with robots (Turek et al. 2017). Further studies discuss the major shift that needs to occur in the construction industry if it were to accommodate automation (Bernold 1987). They provide points on the incentives for the construction industry to embrace automation and the barriers restricting the entry of robotics to many construction markets.

1.2.3 3D Printing

Hager et al. evaluate the effectiveness and future of 3D building technology. The paper describes the different methods of 3D printing such as stereo-lithography, selective laser sintering (SLS), and Fused Deposition Modeling (FM). The main advantages of 3D printing in construction are the reduction of manpower, expenses, construction time, and construction waste and the increase of customization and design flexibility. The main disadvantages are the high cost of the printing materials and the required software packages for the printers, the fact that 3D printing is an indirect process of construction, the brittleness of a range of the materials and the yet unclear life cycle performance of the buildings (Hager et al. 2016). However, there have been several breakthrough advances in the field of 3D printing in construction over the past few years, including the integration of BIM in the process (Wu, Wang, and Wang, 2016).

1.2.4 Building Information Models (BIMs)

Pătrăucean et al. discuss the as-built building information models or (IB BIMs), as-built BIMs differ than the regular BIMs in the sense that they reflect the actual condition of the building or the project. Moreover, they are essential for when the actual conditions of the building differ from the designed conditions or the as-designed Building Information Models (AD BIM) (Pətrəucean et al. 2015).

1.2.5 Process Models and Robotics

Kasperzyk et al. present a study of the integration of re-fabrication into a Robotic Prefabrication System (RPS). The authors first explain the benefits of prefabrication in the construction industry, which include cost and time reduction, as well as increased assembly efficiency. However, the use of prefabrication is limited due to the process's inflexibility to design change. Hence, the study presents the concept of "re-fabrication" in RPS, where a prefabricated structure is automatically disassembled and reconstructed according to a design change (Kasperzyk et al. 2017). Škrjanc and Šubic describe the use of an Internal Model Control (IMC) system to control the CO2 levels of buildings depending on the occupancy fluctuations. The model is simulated in a gallery and the results show a successful achievement of desired air quality coupled with a decrease in operating costs in comparison to the typical air control system. This system is very advantageous in buildings where the occupancy-level fluctuations are high (Škrjanc and Šubic

2014). (2015) suggest five management innovative techniques that are vital in implementing robotics within construction. These are robot-oriented design, robotic industrialization, construction robots, site automation, and ambient robotics (2015).

1.2.6 Museum Requirements

Janeen (Ault 2000) explains the required environmental factors in museums for the preservation of artifacts and the comfort of visitors. The author states that the main factors requiring consideration are humidity, temperature, light, pollution, and biological attack. Humidity and temperature changes can damage artifacts by causing them to expand or contract. If the artifacts' material is rigidly bound, mechanical failure may occur. Light in the infrared region may also cause severe damage through the dehydration of materials and its effect on their appearance and mechanical strength. Air pollution in the form of sulfur dioxide, oxides of nitrogen or ozone can discolor textiles and fabrics and weaken materials. Finally, biological attacks in the form of fungi and mold consume artifacts and weaken their material. The author tests these environmental factors inside the Field Museum and finds the control severely lacking. She suggests a renovation of the building's HVAC as a solution (Ault 2000). This study explains the environmental factors that must be considered in museum construction.

1.3 Statement of the Problem:

In *The future of construction automation: Technological disruption and the upcoming ubiquity of robotics*, Thomas (Bock 2015) argues that the conventional construction method is slowly reaching its limits, and the need for a new automated one is arising. The project aims to tackle automation specifically in museum construction. The choice of museums as the object of this study is due to the multitude of unique factors associated with these structures. First, the uniqueness of museums invites innovative architectural designs. These new designs include complex details, and hence require prefabrication for vast spans. This can be achieved using an automated system, saving time, and easing adaptation to any design change. Secondly, museums have their own environmental specifications. This is because they accommodate large crowds and because they contain objects and collections of high value which must be preserved in a safe, healthy environment.

1.4 Significance of the Project

This project aims to introduce new concepts of automation into the construction and operation of museums. This would simplify and bridge the gap between automation and museum construction. By using museums as an example of a standard and well-defined structure that requires specific construction methods, automation implementation can be applied to other building types ranging from industrial factories and power plants to residential buildings and villa compounds.

As the conventional method reaches its limits, many of its fundamental problems such as low worker productivity, high accident rates, deteriorating quality, and shortage of skills (Bock 2015), can be solved by automating the processes of construction one task at a time. Not only does this technology have the potential of increasing work safety and comfort, but it can also improve construction efficiency and quality while reducing the requirement for human intervention in the construction phase. If successfully implemented, automation tool kits would represent a leap in the industry, increasing efficiency and project potential.

1.5 Objective

The objective of this effort is to propose an automation toolkit for museum design, construction, and operation.

2 Automation Toolkit

This section presents a toolkit for automation in museum construction and operation. It is designed to be used when evaluating the level of automation in a particular project. The rating system that is used follows the Likert scale that ranges from 0 to 5, where 0 represents no level of automation and 5 represents full use of automation. Table (1) divides automation into two main stages: design and construction and operation. Each stage contains multiple automation components. In turn, these components have a variety of applications, or automation subcomponents, which are also displayed in the table. Accordingly, each number on the Likert rating scale represents a degree of automation, or how extensively the automation subcomponents, as listed in Table 1, are used in the museum. 0 indicates there is no automation used in the project, 1 indicates there is scarce use

Table 1 Automation Toolkit Components

	Component	Use
Design & Construction	Building Information Modeling (BIM)	Risk Management
		Budget Maintenance
		Schedule Maintenance
		Quality Maintenance
		Energy &Carbon footprint Estimation
	3D Printing	Façade component Creation
	Robotics	Paint and Coating
		Optimum Design Change Sequence
		Assembly by Disassembly
		Lift/Transport Equipment
Operation	Internet of Things (IoT)	HVAC Optimization
		Information
	Holographic Display Cases	Object History
		Object Purpose
		Hidden Details
	Indoor Air Quality	Carbon Dioxide Monitoring
		Humidity and Temperature Control

of automation, 2 means there is a poor use of automation, 3 means an average amount of automation is used, such that almost half of the project is automated, 4 shows the project uses a high percentage of automation, while 5 indicates there is a 100% effective use of automation. In the particular case of robotics, for example, a 0 rating would mean that there is no use of robotics in any task, a 5 rating would mean that robotics were used in every possible task they could perform (coating, painting, finding optimum sequence to design changes, using assembly by disassembly, and lifting/transporting the equipment) and a 3 rating would mean that robotics were used in approximately two out of the four tasks they are capable of performing. Table 2 illustrates the use of the automation toolkit rating scale for a hypothetical museum. If the hypothetical museum's implementation of automation was evaluated as shown in the example in Table 2, its automation score would average to 3.24, which is considered an acceptable automation performance.

3 Discussion

Based on techniques investigated in previous studies, a multitude of automated construction and operation components are chosen and customized to create an automation toolkit that best fits the requirements of modern museums. The first step for customizing automated construction and operation methods for museums is to collect information through research on existing automation methods and their requirements. Additionally, information about the specific requirements of museums such as safety, indoor air quality, and visitor comfort and entertainment must be acquired. The next step is to choose the most suitable automation approaches that meet museum requirements depending on cost, efficiency, and sustainability. The final step is to understand how the chosen automation methods complement each other and how they can be applied together to produce the most efficient and effective model in construction and operation.

4 Conclusions

Automation can be applied in the design, construction, and operation stages of any museum. Due to the current limitations within the conventional method, automation has become an inevitable necessity. It offers various benefits and can save time, energy, and cost if utilized properly. The presented automation toolkit is designed such that it can be used to evaluate the level of automation in any project. The

Table 2 Automation Toolkit Scale Example

Automated	Likert Scale						Description
	0	1	2	3	4	5	
	No use	Scarce use	Low use	Acceptable	High use	Full use	
Risk Management			✓				Schedule, cost, and design change tracking
Budget Maintenance				✓			Earned value analysis
Schedule Maintenance					✓		Earned value analysis
Quality Maintenance		✓					BIM quality log
Energy &Carbon footprint Estimation			✓				BIM into Simapro
Façade component Creation	✓						3D printed designs
Paint and Coating						✓	STCR replacement of manual labor
Optimum Design Change Sequence						✓	Software in re-prefabrication
Assembly by Disassembly						✓	Hardware in re- prefabrication
Lift/Transport Equipment				✓			STCR
HVAC Optimization				✓			Energy saving system
Information					✓		Holographic guides
Object History					✓		Holographic display cases
Object Purpose				✓			Holographic display cases
Hidden Details				✓			Holographic display cases
Carbon Dioxide Monitoring					✓		Air quality control
Humidity and Temperature Control					✓		Air quality control

components chosen were based on the optimal level of automation, rather than the maximum one. In other words, the automation methods were selected according to the optimal levels of cost, time, and energy. As previously mentioned, labor costs can be reduced up to 40% when using automation. Automation also minimizes labor transportation thereby saving energy. The energy recovery wheel within the HVAC system can save energy as well. Finally, STCRs save time by 37.5%. Time efficiency is also increased due to the use of IoT and holograms in operation.

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Perception of University Students on Gender Issues in the Industry

Subashini Suresh, Amal Hj Abdul Aziz, Mark Stride, Suresh Renukappa, and Paul Hampton

Abstract

The UK construction industry is currently suffering from a skills shortage. There are many reasons and issues that surround this, however, Office of National Statistics data shows that only 13 % of the construction industry is employed by females. This research study will discuss the perception of the construction industry by students studying construction subjects. The research within this study involved literature review and 12 qualitative interviews. The results revealed that there are campaigns to encourage women to join the constructions industry; however, there is still a stigma attached that the industry is scarred by discrimination, harassment, pay equality and stereotyping that are deterring females from offering greater diversity, new ideas and a solution to the skills shortage from joining the industry. On this basis, a culture change and new legislation clearing up the major issues within the construction industry needs to be completed prior to remarketing the image of the industry campaigning enabling females to join the sector.

Keywords

Discrimination • Harassment • Gender • Skill shortage

1 Introduction

The construction industry is currently battling with a shortage of skilled tradesmen and professionals—many of the current workers are ageing and young adults are not interested in joining the sector. Schouten (2017) explains that there are a total of 27 million people employed within the UK, with an approximate 50:50 split between both genders. The construction industry employs 2.3 million workers, however, the Office of National Statistics (ONS 2018) understand that only 13 % are female, displaying a large unbalance. According to the Construction Industry Training Board (CITB 2019), the construction industry will need to recruit a further 157,000 people to keep up with the demand of the sector by 2021. The aim of this study is to review what the limitations and perception barriers that stop women joining the construction industry, but also to raise awareness of the shortage and the benefits of the built environment from a student's perception.

The main objectives within this study are to

- investigate what the industry is already doing to help reduce the skills shortage,
- understand what the student's perception of construction sector is,
- discover what the limitations are for women within the construction industry,
- how to overcome the limitations for females in the construction industry.

By following these objectives, it enabled the researcher to find an adequate method to encourage women to join the industry. To complete this study, a literature review has been undertaken to find out what research has already been carried out. This was continued by carrying out a qualitative assessment of student's perception of their education and the industry.

2 Literature Review

Grant Prior from Construction Enquirer (2019) stated that a further 168,500 construction-related jobs will become available over the next five years despite the uncertainty of

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Brexit. However, as the job opportunities continue to rise, this causes the shortage in workers to increase also, therefore, there must be an increase in methods taken to fill the skills deficit. We know that there are many opportunities for females to join the industry; however, are they aware of them?

2.1 Skills Shortages and Its Impact

The last recession caused a huge decline in employment within the construction industry; the CITB explained that the total construction output hit an all-time low in 2009, and, therefore, forced many construction workers to leave the industry. The CITB (2018) explained that these workers have never been replaced and has left a shortfall within a booming market. Due to the small workforce within the construction industry, it has proven difficult for employers to recruit. Therefore, one of the incentives to entice applicants is an increase in salaries. Dominic Claeys-Jackson from Prospects (2017) and Construction Enquirer (2016) reported that salaries had increased by 6 %, a rate three times larger than across other industries. Brian Berry Chief Executive of the Federation of Master Builders (FMB) (2018) also explained that 'two-thirds of those running small and medium-sized construction firms are struggling to hire bricklayers and carpenters as construction skills shortages hit a record high'. Brexit has left many employers and employees with doubts over their job security, and this could prove to have a huge impact. Jodie Cox from the Independent (2017) reported that 176,500 European workers are employed within the industry, meaning that a huge vacuum could be left if they are forced to leave the country. The industry is also battling against an ageing workforce. In 2013, the CITB announced that over 400,000 people were expected to leave the industry within the next 5–10 years and the rate of recruitment is not matching the number of workers retiring. Radford (2017) explained that due to the age of the workforce many tradesmen are retiring from the industry and are not being replaced. RICS Chief.

Economist, Rubinsohn (2016) also explained that the labour shortages in the construction sector are causing significant delays at various stages of the construction process and cannot keep up with the demand of building 110,000 houses per year. Therefore, the construction industry cannot build enough properties to house the expanding population (The Construction Index 2016). Millennials are having a huge impact on the construction industry, due to them not wanting to join the sector. Neil Martin of Lend Lease (2016) describes that the industry is poorly communicating with young adults and not describing what there is to offer and what career opportunities are available, therefore, the workforce will reduce until this issue is corrected. Hilary Osbourne (2016) from The Guardian explained that the impact of the skills shortage covers issues such as the housing programme, salary inflation and a smaller workforce. Due to the construction industry demanding more progress with building projects but having a limited workforce available, construction companies are battling for tradesmen and professionals, enabling employees to have higher salary expectations.

2.2 Obstructions Stopping Females Joining the Industry and the Benefits of Joining the Industry

There are many advantages for women to join the construction industry such as diversity, skills shortages, teamwork and to satisfy the growing population, however, equally there are also negatives that stop females joining the sector such as harassment and discrimination, stereotyping, their family commitments, a lack of opportunity and awareness. Matthew Goff (2019), Director of UK operations at Actavo Building Solutions, explains that having a diverse workforce can achieve better results across the business. He furthered this by stating that within the sector there is a huge gender pay gap of almost 45.5 % and that if an individual is capable of undertaking a task regardless of their age, gender, ethnicity, sexual orientation or physical impairment they should have the opportunity to do so. The Royal Institute of Chartered Surveyors (RICS) (2018) explain by encouraging a more diverse workplace, it helps inspire more people to join the industry as it will complement the individual's personalities enabling more personnel to review projects increasing the teamwork and satisfying the skills deficit. However, unfortunately there are several negatives that must be addressed that are currently deterring females and students from joining the construction industry. Kimberle Crenshaw (2016) claims that there must be support against intersectionality within the workplace as she believes that multiple factors such as gender, religion, ability and race discrimination are stopping the public from joining industries and employers are discriminating against potential employees. She also believes that white women are traditionally employed to complete administration positions and white men would complete the manual jobs. Using this analogy, it suggests that women cannot complete the manual or professional positions, and RG Group (2017) confirm this by claiming that the stereotype that men are physically bigger and stronger deters females from joining the industry and get drawn to other sectors. RG Group furthered this by explaining that the perception of the construction industry is that it is male dominated and, therefore, when women join the industry they feel they might be treated differently, thus keeping their heads down and acting as 'one of the lads'.

This view enhances the evidence that the construction industry is poorly marketed—not only is it perceived to be low status, dirty and badly paid, an opinion that has stigmatised the industry for many years (CIOB 2018), but RG Group perceive the industry to be advertised to men as it is proposed to be a masculine and strong industry that will build purpose and identity as a man. Another issue that has been identified is that women will not join the construction industry due to family commitments. Meg Munn (2014) described this as indirect discrimination, explaining that women struggle to deal with the responsibilities of a family as well as staying at work within the industry. Due to this, females view this as an infringement when attempting to progress their careers and feel that they are judged by senior management if they get married or have children.

2.3 What is the Industry Doing to Attract Females to Join the Industry?

There are various efforts within the construction industry to reduce the skills deficit by targeting both genders and females individually of all ages. An example of this is The Black Country Children's University. University of Wolverhampton (2018) explains 'as the University of Opportunity, they are committed to raising the aspirations of children within our communities'. Using this initiative, it encourages young adults to learn about the construction industry and other sectors within the workplace. This initiative reaches out to many schools and academies in Wolverhampton, Sandwell, Dudley, Walsall and Education Central Multi Academy Trust (ECMAT). The Construction Youth Trust (CYT) (2017) offer short courses that are designed to present the opportunities that exist within the industry. The CYT aims their courses at young people aged between 18 and 30, who may be unemployed. Athena SWAN (2019) support universities and colleges to build inclusive cultures that build the values of diversity, and resist the barriers for students and employees to progress whilst challenging the unfair practices that disadvantage their peers. Athena SWAN offers bronze, silver and gold accreditations to the educational sectors enabling institution to meet the criteria and aim for gold. Athena SWAN understands that the main diversity issues are age, disability, ethnicity, gender, intersectionality and new protected characteristics such as religion and sexual orientation. Apprenticeships are also a popular method to help reduce the skills deficit as there are many advantages to them, such as the employer being able to apply for funding and having the benefit of training an individual within their company whilst learning the companies model and working methods, and the apprentice has free training earning a salary for his service whilst gaining qualifications. The RICS (2018)ispromoting 'degree apprenticeships' which have similar advantages to a regular apprenticeship; however, these are aimed at A-level students with the intention of reducing the skills deficit in professional positions such as in quantity surveying and architecture. This enables experienced employees to train apprentices which enables the average age of an ageing workforce to be reduced. In 2017, the Government enhanced the apprenticeship-funding scheme by introducing an apprenticeship levy to companies who had salary outgoings greater than £3 million (GOV.UK 2016). The levy is 0.5 % of their salary output; however, companies can recover the costs by employing apprentices. The Government took that view that companies needed to employee and train more employees, enabling the individuals to gain qualifications whilst working. Work experience and sandwich courses are also good methods to persuade students that the construction industry could include a career that is suitable for them. Many year 11 school students have the opportunity to gain 1–2 weeks work experience with an employer to help decide a career path for when they leave full-time education. My World of Work (2019) explain many advantages of work experience and sandwich courses such as it helps gain an insight into work; it uses the required skills used within the workplace; it develops self-awareness; it helps to understand the links between school subjects and work and it helps the students meet new people. Balfour Beatty (2018) explains that only 13 % of the construction industry is made up of females; however, they are encouraging more females to join the sector by raising the profile of their current female employees, campaigning to help females join the industry and using their 'Women In Construction and Engineering' (WICE) awards to promote it. Through this Balfour Beatty expects women's participation to increase in 25 % by 2020. The CITB (2018) have also developed an organisation called Women in Construction (WIC) to help persuade females to join the sector and to help solve the skills shortage. However, WIC explained five key objectives to help potential candidates, they are advice, training, work placements, mentoring and jobs. By completing these objectives the CITB feel that they will improve the following retention of women in construction, productivity, opportunity to secure work and capacity and skills to implement new policies to attract and retain women. By reviewing these main areas, it enables further research to be reviewed, detail and recommend new methods to reduce the skills deficit, encouraging young adults to join the industry**.**

3 Methodology

A mixture of primary and secondary research was used for this study. Saul McLeod (2017) describes qualitative research as data collected through participant observation and interviews. Therefore, within this study interviews were completed consisting of both closed and open questions, enabling the interviewer to extract as much information from the participants as possible. The participants for this study were all students in Universities studying towards their degree in construction-related aspects, doing Bachelor of Science (BSc), Master of Science (MSc) and Doctor of Philosophy (PhD) courses containing 6 males and 6 females. This enables the researcher to gain experienced views from both genders and students who are studying different levels of education. Each interview took up to 40 min. The questions during the interview were aimed to gain a brief idea of the participant's general knowledge and experience within the built environment and to understand the participants' perception of women in construction. To help find further information about the skills shortages within the construction industry, journals from construction bodies such as the CIOB, the RICS and the CITB, Government and ONS documents have been identified and studies to ensure research and data have been maximised enabling a full research study has been completed. By using the information gained throughout the literature review and the interviews will enable the researcher to complete the research objectives and conclude the study with a solution to this issue.

4 Results and Analysis

This section summarises the data collected, enabling the researcher to depict an analysis of the information provided. Twelve interviews were successfully completed with participants whom were studying towards construction-related degrees. The first question that was asked was 'What did the students feel are the main challenges to women in the construction industry'? Table 1 displays the results that students felt discrimination and harassment was the highest challenge to women followed by the stereotype of society. This perspective was the view of both genders combined and individually, however, the males also felt the stereotype of the industry by the public was a deterrent to females. Males did, however, have the opposite view to females about gender equality and awareness of the industry.

1 The participants were then asked a series of open-ended questions, requesting their opinion on what they thought females can bring to the construction industry. The first question was how did the participants feel women could benefit the construction industry? Some of the most common answers were greater diversity, new ideas, a different perspective and a solution to the skills shortage. The following question were asked to the 12 participants what motivated the students to enrol on a construction-related course. 25 % of the students explained that they enrolled due to other family members working in the construction industry, other answers included that the construction industry is a popular industry in their homeland and because some of the participants were good with numbers they studied quantity surveying and commercial courses that complemented the academic ability. The next question asked the participants why they felt that women were less likely to be employed within the construction industry. Figure 1 displays the answers that have been categorised, explaining that discrimination and harassment was the answer offered most commonly, however, the participants also felt that females taking maternity leave were also a big factor.

The participants were then asked a series of closed questions that were specific to women in construction. The first question was have the participants seen any advertisement towards women in construction. 67 % of the participants answered yes, and then the participants were asked if they knew any women working in construction. 75 % of the participants said yes to this question. This suggests that the construction industry is attempting to promote itself to women. 92 % also felt that the public's perception of the sector feel that it is a male-dominated industry, and 100 % of the students felt that the awareness of the construction industry needs to be taught to people at a young age. Consequently, the participants were then asked how they felt that women could be further encouraged to join the construction industry.

Figure 2 shows that greater awareness of the industry takes precedence over all of the other suggestions to get more women involved, as 7 of the participants suggested this

Table 1 Challenges women face within the construction industry

Challenges	Combined ranking (%)	Male Ranking (%)	Female Ranking (%)
Gaps in gender equality	8	0	17
Society's perspective/stereotype	25	33	17
Lack of awareness in opportunities	8	0	17
Discrimination and Harassment	42	50	33
Family Commitments	17	17	17

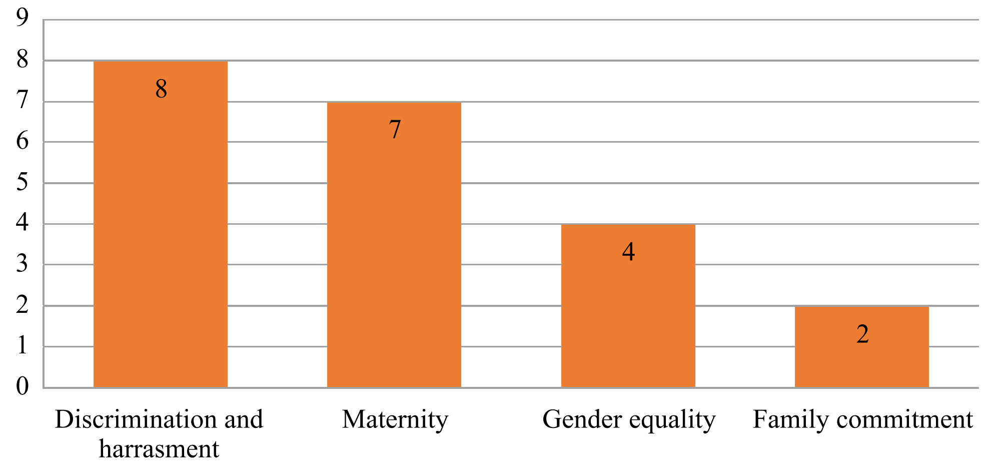

Fig. 1 Factors those are less favourable for women

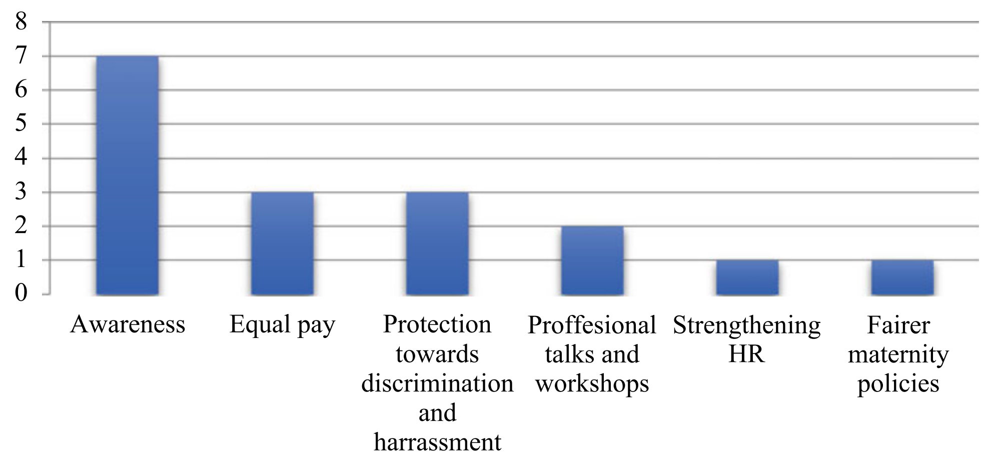

Fig. 2 Factors that encourage women to join the construction industry

compared to only 3 participants feeling that further support towards equal pay and protection against discrimination is required. Figure 3 displays the student's understanding of Athena SWAN and WISE is poor as only 25 % feel that they have a good understanding of it. Therefore, this shows that academic sector is not teaching or expanding their support of Athena SWAN and the aims academia are working towards.

Fig. 3 Students' knowledge of Athena SWAN and WISE

5 Discussion

The skills shortage is affecting the construction industry in many ways, but most significantly the UK's housing shortage, ageing workforce, rising salary costs and the UK's construction programme to build the required properties. One of the main items that are being reviewed is the difference between males and females working within the construction industry. ONS (2018) explain that only 13 % of construction employees are female. There are many issues that have been identified that explain the reasons for this including discrimination and harassment, equality, awareness, family commitments, maternity and diversity.

RG Group (2017) claim that women will not join the construction industry due the stereotypes that exist, explaining that females feel inferior to men in a male-dominated industry and, therefore, are often drawn to joining other sectors. This proves that the construction industry is poorly marketed as it has been described as low status, dirty and badly paid (CIOB 2014). This is supported by 75 % of the participants in this study agreeing that harassment and discrimination is a huge factor stopping females joining the industry. However, having been identified by industry professional Matthew Goff (2019), Director of UK operations at Actavo Building Solutions, that there is pay inequality issues with males being paid an extra 45.5 %, consequently 25 % of students agreed this is an issue that needs to be resolved. 10 participants confirmed family commitment and 2 participants further confirming maternity legislation as issues for females joining the sector. Meg Munn (2014) confirmed this view explaining that females do get judged, especially if they get married or have children. Meg Munn, also confirmed that this is indirect discrimination and women struggled to cope with the pressures of both work and family commitments due to a lack of support from there companies. Although there is not much that can persuade women to change their internal perception of how they feel about coming back to work when starting a family, businesses can do more to show support to working mothers.

The research completed via the literature review and the interviews with current students coincide. Matthew Goff (2019), Director of UK operations at Actavo Building Solutions, firstly admitted that including females within the workforce enables greater diversity and will help achieve greater results across a business. This is supported by many of the students who were interviewed explained that females joining the industry would bring greater diversity, new ideas, a different perspective and a method to reducing the skills shortage. The CITB (2018) also confirmed that by offering females advice, training, mentoring, work placements and jobs it will offer the construction industry a greater skill set and the opportunity for organisations to retain their staff reducing the staff turnover and a reduction in recruitment costs but also the potential to win further work.

The construction industry is attempting to improve the awareness of the construction industry for both males and females. 58 % of participants suggested that greater awareness needs to be improved within the construction industry to enable further people to join the sector. The University of Wolverhampton is supporting the Black Country Children's University, encouraging young adults to join the industry. Balfour Beatty is one of many companies encouraging women in construction through their 'Women in Construction and Engineering' awards, and, therefore, expect women's construction participation to increase by 25 % by 2020. The participants also explained that workshops, work experience and construction talks would enable prospective construction workers to gain a greater understanding of the sector. The Construction Youth Trust (CYT) (2017) promotes short courses that are designed to help 18–30 year olds get back into employment, supported by Meg Munn (2014) confirmed that contractors should offer work experience to females, and explaining that women should contact contractors to gain a greater understanding of the industry and feminist Kimberle Crenshaw (2016) claims that there must be support against sectionality.

The students were asked if they had seen any advertisement promoting to the industry to females. 66.66 % answered yes; however, other research suggests the construction industry is low status, dirty and badly paid. Therefore, this shows effort needs to be made on specific campaigns enabling females to learn more about the industry giving them the opportunity to display the talents they have and having a major input into the construction sector. Jon Henley of The Guardian (2018) announced the Icelandic Government have now made it a legal requirement for both males and females to receive equal pay. The UK government must now reflect upon the legal changes within Iceland and support those changes reviewing the pay equality UK legislation. The UK Government should also review the Swedish policies surrounding the maternity policy as Libby Kane of Business Insider (2018) revealed that Sweden's maternity and paternity policy is one of the best in the world as males and females are allowed to share 480 days earning at least 80 % of their salaries. By supporting these policies, it will encourage females to join the construction industry by reducing the discrimination.

6 Conclusion

The scope of this study was to review what the limitations are that stop women joining the construction industry, but also raise awareness of the benefits of the industry from a student's perception and, therefore, a literature review of the current market research was completed to find out what the impact of the skills shortage was, the obstructions stopping females joining the industry and how women are a benefit to the sector. Therefore, using this information enabled qualitative research to be completed, however, one limitation was that only 12 students were interviewed and interviews could have been conducted with women working in the industry to gain an incite of their experiences.

The results from the collected data show that the construction industry displays limitations that are deterring women from the industry such as harassment and discrimination, awareness, equality, and family commitment. However, research also suggests that females also have many attributes that could benefit the construction sector such as bringing greater diversity, new ideas, a different perspective and a method to solve the skills shortage. There are many initiatives that are attempting to solve the skills shortage such as teaching students from a school age, an idea that the participants promoted and are supported by the University of

Wolverhampton. There are also other organisations such as the Construction Youth Trust, Athena SWAN, Princes Trust and the Lighthouse Club that promote the industry to the public and construction bodies such as the CIOB, CITB and the RICS whom develop and promote programmes. The industry also needs to prove that it has removed the poor stigmas, by removing the harassment and discrimination issues that surround the sector. This must be supported by a culture change, teaching young adults that the sector supports both genders, enabling females to have raise families as well as the opportunity to enhance their career. Research also suggests that there are other nations support legislation such as pay equality and maternity leave and pay and, therefore, it is suggested the UK government should review their policies. Large construction contractors similar to Balfour Beatty must publicly challenge themselves to improve the employment conditions females are working in and be supported by improved government legislation and construction bodies such as the CIOB, CITB and the RICS to remarket the sector teaching young adults from a school age about what the construction industry involves enabling males and females to have a greater input into the sector.

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Residential Construction Risk Management: Does It Happen in Real Life?

Kamalesh Panthi, Lewis Waller, and Syed M. Ahmed

Abstract

Risk management is a key component to successfully operate a residential construction company, whether it is a spec builder, custom home builder, or a specialized subcontractor. With each type of contractor, there are many risks that exist but differ greatly between each type of contractor. With differing risks and business strategies, methods of mitigation are also expected to vary. The research was conducted where several residential contractors were interviewed to discuss their businesses, the most important risks, and their risk management process. This was an exploratory study and did not pose a hypothesis or test relationships between variables. This research presents the thoughts and habits of homebuilders as they relate to risk management. This small sample size is not sufficient to conclude with any confidence how a specific type or size of the builder is likely to see and respond to identified risks but gives insights into the processes companies go through in evaluating risks, how they perceive certain risks, their response, and factors that go into the allocation of these risks.

Keywords

Residential • Risk management • Custom home builders

1 Introduction

In 2018, the value of new private residential buildings put in place was around 540 billion U.S. dollars. (US Census Bureau). New residential construction spending was projected to be approximately 672 billion (current) U.S. dollars in 2022 (FMI Corporation, n.d.). This statistic shows how important residential construction is to both the economy as a whole and to the individual builders across the country.

Residential home builders are faced with projects that represent substantial financial investments and inherently deal with a wide spectrum of associated risks. In the best interest of their business, the risks involved in their projects must be continually identified and managed. However, often, their main day-to-day problems shift their focus away from these risks, and they are forced to devote much of their bandwidth to the task at hand—the actual building of the structure. Much of the associated risk is therefore not given the required attention and subsequently handled inefficiently. These builders do, however, have a great depth of knowledge and experience pertaining to what can happen on a project and how best to adapt. Whether they intentionally or systematically identify and respond to their risks or not, they do have procedures and processes in place to deal with these risks.

Large commercial construction companies operate in an arena that can require an investment of vast amounts of capital and corporate assets in their projects. Therefore, these companies dedicate a significant amount of time, money, and manpower to identify, assess, respond, and monitor risks. These companies recognize that creating a systematic, formal, and comprehensive Risk Management Plan (RMP) is essential for a project's success, and effective use of corporate assets. Large residential construction companies can have projects that utilize large tracts of land to accommodate hundreds, even thousands, of homes. These companies also invest vast amounts of capital and corporate assets in their projects and therefore recognize the need for, and benefits of, a comprehensive RMP.

Small residential construction companies typically do not have corporate assets, either capital or labor, to invest in large projects. Their projects are small in terms of scope,

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size, and corporate assets invested. However, the risks they face can be just as impactful, and perhaps even more so than those faced by larger companies.

2 Research Purpose

The purpose of the study is to identify the perceived importance of risk management of any type as well as try to explain why (why not) risk management is happening. The research study will help us understand where the companies' priorities are in risk management and what real-life risks they are concerned about on a daily basis. The research study will document the techniques and procedures used by small residential contractors in North Carolina in order to better understand how and why residential builders either perform or don't perform risk management.

3 Literature Review

The primary focus of this research is to gain a better understanding of the business practices and opinions of small residential contractors, their recognition of risk, and their preferred methods of responding to this risk. Unfortunately, no research literature was found directly on point that would provide a foundation upon which this research project could build. This being the case, a broader approach to examining the existing research on this topic was required. To this end, a review of the more pertinent literature researched follows.

Cullen (2016) suggests that risks can be classified in the following manner; schedule risk, cost risk, contractual risk, health and safety risk, reputational risk, organization/mission risk, technical feasibility, building performance risk, risk of technical obsolescence, dependencies between a new project and other projects, and physical events beyond direct control while Al-Bahar and Crandall (1990) identify the following classifications: financial and economical, design, political and environmental, construction related, physical, acts of God. This will be the classification method used in this study. Finally, Schieg (2006) proposes placing each risk in the category of quality, personnel, cost, deadline, strategic decision, or external.

While risk management has been successfully implemented in the manufacturing and service industries, the construction industry, due to its one-off and project-based nature, is not known for being effective managers of risk (Mills 2001). For construction companies to find success managing risk, many believe corporate leaders must recognize that risk and opportunity are interrelated and that the risk management process must move from corporate boardrooms to the project and individual levels to be effective (Mills 2001; Morris and Jamieson 2005).

Systematic risk management, which includes identification, analysis, response, and monitoring, should be started as early as possible in a project in order to establish some measure of control over the unexpected (Mills 2001). The critical task of identifying risks should be performed by those directly affected by the risks, including risk analysts, project teams, workgroups, and even peers outside the company (Mills 2001; Hlaing et al. 2008; Kaplanogu and Arditi 2009). During risk analysis, critical risks are identified (Mills 2001). Once identified, the critical risks can be responded to by transferring the risk to the party most affected by it, or to the party best able to accept it (Mills 2001; Liu et al. 2007). Common transfer vehicles include contract modification, subcontracting, and insurance (Liu et al. 2007). In terms of insurance, some owners and contractors buy project or umbrella policies for added protection against risks (Ndekugri et al. 2013). For accepted risks, Project Managers can play a significant role in designating the best party responsible for monitoring and control (Laufer et al. 2015).

Risk management should be viewed as a positive process that can save companies both time and money (Mills 2001; Hlaing et al. 2008). It is an exercise when approached with realistic expectations, can be extremely effective and can contribute to construction projects' success (Mills 2001; Liu et al. 2007; Hlaing et al. 2008). Some of the research above promotes a pragmatic approach to risk management, and is particularly relevant to this research project, especially for accepted risks. When risk management can be de-mystified and theories can be reduced to a more practical, even common sense level, more small builders and developers are likely to understand the benefits of identifying and managing risk. This is particularly true for understanding the costs associated with managing risk. A recent study conducted by Allen et al. found that while risk management does add to project cost, in most cases, the benefits of reduced risks outweigh the initial financial impact (Allen et al. 2015).

4 Methodology

This study involves qualitative research on small and local residential construction businesses. After the bulk of the literature research was completed, work began on designing the questions to be used in a survey of construction professionals. The questions were originally designed based on interviews of twenty-one construction and real estate professionals. The first group of questions asked respondents to describe their companies in terms of the number of employees, revenues, and production levels. The respondents' answers to these questions helped categorize the results for comparison purposes. The second group of questions concentrated on risk management. Data collection was done through either a phone interview or a face-to-face interview. There were 21 companies interviewed. All of these companies were based in North Carolina. A summary of the risk management practices of the 21 residential contractors/subcontractors is presented next.

5 Results

Since it is not possible to present the details of the interview of all the 21 residential contractors surveyed, a summary of the responses has been presented in a tabular format as shown in Table 1 through 3.

Table 1 Summary of risk management practices of small residential contractors (1–7)

	Company 1	Company 2	Company 3	Company 4	Company 5	Company 6	Company 7
Type/target market	Residential spec general contractor	Residential specialty subcontractor	Real estate developer	Custom homebuilders	Custom homebuilders	Custom homebuilders	Residential spec general contractor
Location:	Pitt County, NC	Most of NC and parts of SC and TN	Outer banks, NC	NC	NC	Pitt county, NC	Pitt county, NC
Top 3 risks:	Unpredictable real estate trends	Clients	Design changes	Design changes	Design changes	Design changes	Financial risks
	Frequent changes in interior design and layout	Changes by owner/client	Supply chain issues	Differing site conditions	Cost under-estimation	Differing Site conditions	Design changes
	Cost under-estimation	Changing site conditions	Cost under-estimation	Supply chain issues	Labor delays	Defective design	Defective design
Risk management method	Formal risk management technique	No formal risk management technique	Formal risk management technique	No formal risk management	No formal risk management	Yes	Yes
Type of risk management most concerned with	Risk transfer and retention used mostly	Risk retention and reduction used mostly	Risk transfer-subcontract	Risk transfer-subcontract	Risk transfer	Risk transfer	Retain
Use of Software to evaluate risks	NO	NO	ProCore	NO	NO	NO	NO
Focus area for top risks	Market trends	Clients and employee/vendor performance	Customer driven changes	Customer driven changes	Customer driven changes	Unforeseen conditions	Design changes
Risk mitigation strategies	Due to being a spec contractor, pricing typically cannot be adjusted to compensate for risks but usually just affects potential margins, etc	Due to being a subcontractor, pricing will always be adjusted to compensate for identified risks of each project	Has implemented 4 steps review process for design that goes through each department-legal, estimating, design and management to detect problems	Relies on experience to do deal with construction risk-viewed as a trial and error program	Utilized a well written contract to transfer any risk to the design firm	Subcontracting and thus transferring the risks to the subcontractors was a major form of risk response techniques utilized	Retaining the design risks and submitting a timely change order at a higher price

6 Discussion

The construction companies surveyed here have at least one thing in common with regard to risk management. They all rely on the judgment and experience of their management team on a case-by-case basis rather than relying on any structured risk management plan. The majority (62%) of the surveyed companies stated that they did not have a formal risk management structure in their company. The top three risks identified were design changes (57%), cost under-estimation (48%), and differing site conditions (24%). Almost all of them, with the exception of one, stated that they did not use any risk management software or applications for dealing with risks. Even the one company that stated that they used software to manage risks actually used Pro-core software which is not truly a risk management software or application. As can be observed from Table 1, 2, and 3, there is no common theme of risk mitigation strategies adopted by these companies. In response to the risks, each company approaches the subject from a slightly different perspective.

Table 2 Summary of risk management practices of small residential contractors (8–14)

	Company 8	Company 9	Company 10	Company 11	Company 12	Company 13	Company 14
Type/target market	Renovation and repair	Custom homebuilders	Custom homebuilder	Custom homebuilders	Residential spec general contractor	Residential spec general contractor	Residential spec general contractor
Location:	Pitt, NC	NC	NC	NC	NC	Central NC	Central NC
Top 3 risks	Design changes	Lower demand for product	Subcontractor caused delay	Material/labor price increase	Material/labor price increase	Cost under-estimation	Bad installation
	Unforeseen site conditions	Permitting delay	Material/labor price increase	Design errors and omissions	Differing site conditions	Labor delays	Cost under-estimation
	Defective design	Design changes	Weather delay	Lower demand for product	Design errors	Design changes	Weather delays
Risk management method	Yes	Yes	No	Yes	Yes	NO	NO
Type of risk management most concerned with	Risk retention	Retain and mitigate through market research	Elimination	Retain and mitigate through market research	Avoiding the risks	Acceptance	Transfer
Use of software to evaluate risks	NO	NO	NO	NO	NO	NO	NO
Focus area for top risks	Unforeseen site conditions	Market risks due to lower demand for product	Incompetent subs and their replacement always causes delays in the projects	Market risks	Differing site conditions	Cost under-estimation as a result of design changes by the customer	Cost under-estimation as a result of design changes by the customer
Risk mitigation strategies	By conducting renovations and repair work interview with the owner is a way of reducing the risk of design changes	They rely on historical data and most of all, the judgment and experience of their management team	Proper vetting of subcontractors to reduce the risk of this delay	They retain or mitigate risks through market research	Presales are a way to avoid the risk and stay in business	Acceptance of the risks was a popular risk response strategy	Detailed meetings with the clients to have a mutual understanding of the product requirement

Table 3 Summary of risk management practices of small residential contractors (15–21)

	Company 15	Company 16	Company 17	Company 18	Company 19	Company 20	Company 21
Type/target market	Luxury homebuilder	Residential GC	Residential GC	Residential GC	Custom high-end homebuilder	Subcontractor- custom trim	GC-disaster rebuilder
Location	Central NC	NC	NC	NC	Guildford, NC	Guildford, NC	Guildford, NC
Top 3 risks	Weather delays	Cost under-estimation	Labor injuries	Labor injuries	Unforeseen Site Conditions	Labor injuries	Warranty risks
	Cost under-estimation	Labor injuries	Cost Under-estimation	Cost under-estimation	Lower demand for product	Cost under-estimation	Design changes
	Design changes	Differing site conditions	Differing site conditions	Design changes	Design changes	Material/labor price increase	Labor injuries
Risk management method	NO	NO	NO	NO	NO	NO	NO
Type of risk management most concerned with	Acceptance	Elimination/transfer	Reduction	Reduction	Transfer	Elimination	Elimination
Use of Software to evaluate risks	NO	NO	NO	NO	NO	NO	NO
Focus area for top risks	Cost under-estimation as a result of design changes by the customer	Cost under-estimation was prevalent and had consequences in their profit	Labor injuries, although less likely, had a severe impact	Labor injuries, although less likely, had a severe impact	Financial exposure risk caused by building too many speculative homes is mitigated by maintaining a 2 to 1 ratio of spec homes to pre-sales	Cost under-estimation due to mistakes in item takeoff	Warranty risks
Risk mitigation strategies	Contractors choosing acceptance strategy have contingency plans such as back-up subs if the problem arises with the original subs	Experience of managing the project for many years was perceived to be the most useful and only available tool to deal with risks	Workers safety was a major risk factor perceived and was handled through a safety meeting with the workers every day	Reduction of the labor injuries (both the likelihood and the impact) through PPE and OSHA training	Active risk management is not an important piece of the building process but certain techniques used in the past help reduce the risks	Contracts are not used in the business as the work is only done for a handful of contractors. Eliminates the risk of not getting paid by the contractor by only working for certain companies	The company gives a 5year warranty on all insurance fed program work which is a risky thing but is offset by bidding at a higher price

7 Conclusions

In conclusion, risk management at the residential construction level happens on a limited basis and the methods differ slightly between companies. The years of experience and types of projects undertaken play a large part in how risk management looks to each business. There is no question that risk management is important and would influence these businesses at all levels but the amount of time and effort needed to do it properly and in-depth can be overwhelming for small companies. All of the businesses do identify the use of software would help streamline the process but still require extra time to be dedicated to risk identification, risk assessment, risk response, and risk control and monitoring.

There does not appear to be a common theme in which risks are identified, assessed, and mitigated among these relatively smaller companies. It is only natural that different people with different experiences would give different responses as to the impact and probability of certain events. Risk management is looked at as a trial and error program, where nothing is mitigated unless it is needed. The questions that must be asked are "Do small residential contractors need to implement a risk management process?" "Does a process warrant the time and effort for projects costing between $100–400 k?" It is believed that these contractors could still benefit from a systematic risk management process. Many of them are already doing something that resembles risk management, however, they do it because it is what they have always done. A standard risk management procedure would establish a systematic process that could be referenced and taught to new employees and new supervisors. This would prevent each company from having to solely rely on experience from project managers, superintendents, or supervisors that have worked in the local area for years. This would also establish the foundation for making a company sustain the challenges and complexity of the new world that we live in.

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Assessment of the Role of Owner's Representative on Construction Performance: An Owner's Perspective

Hala Nassereddine, Tia Endres, and Awad Hanna

Abstract

The modern construction industry is complex and heterogeneous. The three major players in this industry are owners, constructors, and architects/engineers. However, there is a fourth party that can also be involved in construction projects: the owner's representative (OR). ORs are individuals or firms hired by an owner to manage the construction project in the owner's stead. They have a relationship contractor, architect/engineer, and the owner and provide a range of services depending on the needs of the owner. Given the important role ORs can play in this industry, there is a dearth of literature today concerning them, and extant literature is significantly biased with shortcomings including authors' perspectives and overall lack of industry-driven data. The objectives of this research are to gain an understanding of when an owner is likely to hire an OR and what impact ORs have on project performance. This study placed a priority on remaining unbiased, and was conducted from the owner's perspective using data from projects with and without ORs.

Keywords

Owner's representative • Construction industry • Project performance

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1 Introduction

The body of literature which concerns modern construction is well saturated with documentation of the role and impact that contractors, architects, and engineers may have on any given construction project. However, since the impetus for any construction effort is the owner's need to build, construct, or renovate something, an understanding of the responsibilities and impacts that an owner or owner's representative (OR) may have is needed. The exigent literature concerning ORs is fraught with bias and subjectivity, given that a large portion of it is written by ORs themselves. Furthermore, the use of an OR to manage construction is not universal, and many owners do not use one. Therefore, it must be understood why owners choose to hire ORs, and what impacts they have on projects once retained.

The literature that exists provides two conflicting views on ORs, but does not provide to the owner an objective assessment of the value of an OR. Contractors have mixed opinions on OR—some view them as a hindrance to completing work, while others note the benefit of an OR handling project tasks. However, literature concerning ORs that is published by ORs is understandably partial and does an inadequate job of examining the decision to hire an OR and their potential impact.

Owners deserve to understand the return they receive from their investment of hiring an OR. OR can cost between 3–5 % of the overall project cost (Gainsboro 2006), which can add up to a substantial sum, depending on the size of the project. The construction industry as a whole can also benefit from understanding why owners hire ORs on their projects. This research gives insight into the current use of ORs on construction projects, the value they provide, and the responsibilities they perform.

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2 Literature Review

Bubshait (1994) said that "owner involvement is essential to project quality. Success or failure is, in many cases, related directly to the level of owner involvement." This still rings true in modern construction, and many owners understand the importance of involving themselves on construction projects. Many times, owners decide to hire an OR to act in their stead. An OR is best described as "an individual tasked with controlling the design and development process while protecting the best interest of the owner" (LEED Certification (2017).

ORs have become prevalent in today's construction industry, particularly as project sizes and complexity continue to grow. Owners choose to hire ORs to act on their behalf, however, the exact duties of and extent of responsibilities for an OR can vary from owner to owner and project to project. It is common for ORs to make decisions, solve disputes, and manage changes and coordination with multiple parties on a construction project (Jawahar-Nesan and Price 1997).

There are several articles written by ORs about their general importance to construction, although each owner has their own individual reasons for hiring an OR. ORs argue they are important because they help with complex, expensive, and risky projects. These projects are prone to significant financial and schedule impacts from the design and construction teams, which may be difficult for an owner to understand and navigate. In this scenario, an OR can facilitate communication and increase owners' understanding of the project, which can improve outcomes, reduce risk, and prevent unnecessary expenses (Gainsboro 2006). ORs can also assist in contract negotiations to help owners get the best price possible (Res 2016).

When owners make the decision to hire an OR, they must first define what precisely the role of the OR will be. This is important as not all ORs are the same, not all projects are the same, and the skills and effectiveness of the OR will affect the project performance. Res (2016), an engineer and attorney who acts as an OR, says that "the OR should have sufficient experience working for owners, but also for contractors and subcontractors. Credentials as an engineer or architect are helpful, but it is more important that the OR has worked intimately with the owner's organization to the greatest extent possible." It is also said that the best ORs have experience working for the owner, facilities, and design. The best way to find qualified ORs is to talk to industry experts, board members, and associations (Gainsboro 2006). Lastly, having a proactive OR is significantly better than having a reactive OR. The proactive ORs will be the ones taking initiative to be a leader, while the reactive will deal with issues and opportunities only after they have presented themselves (McKew 2001).

From the limited amount of literature available for review, an understanding can be gained about who ORs are, what their job is, and why they are important. However, there are shortcomings to the available literature regarding authors' perspectives and a lack of data. This paper introduces data from projects that both have and do not have ORs, and analyzes it to understand the impact that ORs have on projects. This paper also looks at the responsibilities and characteristics of what makes an effective OR on a project from collected data, all of which is lacking in today's literature. Looking at the impact of ORs from an outside perspective allows an unbiased evaluation of their significance.

3 Methodology

A question many in the construction industry have is why do owners decide to hire an OR and what is the true value of hiring one? The opinions on ORs vary in the industry, and it is not uncommon to hear contractor's mixed feelings about ORs. However, the ultimate decision to hire an OR lies with the owner. There is inadequate data supporting or opposing ORs' value on construction projects, which makes one question why they are hired. This paper introduces data from projects that both have and do not have ORs and analyzes it to understand the impact that ORs have on projects. This paper also looks at the responsibilities and characteristics of what makes an effective OR on a project from collected data, all of which is lacking in today's literature. Looking at the impact of ORs from an outside perspective allows an unbiased evaluation of their significance. The methodology of this research encompasses three distinct stages.

3.1 Stage A: Project Performance

This stage is meant to define key performance variables to help understand the impact that ORs have on overall project outcome. Five qualitative project performance variables that are measured at the end of the project were included in this research: budget performance, schedule performance, change performance, owner satisfaction, and user satisfaction. These factors were assessed by the owner using a five- or seven-point Likert scale. Likert scales ask respondents to rank the strength/intensity of their experiences on a linear scale. Using Likert scales makes it possible to perform nonparametric tests on the results, and to find correlations between aspects of the project, particularly focused on ORs. The specific scales used to measure performance of the different metrics are as follows:

- Budget Performance was measured on a seven-point Likert scale ranging from "Extremely lower than budgeted" to "Extremely higher than budgeted"
- Schedule Performance was measured on a seven-point Likert scale ranging from "Extremely shorter than scheduled" to "Extremely longer than scheduled"
- Change Performance measured on a five-point Likert scale ranging from "None at all" and "A lot"
- Owner Satisfaction measured on a seven-point Likert scale ranging from "Extremely dissatisfied" to "Extremely satisfied"
- User Satisfaction measured on a seven-point Likert scale ranging from "Extremely dissatisfied" to "Extremely satisfied."

3.2 Stage B: Survey

In order to better understand the opinions owners hold about ORs, and to gain insight into why they do or do not choose to hire one, a survey was distributed to a variety of owners and facility managers who were asked to respond concerning a recent project. The survey was broken into three sections: First, the survey asked respondents about project characteristics and whether or not they hired an owner representative. Their answer to the latter questions led to a separate set of follow up questions which investigated the decision to hire or not hire an OR. Finally, respondents were asked about the overall project performance. 137 respondents (61 %) reported hiring an OR, and 88 respondents (39 %) did not.

3.3 Stage C: Analysis

Two types of analyses were performed on the collected data. Univariate analysis was used to describe, explore, and summarize some of the research questions. A variable in univariate analysis is a subset of the collective data that requires further investigation. The second type of analysis employed in this research is the bivariate analysis. This type analysis was performed on the collected data to compare the two groups of projects–projects where owners hired an OR and projects where owners did not hire an OR and test whether ORs have an impact on project performance. Three tests were used to provide a comprehensive comparison between the two groups: (1) the Pearson's Chi-Square test, (2) the nonparametric Kruskal–Wallis test, and (3) the Mann–Whitney–Wilcoxon (MWW) test. Pearson's Chi-Square test is used for qualitative analysis when the independent variable is a nominal variable and when no more than 20 % of the expected values are less than five. The Kruskal–Wallis test is employed when the independent variable is ordinal. The MWW test is a nonparametric test that is used to assess the statistical significance between two sample means. All testing procedures were carried out based on a 95 % confidence interval and statistical significance was concluded when the p-value was less than or equal to 0.05.

4 Analysis

4.1 Reasons for Hiring or not Hiring an Owner's Representative

The literature has identified various reasons for hiring OR. In an attempt to overcome bias present in the body of literature concerning the hiring decision, the survey distributed as part of this research asked owners who hired an owner representative to select the reasons for which they hired an OR. The survey included 12 possible reasons: improved communication, cost savings, heavy workload, lack of technical knowledge, create budget, create schedule, quality assurance/quality control (QA/QC), avoid conflict of interest, provide value engineering, conduct constructability analysis, control contingency money, and approval of change orders In addition to these reasons, respondents had the option to write in any additional influencing factors that were not enumerated. The factors that were written in by owners included risk management, helping with selection of contractor and architect, oversight management, and assure maintainability—however, no added factor was written in multiple times. The five most common reasons why owners chose to hire an OR are improved communication (87 %), approval of change orders (83 %), QA/QC (83 %), heavy workload (81 %), and providing value engineering (76 %). However, most of the reasons listed above are still important for a large number of owners, with over 50 % of respondents indicating that they played a role in the decision. Avoiding conflict of interest was the only reason that less than 50 % of respondents felt hiring an OR was required.

Similarly, there are many reasons why owners may decide not to hire an OR including owner's prior experience with the project team, in-house capacity to manage project, could not find qualified OR, did not want to lose control of project, cost/value perceived of OR, overlap between ORs responsibilities, and general contractor can perform same tasks. The owners were also encouraged to write in any additional comments they had about reasons they decided not to hire an OR, which included having a well-qualified senior manager, or an in-house project manager on staff. The results show that the major reason why most owners decide not to hire an OR is because they have the in-house capacity to manage the project (94 %), with the second-highest reasoning being the cost/value perceived from hiring an OR (79 %). This shows that companies are less likely to hire ORs if they feel they can handle the responsibility themselves, and that many owners question how many benefits they receive from hiring an OR compared to the cost.

This research also investigated who represents the owner when an OR is not hired and found that 84 % of owners who choose not to hire an OR represented themselves. This can be explained in several ways the owner may have enough time, experience, and willingness to represent themselves, or the owner trusts the general contractor fully and does not think he/she needs an OR. On the other hand, 9 % of owners who did not hire an OR reported that they chose the architect/engineer to represent then, and another 8 % chose a construction manager.

4.2 When and How an Owner's Representative is Hired

Deciding when to hire an OR is as important as the reasons for hiring one. The point in the project lifecycle at which an OR is hired varies from owner to owner: some hire an OR prior to design, while others wait until as late as after the GC is hired. The results of this study show that owners tend to hire OR before hiring the general contractor (GC) or before the design phase of the project. The timeline of hiring an OR may depend on the responsibility that OR will perform they may help with the selection of the general contractor, or work with the architects and engineers during the design phase.

As ORs are frequently hired prior to the general contractor, owners were also asked if their ORs were involved in the selection of the general contractor. 81 % of owners indicated that their ORs were involved in the selection of the general contractor. The reason behind this could be the additional experience the ORs have with general contractors and the advice that ORs may offer on the hiring process—a crucial project decision.

As a large percentage of ORs are involved in the selection of the general contractor, it was important to test if this involvement has a significant effect on the five project performance metrics studied in this research. The MMW test was used to determine if the involvement of the OR in selecting the general contractor had an impact on each of the five performance metrics. With p-values greater than 0.05, the results indicated that there is no statistically significant impact for having the OR involved in the selection of general contractors on project performance. Therefore, whether or not an OR is involved in the selection of the general contractor, there will be no statistical difference in the performance of the project.

How ORs are selected is also an important process. The survey included five major criteria based on which the OR could have been selected including bidding, negotiated contract, previous contact, recommendation by others, and voting of key people. The results showed that 27 % of the ORs were selected by negotiated contract, 26 % were recommended by others, 24 % were chosen based on previous contacts, 16 % were selected through bidding, and 7 % were appointed by the voting of key people.

How the OR is selected can have an impact on the overall project performance. For instance, if an OR is hired from the previous contact, they may have already proven to be successful, or if an owner selects an OR from bidding that may mean they are looking at cost over quality. However, the results of the Kruskal–Wallis test showed that the selection method of ORs has no significant impact on any of the project performance metrics.

4.3 When and How an Owner's Representative is Hired

This research also aimed to explore nine project characteristics that are likely to affect the decision of an owner to hire an OR. Respondents were asked to provide information about the following variables: (1) project location, (2) project type, (3) project owner, (4) delivery method, (5) project size (SF), (6) project cost, (7) owner's experience with construction, (8) experience with general contractor in the past, and (9) if there are any special conditions on the project. This study then investigated whether a correlation exists between the decision of an owner to hire or not to hire an OR and each of the above-mentioned eight variables. Different statistical tests were used depending on the nature of the variables. The results of this analysis are shown in Table 1.

Out of nine project characteristics, three characteristics were found to be significant in the owner's decision to hire or not hire an OR: project size (SF), project cost, and owner's experience with construction. Project size (SF) and overall project cost are significant in this decision, as larger and more expensive projects are more likely to hire an OR than smaller cheaper projects. As for the owner's level of experience with construction, the results showed that the more experience an owner has with construction, the less likely they are to hire an OR than an owner that has less experience.

Table 1 Project characteristics variables

Variable	Type	Levels	Statistical test	*p*-value
Project location	Categorical–Nominal*	3 levels	Pearson's Chi-Square	0.2183
Project type	Categorical–Nominal*	5 levels	Pearson's Chi-Square	0.7783
Project owner	Categorical–Binary	2 levels	Pearson's Chi-Square	0.2619
Delivery system	Categorical–Nominal	6 levels	Pearson's Chi-Square	0.1806
Project size (SF)	Numerical	–	MWW	0.0093**
Project cost	Numerical	–	MWW	0.0392**
Owner's experience with construction	Categorical–Ordinal*	2 levels	MWW	0.0241**
Experience with general contractor in the past	Categorical–Binary	2 levels	MWW	0.9898
Special conditions on the project	Categorical–Binary	2 levels	Pearson's Chi-Square	0.9112

*A nominal variable does not have any intrinsic order, whereas an ordinal variable does
*The owner's experience with construction was measured on a five-point scale from "no experience at all" to "a lot of experience"
**Indicates a statistical significance at the 0.05 level

4.4 Responsibilities the Owner's Representative Perform During the Project

A primary goal of this research was to determine what responsibilities ORs have on construction projects. The survey sent out to owners asked if ORs held certain responsibilities during the design and construction phases. The results of owners who responded "yes" show that the most common responsibility of an OR during the design phase is to review the schedule, however, less than half of the owners reported that the OR solicited bidders. During the construction phase of the project, most ORs review the schedule, approve progress payments, and track the project program, while slightly more than half produce schedule updates. There was also the option for owners to fill in any other responsibilities they felt were important, and some respondents reported that ORs review and complete inspections, prepare project justifications, develop specification during the design phase, review cost, review proposals, and help with coordination.

Given that there are many responsibilities that ORs can have on a project, it is important to assess whether these responsibilities have an impact on project performance. Knowing this information can help owners determine how best to allocate responsibility to their OR. The performance of the projects on which an OR was hired was compared to the projects that did not have an OR using the MMW test to individually compare each of the 14 responsibilities to each of the five performance metrics. The results showed that only two OR responsibilities had a significant impact on the project performance: approving progress payments and approving change orders.

Both of these responsibilities are significant at the 95 % confidence level, but their impact is only on budget performance: when ORs approve progress payments and change orders, the budget is lower than when ORs do not, indicating the positive impact of hiring an OR.

4.5 Greatest Benefits Perceived from Hiring an Owner's Representative

It has already been discussed why owners hire ORs and the different responsibilities ORs can have on a construction project, however, each owner has their own benefits they see most from hiring an OR. The results indicate that the greatest benefit owners receive from hiring an OR is avoiding or minimizing budget problems, however, many other owners report (1) avoiding or minimizing schedule problems, (2) greater accountability to the owner, and (3) leadership to the project team as their greatest benefits. However, few owners reported implementing new technology as the greatest benefit received, and higher quality outcomes received as the second-lowest number of responses.

5 Conclusions

Owner Representatives are an increasingly integral part of the construction industry, with an increasing number of owners choosing to hire one. The lack of research regarding ORs is alarming when compared to the substantial amount of research performed on contractors and architects/ engineers. To study understand the decision to hire ORs and their impact on project performance, this research analyzed data collected from owners who did and did not hire OR on their projects. The analysis showed that owners decide to hire an OR for five major reasons: improved communication, approval of change orders, QA/QC, heavy workload, and providing value engineering. On the other hand, the collected data showed that the major reason why most owners decide not to hire an OR is because they have the in-house capacity to manage the project. It was also found that three project characteristics have an impact on owner's decision to hire or not hire an OR: project size (SF), project cost, and the owner's experience level with construction. For larger projects, owners are more likely to hire an OR. Owners who have more experience with construction are less likely to hire an OR. The research also concluded that the only two responsibilities of ORs that were found to have a significant impact on budget performance are approval of progress payments and approval of change orders: when an OR is performing these tasks, the project is more likely to be on or under budget instead of over budget. Thus, it is concluded that the greatest benefit owners receive from hiring an OR is avoiding or minimizing budget problems.

It is understandable that each owner is different and will have unique circumstances that may influence their decision to hire an OR or not. This research is beneficial for the construction industry as a whole to better understand ORs and the value they add to a construction project, however, there are many more factors that can be considered for future research. Collecting quantitative data about ORs and their projects and increasing the sample size is an additional research step that can be conducted in the future.

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STREBLO: The App Prototype for Managing Stress in the Construction Industry

Silvia Riva, Paul Hampton, and Ezekiel Chinyio

Abstract

High levels of stress at work, great responsibilities, hazards and lack of balance between tasks and deadlines are common in the daily lives of many construction workers. E-health applications can help manage stress. Accordingly, an App is being designed to enable construction workers to (1) detect the onset of stress quite early, (2) track their stress status, (3) empower persons to cope with stressful and/or demanding situations in an adaptive way, (4) improve and streamline the operability of job tasks and (5) optimise efficient solutions for the construction industry. The development of this innovative app, known as Streblo, is part of a wider research that is studying stress management in the construction industry. Streblo's blueprint will match personality traits with coping strategies in real-life situations. Its inputs are being generated from a field study that has commenced, where 23 structured interviews have been used to collect data from construction workers on their (1) personality and (2) behaviours while experiencing stress. Results of the data collection and analysis are being used to develop Streblo (an App) with IT experts. The paper reports the detail development and performance of Streblo's prototype. Ultimately, users will be able to engage Streblo on electronic devices (mobile phones, tablets and computers) through both text and image-based communication, obtain real-time solutions and feedbacks on their stress status. Streblo will enhance and support attitude and behavioural changes in people who suffer from stress symptoms in the construction industry.

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Keywords

Stress • Tool • Coping • App design • Streblo • Well-being

1 Introduction

The UK Health and Safety Executive (HSE) has defined work-related stress as the adverse reaction people have to excessive pressure or other types of demand placed on them. Due to the risky and often problematic environments of construction projects, time management and other crisis-ridden working issues, the construction industry has long been known to be stressful (Bowen et al. 2014b; Chan et al. 2018). Stress arises when there is an incongruity between a worker's estimated capability and resources and actual context to cope with his or her activity (Leung et al. 2016; Haydam and Smallwood 2016). Stress in the construction industry has been tightly linked to arduous activities, scarce support of relationships, difficult climates, uncomfortable physical environments, work overload, lack of autonomy and conflicting roles. Stress can impact negatively on an individual's psychological health and performance, and can manifest as a simple strain or sense of frustration, low motivation and lesser productivity (Lingard and Francis 2004; Love et al. 2010; Chan et al. 2012; Bowen et al. 2014b).

In 2006, a pioneering large study conducted by the Chartered Institute of Building (CIOB) in the UK showed how stress in the construction industry was extremely linked to inter alia, interpersonal and cultural/organisational factors, i.e. lack of feedback (56.8%), poor communication (55.7%), inadequate staffing (55%), too much work (64.1%), ambitious deadlines (59.7%), pressure (59.9%) and conflicting demands (52.2%). On the contrary, site safety, inadequate equipment and poor physical environment were among the lowest scoring factors with over 80% of the survey respondents stating that these were not a cause of occupational stress.

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Stress impacts not only on individuals' physical and emotional status, but also on their job and general performance in terms of efficiency, outputs, teamwork and collaboration (Enshassi et al. 2018). Stress in Construction has been associated with a high presence of anxiety and depression, whereby workers spend less time maintaining their health status, take on less personal responsibility and invest less energy in their work activities (Derr et al. 2001; Love et al. 2010; Enshassi et al. 2018). It is therefore important for players to cope with a challenging construction industry and be able to deal with stress (Bowen et al. 2014a; Chan et al. 2014). 'Coping' is the psychological description of the ability to deal with stress and it represents the behavioural and cognitive solutions an individual adopts to manage stress (Lazarus 1966). Coping behaviours may be adaptive (when they help people to find efficient solutions to their stress) or maladaptive (when they cause detrimental effects at the physical and/or emotional levels).

2 E-Self Management Applications

E-self management applications may represent a valid support to managing stress, and they can easily be adapted within the work environment (Wu et al. 2017). An App may contribute to help the worker to manage his/her activities autonomously and prevent any detrimental outcomes. E-self management applications can contribute to monitoring the level of stress and users' health status through their ability to foster continuous interaction. Particularly, mobile phone apps have shown promising results in the field of 'self-management, health conditions and wellbeing' (Payne et al. 2015; Whitehead and Seaton 2016) with good results in terms of improved quality of life, reduced need for care and cost efficiency. Different applications have shown significant improvement in health distress and increased self-efficacy and satisfaction (Lorig et al. 2001; Bauer et al. 2014). Support for different health conditions is now feasible through information and communication technology (ICT), e.g. self-management of appointments and check-up visits to doctors, smartwatches, and virtual trainings, social networks and discussion forum. There are also apps that can link vital symptoms with personal health devices and electronic medical record systems (Wang et al. 2014; Årsand et al. 2015). Apps can be implemented in work settings to transmit the unique needs of workers with a mental health condition. Individuals can choose different functionalities of apps towards managing their particular problems and grade of severity. Many apps permit personalisation to a specific user's needs and goals (Shaw et al. 2014; Jonkman et al. 2016).

The potential usefulness of apps may be superior for some specific mental health conditions, such as stress. Mobile applications for stress management have been applied in different sectors (e.g. health) with promising results (e.g. Gaggioli et al. 2014; Engel et al. 2015; Khusid and Vythilingam 2016). However, no construction-specific application exists. Hence, the aim of this paper, based on an underpinning research, is to attempt to describe the design of an interactive App for construction professionals for coping with stressful events at the workplace. The overall goal of this tool is to detect

1. Early signs of stress; that is the mental and physical states resulting when the resources of the individual are inadequate to cope with the demands and pressures of the situation.
2. Stress consequences that can undermine the achievement of goals, both for individuals and for organisations; monitor these; and propose innovative solutions to overcome problems for construction workers.
3. Signs of stress that can be seen in people's behaviours. Responses to stress may be in the areas of feelings (e.g. anxiety, depression, irritability, fatigue), behaviour (e.g. being withdrawn, aggressive, tearful, unmotivated), thinking (e.g. difficulties in concentration and problem-solving) or physical symptoms (e.g. palpitations, nausea, headaches).

3 Methods

The development of the Streblo app (prototype) included participatory design (interviews) with inputs from different construction workers (N = 20) and IT academic staff (N = 3). The interviewees consisted of 5 operational managers and 15 supervisors while the academic staff consulted were two informatics engineers and one specialist in the Build Environment.

Brief structured Interviews facilitated the assessment of users' needs and afforded potential consumer input into the app's focus and features. Table 1 describes the content of these brief interviews.

The interview is part of a larger study about stress management in the construction industry characterised by the collection of both quantitative and qualitative data. The results described below are inspired from the results of the interviews and form the large qualitative study based on an ethnography research at 3 Construction sites: this lasted 6 months and involved more than 50 observed participants at work.

A Delphi approach (Delphilike) was applied in which a forecasting method based on the results of questions is sent to a panel of experts (Benarie 1988; Nevo and Chan 2007).

Table 1 Interview guide

Construction workers' questions	IT academic staffs questions
Open question: Which are the main features that a technological tool should have to help persons to cope with stress?	
Which are the technological requirements for a good app? Which services an app should provide?	
How to incorporate graphical aspects?	
How to design a tool feasible for construction workers (office based and site based)?	

The responses generated during the interviews were transcribed and summarised, manually.

4 Results

The suggestions generated from the analysis led directly to the development of Streblo's features and content. For example, some research participants requested tools that they could use easily at the workplace (e.g. for remembering previously inserted or stored user-data). Some participants also wanted the app to provide a record of the suggestions received. Employing this user-centric design procedure was intended to develop an app that would be most relevant to the users' needs and provide functionalities that were most attractive to them. Streblo is being designed to be used either as a stand-alone psychological and self-management tool or to cope efficiently with stress at the Construction workplace.

Results of the preliminary data collection have permitted the delineation of the main features of the Streblo app (Table 2).

4.1 The Streblo App

4.1.1 Design Principles

The following design inputs and principles generated through the research were applied in developing the prototype web-based stress management system:

Social connections. New information and knowledge are shared when different workers are invited to online conversations. Also, people with previous situation of stress, who have managed to recover from difficult situations in construction job activities, can contribute with their insights. By this, both strong-tie and weak-tie relationships are made possible.

a. Self-Learning on Stress. Through questions and practical experiences, users can get help in their learning processes and become more aware and more confident to cope with them.
b. Wide range of solutions. The system should help the users to enhance their strategies in order to cope with stress better and positively. This can be through an array of behaviours, such as advice on how to approach a specific stressful situation, and how to interpret a particular event and demanding requests.
c. Constant e-Learning. Continuous efforts are needed for people who want to change maladaptive coping behaviours and patterns of actions. Therefore, it is important that the system has tools for ongoing help in everyday events in the workplace.
d. Practical A. The inner architecture of the system is learning based on the users and their experiences. By identifying good solutions and adaptive behaviours, feedback on what goes on in the users' lives is available, and the system can be adjusted when necessary. For example, exercises can be tailored to better fit the needs of the user for a circumstance.

Table 2 Features of Streblo

Main features
Graphical-friendly (the tool must be graphically easy to learn and use); Fully integrated in their usual smartphone
Customisable (lay people with no programming skills should be able to use all the functionalities)
Discreet (the application should not interfere with normal mobile phone usage or with normal working routine activities)
Multilevel usability (the application is connected to an icloud system permitting the user to use the App on smartphone, IPad or PC according to personal requirements and/or laws, e.g. a user working on site may use the application on his/her PC because the law does not permit the use of smartphone during routine activities)

e. Multimedia Tutorial. E-learning between the user and the system is mediated by using a tutorial. Breathing exercises can, for example, be easily demonstrated through online video clips. Likewise, other exercises can be recommended to mitigate stress.

4.2 Web System Components

The app consists of four major sections:

1. Who are you? This section provides psychological information about personality (e.g. symptoms, prevalence rates, how stress develops) and various types of behaviours that are available. It includes information about habitual behaviours, cognition and emotional patterns.
2. Self-Assessment: This section includes the Streblo COPE Inventory version (a well-validated, widely used self-report that measures the ways to cope with stress). After completing the COPE, users are provided with interpretive feedback about the efficacy of their coping strategies (adaptive, maladaptive strategies or alerting information). Users can also track their strategies over time by viewing a line graph of past assessments. Finally, users can schedule future assessments at regular intervals (e.g. monthly).
3. Manage stress: This section provides solutions to help address stress symptoms and manage difficulties in the workplace. When a coping behaviour is selected, the user is invited to check if the coping solution adopted is adaptive or not. If not, the system offers solutions to the user. Depending on the problem selected, the user is offered a psychological-based coping tool (e.g. paced breathing, progressive muscle relaxation, concentration exercises, engage in pleasant events) or an organisational-based coping tool (e.g. divide your task into subtasks, identify priorities). If users do not like a solution presented to them, they can choose another option. Table 3 illustrates an example of adaptive, maladaptive coping behaviour and associated solutions.
4. Find Support: This section allows users to easily reach out to sources of support when needed, including their GP, NHS mental support and other allied organisations that offer help for managing stress. Streblo also provides users with a variety of links and phone numbers to facilitate finding face-to-face interaction with qualified professionals.

5 Discussion and Conclusion

There is a considerable body of existing research regarding mobile interventions for self-management; however, new research is also required to test the effectiveness of these new instruments in the field, such as in the case of the construction industry. Meanwhile, new studies are also required to evaluate how such applications can determine a positive change over the time in managing a health condition in different settings, such as stress at work. In this context, Streblo represents a prominent and innovative solution for stress management with potential important impact on personal well-being and quality of life.

While previous research in construction management has mainly focused on the effect of stress and its influence on the performance of an individual and project outcomes, very few studies have touched on the stress experience (Sutherland and Davidson 1993; Leung et al. 2008).

The emergence of mobile self-management and well-being solutions heralds a new era in personal management, and it is particularly pioneering in the field of construction management.

The research described in this paper aimed to assess a prototype innovative app for the management of the common stressors faced in construction projects. Streblo has been developed using a robust, bottom-up, qualitative approach that included consultation with as many stakeholders as appeared to be necessary. The first prototype of the app is based on documented knowledge to provide a firm foundation for subsequent refinement which will require inputs from expert stakeholders on fitness-for-purpose. At its future operational level, Streblo will be tested among different construction workers to measure acceptability and efficacy prior to its public diffusion.

6 Conclusions and Recommendations

The negative effects of stress at work in terms of emotional disorders and organisational difficulties have urged the need for new tools and solutions, especially direct-to-user tools such as mobile applications. The use of Streblo should orientate the better management of health and safety issues in Construction.

An important aspect of Streblo is that a user does not just make an assessment to see if they have a problem with stress in the workplace, but the app also helps them to eliminate or at least ameliorate the potential impacts of any identified stressor. The potential of Streblo is thus wide and in line with the actual and current needs of professionals working in the construction

Table 3 Coping behaviours and solutions in Streblo model

Coping	Behaviours	Examples of actions	Evaluation	Solution's proposed
Use of instrumental social support	Asking for advice, and help or information from your colleagues	Ask for the collaboration of colleagues Ask for the support of own supervisor/boss	Green	The team exercise (applicable when working in a team): • Set precise timelines and deadlines for others • Set false, early deadlines, to make it more probable that they'll actually finish on time • Communicate your frustration with others' behaviour, if necessary
Active coping	Taking action to decrease or get rid of a stressor or its consequences	Reframing the meanings of problems Seeking more information	Green	The exercise to priorities (1) Prioritise your tasks: • A tasks: Critical and time-sensitive • B tasks: Important, but slightly less time-sensitive than A tasks • C tasks: Not time-sensitive—yet • D tasks: Optional—nice, but neither important nor time-sensitive The exercise of priorities (2) Set priorities: 1. High payoffs. Which tasks will provide the best return on investment for your time and energy? 2. Essential to your goals. Which tasks are absolutely critical for meeting personal and professional goals? 3. Essential to your company's goals. Which tasks will most benefit your company, providing it with the best return on investment for employing you? 4. Essential to your boss's goals, with others' b« Which tasks does your boss regard as most important? 5. Can't be delegated. Which tasks can be done only by you? These will be high priorities
Denial	Ignoring, refusing to acknowledge the problems Denial of the reality of the event is another method which might help reduce the intensity of negative emotions and negative appraisal. The denial of the existence of the threat can have negative consequences because the person using this tactic is avoiding to resolve a stressful situation	Avoid the problem Yellow Delegate the resolution of the problem to someone you can trust	Yellow	Stress can present itself in many different forms. When you are hit by a stressful situation, an emotional storm is likely to whip through your mind and body, tossing painful thoughts and feelings in all directions. Do not escape! Here's what you can do to survive and thrive: S.T.O.P. exercise • Take a few deep breaths, and mindfully observe the breath flowing in and out. This will help to anchor you in the present TAKE note • Take note of your experience at this moment. Notice what you are thinking. Notice what you are feeling Notice what you are doing. Notice how your thoughts and feelings are swirling around, and can easily carry you away if you allow them OPEN up • Open up around your feelings. Breathe into them and make room for them

(continued)

Table 3 (continued)

Coping	Behaviours	Examples of actions	Evaluation	Solution's proposed
				• Open up to your thoughts too: take a step back and give them some room to move, without holding onto them or trying to push them away. See them for what they are and give them space, rather than fusing with them PURSUE your values • Once you've done the above three steps, you will be in a mental state of mindfulness. The next step is to respond to the crisis by pursuing a valued course of action. Connect with your values: ask yourself • 'What do I want to be about, in the face of this crisis? What do I want to stand for? How would I like to act, so that I can look back years from now and feel proud of my response?

industry. The study underpinning Streblo is investigating how technology has been used to influence adaptive coping behaviours and synthesise key aspects into a conceptual model for creating a new mobile application. The conceptual model provides further knowledge of key aspects to consider when developing persuasive tools that aim to encourage more efficient ways of coping with stressful events in construction.

So far, published mobile phone applications have shown promising results. In this paper, we have presented a new prototype of a mobile phone app for stress management associated with a web-based system. This preliminary work will be followed-up by user-based evaluations to identify the needs to be addressed in the next iteration of the design. The research reported in this paper constitutes a significant step towards the understanding and management of potentially stressful situations and their influence on the efficiency and effectiveness of construction industry participants. Similarly, there are triple bottom line implications for all concerned. In particular, those most likely to be exposed to high stressors may expect to at least receive some serious consideration from their managers and advice for self-help. New data, as well as new hypothesis on coping modalities, consequences and wellness at work, are expected from this study. These data should give relevant insights for training, education and more work policies in general.

7 Note

This paper was presented as a working paper (not published conference paper) at the ARCOM 2018 Conference, Belfast, UK, 3–5 September 2018. This content can thus be represented (here) as a Conference paper. Permission was obtained from the ARCOM Steering Committee; as the paper was not previously published as an indexed paper. Google and other sources cannot index working papers as individual papers.

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Water Conservation and Environmental Sustainability Approach

Irfan Abid, Haroon Amal Khattak, and Rai Waqas Asfar Khan

Abstract

Water availability is finite over the world, which requires a controlled usage due to increased population, urbanization, and uneven population distribution. Domestic water usage is one of the major consumptive uses of water, which not only uses the precious water resource but also imparts considerable environmental effects through its carbon emissions in the installation and operational phases. Controlling domestic water usage can help reduce both water consumption and protect the environment. For this purpose, a case study was carried out, where an existing housing society (with fixed billing system) was compared to the metered water supply scheme of similar parameters. Water usage for the two societies was compared to assess the potential water saving, using a conservative assessment. The analysis included both installation and recurring works variables along with their carbon emissions. Suggested policy parameters, by introducing bylaws and other regulatory procedures, to be applied at all residential societies across Pakistan, have also been defined for enforcement of the water metering system. The results show that anticipated water conservation and enforcement of bylaws can not only preserve the precious water resource but can also reduce the carbon credits to help develop a sustainable approach.

Keywords

Water metering • Water conservation • Environmental sustainability • Carbon credits • CO_2 emissions

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1 Introduction

Uneven distribution of finite water resource and increasing population makes it difficult to conserve water while meeting the agricultural, domestic, commercial, industrial, and ecological needs of water. Additional contributing factors include urbanization, population increase, and uneven distribution of water converse to global population distribution. Industrialization and technological advancement have contributed to form a further complex matrix generating global impacts, with the USA and China producing the highest carbon emissions in the world. Because of high population density, population growth rate, proximity of the region adjacent to China, and with stressed water availability in the region, South Asia is one of the most affected regions for water scarcity index. Pakistan is no exception to this situation. Environmental impacts and global warming demands a sustainable approach for water conservation and usage. Domestic water usage contributes considerably to global water needs. Water conservation through water metering and volume-based payment in area of domestic usage can help preserve precious water resource and save upon carbon credits to conserve both water and environment to form a sustainable approach.

2 Literature Review

Pakistan is a water scarce country with having already crossed the water-stressed index in the year 1990 and water scarcity index in the year 2017 as per standards defined by World Health Organization (WHO). The projected increase in the population is about 2.5 times by 2025 in comparison to 1990 population level, resulting in the same increase for water demands, which enforces reduction in per capita annual availability of water. A comparison of the water availability is given in Table 1 with other countries of the world. The availability of water per capita per year accounts

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Table 1 Comparison of water availability for different countries

Country	Year (in Cu M/Capita-year)		
	1995	1990	2025
China	4597	2427	1818
Philippines	13,507	5173	3072
Mexico	11,396	4226	2597
USA	14,934	9913	4695
Iraq	18,441	6029	2356
Pakistan	5250	1672	837

Table 2 Summary of domestic water reduction based on metering system

Country/area	Reduction achieved
East England	16.50%
Boulder, Colorado, USA	35%
California, USA	54 Gal/Day
Bakersfield	37 Gal/Day
Chico	13 Gal/Day
Fresno	17%
Multiple Areas	15%

for the projected increase of the population and the anticipated depletion of the water both in water reservoirs as well as in the groundwater due to over extraction. The number of pumping units in Pakistan for groundwater extraction has increased by more than 100 % since 1990 with no statistical records of over extraction quantities (Kahlown and Majeed 2003).

Water conservation measures like water metering are actively being taken by many developed countries like USA, France, Germany, UK, etc. However, Pakistan is not making use of the available methods with already depleting surface and groundwater resources and increasing population. Water metering ensures effective use of water with charges comparable to the used volume of water in comparison to flat-rate payment irrespective of the used quantity (Renwick and Green 2000).

In 2010, the Universal Metering Program (UMP) was initiated by Southern Water in South East England being a water stressed area. This program resulted in an installation of 500,000 m covering 90 % of the houses in the area with volume-based payment, resulting in a considerable reduction in water consumption (Carmine and Micro 2015). Various studies have shown a remarkable reduction in water consumption after installation of metering system with volume-based payments. One of the very earlier studies was conducted by Hanke in Boulder, Colorado which showed a 35 % decrease in domestic water use (Hanke 1970). Various other studies showed decrease of domestic water consumption with metering and volume-based payments (Maddaus 2001; Mayer et al. 2004; Haagenson 2012; Tanverakul and Lee 2013). A summary of water reduction is shown in Table 2.

Charles conducted a study to formulate a parameter-based formula for the water consumption in a residential society (Charles and Linaweaver 1967). Variables included market value of dwelling (V), age of the dwelling unit (a) which accounts for the leakages and wastage, number of persons per dwelling (d_p), billing periods (p_w), and average water pressure (k) for annual quantity of domestic use per dwelling unit per day (q_{ad}) as shown in Eq. 1

$$q_{ad} = f(V, a, d_p, k, p_w) \tag{1}$$

The linear regression resulted in two different relationships with public sewers and with septic tanks, as given by Eq. 2 and Eq. 3, respectively.

$$q_{ad} = 206 + 3.47V - 1.30p_w \tag{2}$$

$$q_{ad} = 30.2 + 39.5d_p \tag{3}$$

Water supply and usage enforce both capital and recurring costs. The capital cost includes a huge infrastructure to include underground and overhead water tanks both in the society and in the household units, pipelines, pumping units, and civil works for water purification and filtration. The recurring cost includes operational and maintenance cost. This not only imparts high economic value but also accounts for a high production of carbon emissions over the lifetime. A unified carbon emission expression can be applied to the life cycle, which calculates the carbon emissions (E) based on the engineering quantities (Q), and the emission factor (EF) as given by Eq. 4 (Zhang and Wang 2015). The detailed material emission calculation accounts for the material preparation, transportation, and on-site construction. Carbon emissions for some building material relevant to water supply schemes and related to pumping/recurring activities are listed in Table 3 and Table 4, respectively.

$$E = Q \times EF \tag{4}$$

3 Research Methodology

This study comprised of the collection of data from a housing society with flat billing system which provides us sufficient data for the housing units types, water pumping system information comprising of its yield and recurring cost, housing society bylaws for the water storage and domestic use policy, and financial details for billing cost and

Table 3 Carbon emissions for building materials (related to water supply)

Construction material	CO_2 emission factor
Steel bar	3.15 t CO_2/t
Cement	0.86 t CO_2/t
Concrete	0.48 t CO_2/m^3
Composite mortar	0.34 t CO_2/m^3
Cement mortar	0.40 t CO_2/m^3
Clay brick	0.20 t CO_2/t
Concrete block	0.12 t CO_2/m^3

Table 4 Carbon emissions for water pumping (related to water supply)

Construction material	CO_2 emission factor
Raw coal	2060 g CO_2/Kg
Diesel	970 g CO_2/kWh
Electricity	3180 g CO_2/Kg
Natural gas	2700 g CO_2/Kg
Solar photovoltaic system	50–250 g CO_2/kWh
Nuclear power	10–130 g CO_2/kWh
Wind turbines	15–25 g CO_2/kWh
Bio-diesel	1900 g CO_2/Kg
Wood residues	1750 g CO_2/Kg

pumping/maintenance cost information. A housing society (Askari XIV) was selected for the purpose, which provided us with sufficient data of above-mentioned parameters. The methodology adopted is presented in the schematic diagram in Fig. 1.

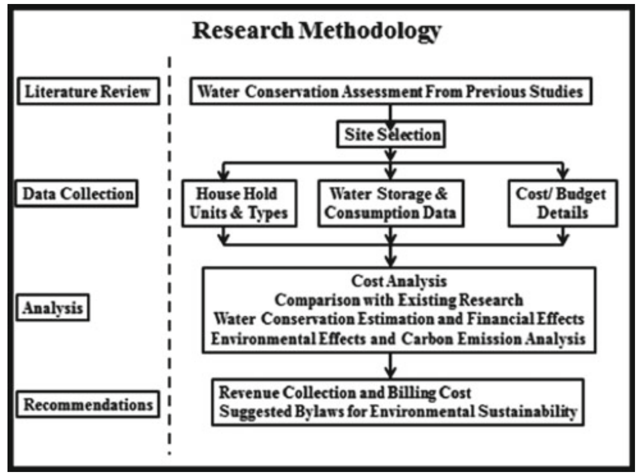

Fig. 1 Schematic diagram for research methodology

4 Analysis

The society consisted of a total of 1699 units which formed three categories of housing units in three sectors of the society, including separate units (SU), semidetached units (SD), and flats. A total of 8 pumps (five 15 HP pumps and three 25 HP pumps) with underground and overhead water tanks ensured water supply at the stipulated times. Although the pumping capacity had reduced over time due to numerous factors including water table depletion, the capacity was still sufficient to meet the consumer needs. Water statistics showed that 88 % of the water supply in the housing society was consumed in the housing units, whereas commercial and horticulture sector consumed 5 and 7% of the water supply, respectively. Although the data for water consumption for each housing unit were not available, the sector-wise type of houses and average inhabitants were available for each housing unit, which helped normalize the data for water consumption of each unit compared to water supply/pumping for each sector (sector-wise water consumption/water pumped in the system data were available).

The analysis showed that water supply was being made at a subsidized rate on a flat billing system, which covered only 10–15% of the recurring cost depending on the type of units and the number of inhabitants. The available water, as per pumping statistics, was about 190 L/capita/day, which is about 95% of international health standards (Indian Code of basic requirements for water supply, drainage and sanitation, i.e., IS1172:1993, Revised 2002). International health standards encompass a high safety factor, thus there were no water shortage complaints in the society.

As the society bylaws allowed storage of water both in overhead and underground water tanks, with flat billing system, without meters, costing only 10–15% of actual recurring cost, which resulted in a high rate of excess water usage. These factors envisaged a high rate of water usage reduction. However, the society was compared to the water reductions achieved in previous studies as mentioned in Table 2. A safe conservative estimate of 17 % was assessed basing on the comparison of different parameters of the under study society, with the societies of previous researches, which included climatic conditions, water availability, public awareness, water consumption patterns, and effects of metered billing. Thus the water requirement was anticipated to be reduced to about 153 L/capita/day. This reduced the total water requirement from international standards of 388,862 gallons/day and available water of 370,788 gallons/day to 330,532 gallons/day for the existing number of inhabitants and housing units as shown in Fig. 2.

Most critical parameter contributing to water reduction is attributed as the cost effect which accounts for volume-based payments with no subsidies. With the suggested billing

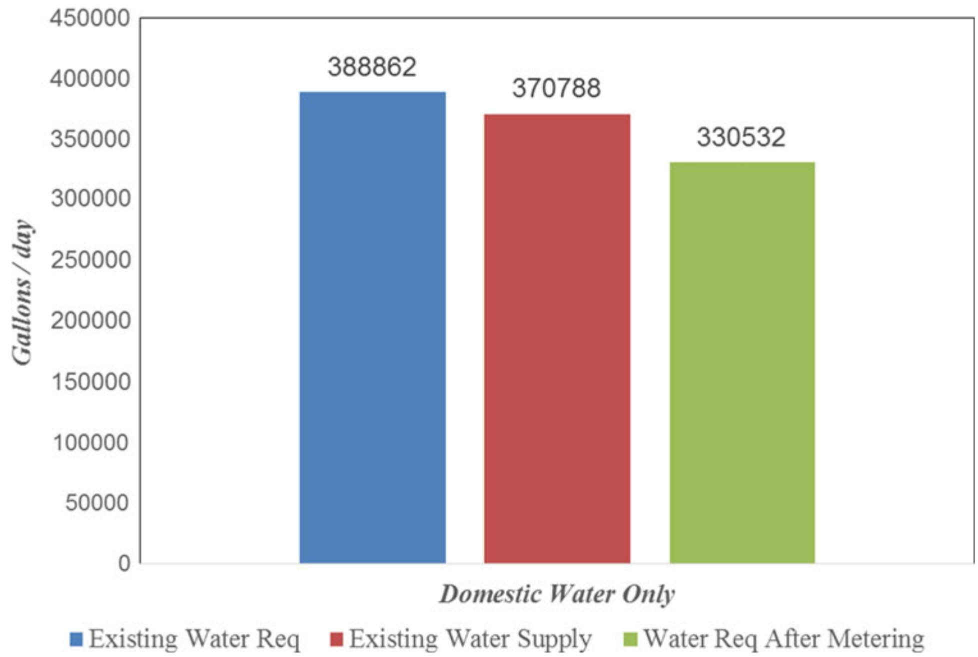

Fig. 2 Water demand for different options

criterion having existing use of water, the billing cost will increase to about 4–6 times depending on type of house and number of inhabitants, which will have serious implications for users. This will help reduce the water consumption considerably. An anticipated reduction of 17 % to about 153 L/capita/day will increase the billing cost to about 2–2.5 times, which will help achieve the desired water reduction. Thus a serious penalty in the water billing exceeding 153 L/capita/day for each housing units can help prevent the excess water usage with less effects on the billing cost. Although the increase in water billing is very high, the total effects on the monthly household budget with existing water consumption and anticipated water consumption are 2.5 % and 1 %, respectively. The detailed cost analysis is shown in Fig. 3.

Current water supply and demand balance along with the available storage capacity both in underground and overhead water tanks of the society can easily accommodate the daily water requirement including the peak hours demand. Also the overhead water tank can fulfill the requirement of gravitational flows to the housing units' overhead water tanks. Thus the underground water tanks impart and additional cost and environmental impact, both for the construction of the underground water tank and the additional pumping of each housing unit to shift water into the overhead water tank. Thus elimination of underground water tanks can save upon the CO_2 emissions for construction of these tanks and for the recurring pumping. The pumping carbon emission for small pumping units is negligible, which is neglected. However, the construction CO_2 emissions for all the housing units of the society impart a heavy carbon emission load to the environment, which amounts to 4125 tons of CO_2 as one-time measure. The details are shown in Table 5.

The reduced water consumption also results in reduced water pumping requirement for the society water supply system, resulting in saving the carbon credits (for reduced pumping of 2.5 h per day for 8 pumps, including three 25 HP and five 15 HP pumps), which amounts to about 75 tons of CO_2 per year, calculated according to the carbon emissions given in Table 4. The comparison is shown in Fig. 4.

5 Recommendations

Based on the effects generated by the water conservation technique, the following is recommended to be implemented as pilot project, for further implementation on gross root level:

- Water meters be installed in all the housing units
- Volume-based billing system be implemented without any subsidy
- Heavy penalty be imposed in the billing for higher units consumption than the anticipated reduced rate of 153 litter/capita/day to enforce water saving
- Billing cycle be continued on monthly basis
- Changes be incorporated in the housing society bylaws where the underground water tanks are not allowed to be constructed
- Public awareness campaigns be also run for a better and faster outcome.

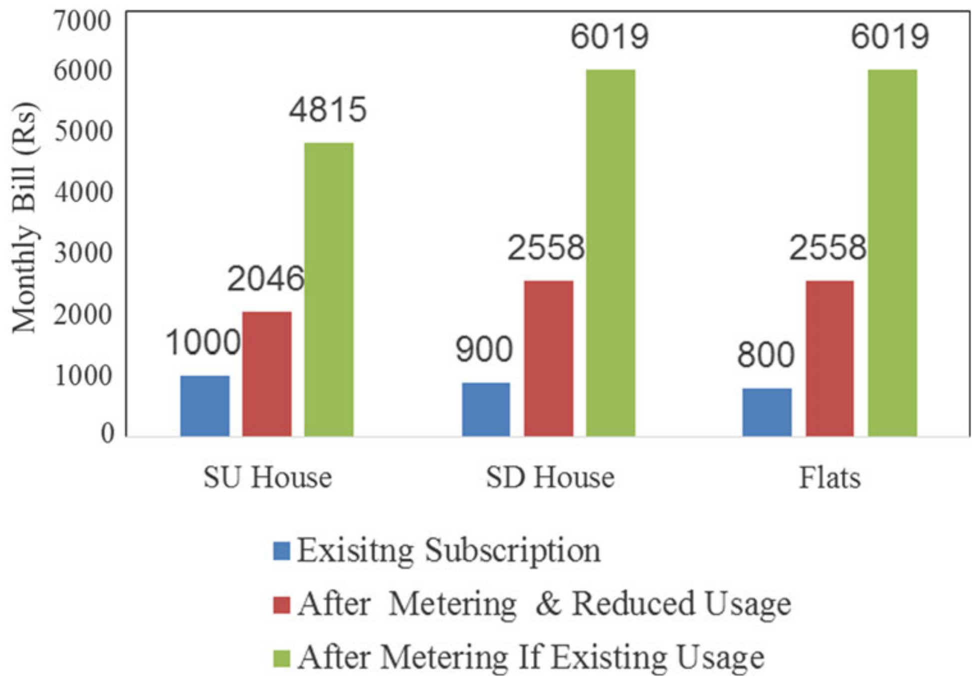

Fig. 3 Water billing for different options

Table 5 CO_2 emissions for underground water tank construction

S. no	Material	CO_2 emission	CO_2 emission ton
		Ton/House	(For all Units)
1	Concrete and Bricks	1.6264	2267.2
2	Steel	1.33	1857.2
3	Total	2.96	4125

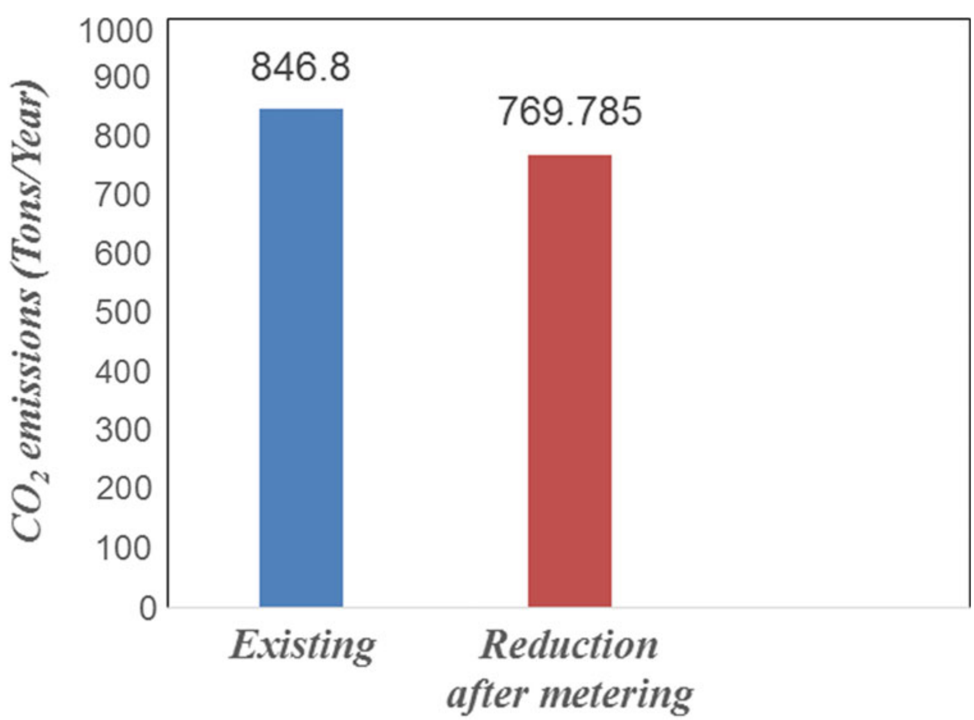

Fig. 4 Carbon emission comparison for pumping of existing and reduced water supply

6 Conclusion

Water is a precious resource which needs conservation for its sustainable use to meet the population thrust and diversified uses of water for human needs. The environmental impacts for the anthropogenic activities related to water supply also need to be reduced for sustainability. Therefore, this case study has been carried out to investigate these two para/meters of water conservation and CO_2 emissions' reduction. Practical application of the same can help identify further room of improvement and application of gross root level.

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Expectations from the Welding Curriculum Based on the Perspective of Engineering Technology Graduates in Nigeria

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Abstract

Welding engineering technology is a key driving force in the growth and development of industrial activities, with its application dominant in a wide range of industrial sectors including structural engineering, transportation, agriculture, healthcare and aviation. Welding activities demand adequate skills from welding personnel due to the high level of accuracy and precision required to produce quality results in finished products as well adhering to strict safety regulations involved in its processes. The quality of skilled welding personnel lies in their training and re-training to meet the continually evolving technology space. Students of higher education in welding are expected to be well equipped with the theoretical and practical skills to fit into the constantly evolving workspace, a feat which can partly be attributed to the content of its curriculum. This research aims at highlighting the outcome and expectations of graduates, from welding engineering technology curriculum in Nigeria based on their experience and highlight the expectations from the welding curriculum and its effect on graduate employability. The survey results from 122 respondents who are graduates of welding engineering technology from the Petroleum Training Institute Effurun, Nigeria was analyzed with the Mean Item Score (MIS) and factor analysis. Results from the analysis revealed that graduates expect to be employment ready and also get immediate employment from industry based on their acquired skills. The outcome of this research is expected to add to the body of knowledge aimed at improving the welding curriculum to meet the demands of the industry.

Keywords

Curriculum • Graduates • Fabrication • Industry • Welding

1 Introduction

Employability is described by many authors as complex and ambiguous to define (Tymon 2013). This is evident because it can be viewed from different perspectives as it concerns the government, the employers, students, graduates and the providers of higher education. The complexity, however, will be slightly ignored in this literature as the focus is on the expectations of welding graduates and the content of the welding curriculum. In essence, it is about the employability of welding graduates and the potential of becoming gainfully employed after acquiring formal education. Knight and Yorke (2003) defined employability as "…a set of achievements, skills, understandings and personal attributes that make graduates more likely to gain employment and be successful in their chosen occupations which benefits themselves, the workforce, the community and the economy".

In other for graduates to fit into work positions on employment, they are expected to have the required knowledge that compliments the dynamic trends in technology (Kinash et al. 2016). Based on research findings, internships, part-time employment and related professional association membership are initiatives that can be employed by institutions to help improve graduate employability (Kinash et al. 2016).

However, it is becoming a growing concern globally and Nigeria in particular that graduates are not ready for work. While some graduates lack the additional soft skills to fit into working environments, others lack the upgraded knowledge

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from their curriculum to fit into the requirements of employers (Umunadi 2014). Higher educational institutions are now integrating employability skills into their academic curricula. The Nigerian labour market is certainly affected by the low level of employable graduates. Leigha (2014) describes the majority of graduates from higher institutions in Nigeria as "unemployable". He further stresses the need for the academia-industry partnership to strengthen the quality of graduates from higher institutions of learning.

As far as it concerns welding and fabrication, the quality of graduates has been a great concern to government and industry. In recent times, the Petroleum Technology Development Fund (PTDF) engaged in the re-training of welding and fabrication graduates to the International Institute of Welding standards. Oil and gas companies also have to re-train welding graduates to meet the requirements of projects (Ovadia 2014).

The need to produce qualified graduates who are employable and meet the requirements of the industry and economic needs of a nation is now a global issue. There is no defined index to measure the employability of graduates but it is important to produce graduates with the right practical exposure, career training, ethics and professional conduct, and communication skills: in other words, ready-to-deliver graduates in the workplace (Datta 2013). It is expected that course material should effectively assess the employability skills through its learning objectives, taking into consideration the specific discipline for which the training is designed.

The National Policy on Education of 1977 which is now in its sixth edition in 2013 has pioneered the reforms in education curriculum in Nigeria to promote the advancement of technical education to meet the socio-economic needs of the Nigerian polity (Ojimba 2012).

2 Research Methodology

This research is a survey study and adopted a questionnaire approach. Target respondents were graduates of the Petroleum Training Institute in Effurun Nigeria—a pioneer institution for the training and re-training of weding engineering technologists, to meet the demands of the oil and allied industries. Respondents were asked to indicate to what degree they agreed or disagreed on the expectations of industry form welding and fabrication graduates using a five-point Likert scale (strongly agree = 5, agree = 4, neutral = 3, disagree = 2, strongly disagree = 1). One hundred and twenty-two respondents completed the questionnaires out of a total of one hundred and fifty initially distributed via emails and hard copies, signifying an 80% response rate. Based on the distribution of the respondents, it was observed that the majority of respondents have between five to fifteen years post-graduation work experience and also graduated between the year 2000 and 2009.

3 Welding and Fabrication Curriculum

The welding and fabrication curriculum is designed to meet the necessary training needs for the competencies needed to achieve a welder status at prescribed levels (Yeomans and Atrens 2001). The curriculum is expected to set the requirements of the expected results on completion of training as well as influence the choice of both theoretical and practical learning activities in the course of training (McCauley 2000). Teaching the art and skill of welding involves the physical and mental aspects of the trade, understanding when to use a particular welding process and why such a process should be used as opposed to another (Joseph 2015).

A welding curriculum should be created to evaluate and approve competency in the long run as this will ultimately determine the quality of welded product and the adherence to standards and procedures (Mathers 2002). Competency levels need to be properly validated in the set-up of a welding curriculum and the process for the evaluation of students (trainees) competency level should be in place to check performance (Rojewski 2002). The student should be seen to understand welding-related terms and their application in the workplace in which welding and fabrication is to be applied (Cutshall 2001).

The welding curriculum at higher education level consists of various areas of study. These areas include, but are not limited to, welding processes, materials, design and non-destructive testing. The process aspect of welding curriculum consists of science of welding for processes such as Manual Metal Arc Welding (MMAW), oxy-fuel welding and other major welding processes. The welding curriculum also covers the physics of welding as well as other mechanical engineering science modules. The inclusion of general studies such as mathematics, entrepreneurial studies and citizenship education in a technical curriculum is also a major cause of discussion by some writers but its source of inclusion can be traced to government educational regulation and the type of institution.

It is, however, pertinent to take into consideration the dynamic nature of welding and fabrication technology in the creation and update of its curriculum (Pitan and Adedeji 2012). Trick (2014) highlighted the need for curriculum update which may very well include tutorials and programmes on DVD and in the near future, subscription of curriculum via the Internet. This stresses the need for a near real-time update of welding and fabrication curricula (Oliver et al. 2007).

4 Presentation of Findings

4.1 Mean Item Score for Graduates' Expectation of the Welding and Fabrication Curriculum

Employment offers from the Oil and Gas Industry [C8.1] were ranked first with a MIS of 4.55 and SD of 0.834 while quality education/qualification in welding and fabrication engineering technology that is globally accepted [C8.2] was ranked second with a MIS of 4.09 and SD of 0.68; ranked third was exposure to a variety of career opportunities in Non-Destructive testing and related fields [C8.3] with a MIS of 4.02 and SD of 0.630 while employment from other industries in specific need for welding and fabrication graduates [C8.4] with a MIS of 4.02 and SD of 0.530 was ranked forth; in fifth ranking was graduates seeking the curriculum to provide familiar principles and concepts in work environment [C8.5] with a MIS of 3.98 and SD of 0.603 while employment into a position that suits their qualification [C8.6] was ranked sixth with a MIS of 3.98 and SD of 0.596; exposure to a variety of career opportunities in welding and fabrication [C8.7] was ranked seventh with a MIS of 3.93 and SD of 0.694 while ability to adapt to work environment on employment [C8.9]was ranked eighth with a MIS of 3.93 and SD of 0.632; employers satisfaction with output as an entry level employee [C8.9] was ranked ninth with a MIS of 3.89 and SD of 0.706 and in tenth ranking was career growth and development on employment [C8.10] with a MIS of 3.89 and SD of 0.592; graduates expect to be prepared to meet the challenges of the labour market [C8.11] was ranked eleventh with a MIS of 3.88 and SD of 0.663 while sufficient practical skills on employment [C8.12] with a MIS of 3.87 and SD of 0.802 was ranked twelfth; competitive advantage in the labour market [C8.13] was ranked thirteenth with a MIS of 3.85 and SD of 0.688; immediate Job preparedness on graduation [C8.14] with a MIS of 3.77 and SD of 0.907 was ranked fourteenth; sufficient theoretical skills on employment [C8.15] with a MIS of 3.75 and SD of 0.816 was ranked fifteenth and lastly ability to function on the job without further training [C8.16] with a MIS of 3.66 and SD of 0.933.

4.2 Results from Factor Analysis

Using factor analysis, variables were grouped and reduced—to a manageable scale—by identifying the relationships among variables, in other to generate theoretical constructs. A factorability of 0.3 indicates that approximately 30% of the variables share a lot of variance and the test of correlation becomes impractical. Average communality of the variables after extraction is as shown below (Table 1).

To further verify the strength of inter-correlation among selected variables, the Barlett's test of sphericity and the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy are used (McCauley 2000).

KMO value of 0. 831 was obtained, and Bartlett's test of sphericity has an approximate chi-square value of 3204.415 (considering 95% level of significance, $\alpha = 0.05$) and degree of freedom of 91 and a significant value of 0.00 which is <0.05 (Pallant 2007). The KMO statistic of 0. 831 was considered appropriate (>0.50). Therefore, factor analysis is considered as an appropriate technique to further analyze the data. Using varimax rotation with Kaiser normalization, two factors were extracted from fourteen variables used in this study. These two extracted factors cumulatively explained 80.770% of the variability on the aspect of the study relating to the graduates' expectation from the welding curriculum. Also, the combined percentages show 83.7% of the total variance before rotation and 80.7% of total variance after rotation, which was sufficient to explain the composite items of these variables (see Table 2). The following variables that were found to be highly correlated with Factor 1, but negligibly correlated with factor 2: Ability to adapt to work environment on employment (91.1%), prepared to meet the challenges of the labour market (88.6%), competitive advantage in the labour market (86.1%), exposure to a variety of career opportunities in welding and fabrication (80.9%), familiar principles and concepts in work environment (79.8%), career growth and development on employment (73.5%), exposure to a variety of career opportunities in non-destructive testing and related fields (72.8%),

Table 1 Communalities

Communalities		
	Initial	Extraction
C8.1	0.742	0.683
C8.2	0.813	0.622
C8.3	0.822	0.678
C8.4	0.986	0.914
C8.5	0.958	0.831
C8.8	0.958	0.853
C8.9	0.986	0.808
C8.10	0.978	0.793
C8.11	0.982	0.655
C8.12	0.946	0.859
C8.13	0.974	0.947
C8.14	0.958	0.889
C8.15	0.970	0.936
C8.16	0.932	0.839

Extraction Method: Principal axis factoring

Table 2 Rotated factor matrix

Rotated factor matrix[a]		
	Factor	
	1	2
C8.13	**0.911**	0.343
C8.4	**0.886**	0.359
C8.5	**0.861**	0.301
C8.9	**0.809**	0.392
C8.14	**0.798**	0.502
C8.16	**0.735**	0.547
C8.10	**0.728**	0.513
C8.3	**0.722**	0.396
C8.1	**0.660**	0.497
C8.11	**0.656**	0.473
C8.12	0.399	**0.837**
C8.2		**0.758**
C8.15	0.617	**0.746**
C8.8	0.567	**0.729**

Extraction Method: Principal axis factoring
Rotation Method: Varimax with Kaiser normalization.[a]

employment from other industries in specific need for welding and fabrication graduates (72.2%), quality education/qualification in welding and fabrication engineering technology that is globally accepted (66.0%) and sufficient theoretical skills on employment (65.6%). These variables were jointly named **"Ready-for-work" graduates**.

Also, the following variables based on the factor loading scores were considered as Factor 2 but negligibly correlated with Factors 1. Sufficient practical skills on employment (83.7%), employment offers from the oil and gas Industry (75.8%), employers' satisfaction with output as an entry-level employee (74.6%) and employment into a position that suits their qualification (72.9%). These variables were thus named **Immediate employment from oil and gas companies**.

5 Discussion of Results

Findings from the questionnaire survey results revealed that graduates expect immediate employment form the oil and gas companies as it was ranked highest among the factors in this section. Literature revealed that higher institutions across the globe are modifying their academic curricula to produce ready-to-work graduates rather than graduates with generic skills (Oliver et al. 2007). Also, Ojimba (2012) highlights the need for specific training for specific industry needs while Pitan and Adedeji (2012) highlight the need for Nigerian students in higher institutions to be well-grounded with relevant soft skills throughout the curriculum to facilitate employability on graduation. The quest by graduates to get immediate employment from the oil and gas industry is an expected outcome from this survey considering that the respondents are inclined to receiving welding education to meet the demands of the oil and gas sector in Nigeria.

6 Conclusion

Graduates—and by extension industry—expectations from welding engineering curriculum are to provide the required knowledge in theory and practical necessary for employment. This can be achieved by creating a framework that enables the evaluation and continuous improvement of welding curriculum content to meet the constantly evolving welding technology space, as well as meet specific industry project needs. Future research may focus on such a framework that involves the key stakeholders in the industry as well as the academia.

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Perceptions of How Lean Practices Could Assure Quality in Construction

Marsha Goliath, Fidelis Emuze, and Michael Oladokun

Abstract

The construction industry is an industry with many problems regarding efficiency. One of those problems is the quality problem. The solutions to quality problem in construction projects are located in the application of lean construction. This paper outlines lean practices that can help contractors to produce quality products in the form of building and infrastructure. The empirical study was conducted using a quantitative approach. The study was undertaken in the Eastern Cape Province of South Africa where a semi-structured questionnaire was distributed to Construction Managers (CMs), Construction Project Managers (CPMs), Quantity Surveyors (QSs), building contractors and civil engineers. The findings reveal that few professionals are aware of the concept of lean construction in their workplace. Lean construction not only affects the quality of projects, but also affects other project parameters, and different factors have an impact on the quality of projects. More importantly, there is no evidence of the adoption and use of lean tools and techniques in the industry. The aforesaid perceptions suggest that the industry have to explore how to use lean construction principles, tools/methods and techniques for improved performance in the sector.

Keywords

Construction • Contractors • Lean • Projects • Quality

1 Introduction

The construction industry is unique and involves a diverse number of professions, specialist and suppliers. However, the construction environment produces poor quality compared to other sectors (Janipha and Ismail 2013). The problems associated with construction are well known. Aigbavboa et al. (2016) identified them as low quality of work, poor co-appointment of building professionals, expensive overruns, amongst others. Also, Emuze and Saurin (2016) identify these problems as fatalities, injuries, time and cost overruns, defects and low productivity.

The interconnection of activities for design and construction of buildings and infrastructure involves the interplay between people, technology, situations and decisions. This interplay increases the complexity of construction and hence, it requires proper management of people, materials, tools, plant and equipment. The coordination is implemented to realise efficiency and enhance quality in products. As previously opined, however, fatalities, injuries, time and cost overruns, defects, low productivity and other problems still manifest in construction. It is evident that quality improvement is needed in the construction industry.

According to Locatelli et al. (2013), there is an alarming number of projects failing to deliver on time or/and within budget or/and with a satisfactory standard and still requires additional work and re-works. Traditional project delivery and procurement methodology has evolved into an inherently inefficient and adversarial process. In contrast, lean construction provides an approach that significantly improves collaboration, innovation, delivery, control and quality in projects (Emuze and Saurin 2016). Lean construction is based on fundamentals such as maximum value

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generation, flows of activities, pull demand systems and perfection in execution at every level of the project (Aziz and Hafez 2013). As such, lean construction concept has demonstrated enough capacity to improve construction project (Emuze and Saurin 2016). Therefore, this study outlines how lean construction practices could enhance quality of construction projects.

2 Literature Review

Quality is one of the critical factors in the success of construction projects. The quality of construction projects can be regarded as the fulfilment of the project participant's expectations or requirements (Ashokkumar 2014). Also, quality is seen as the degree to which a set of inherent characteristics fulfils requirements. Inadequate quality in construction projects is a common phenomenon in the world (Janipha and Ismail 2013). This then results in many cases of disputes happening among clients, house owners and parties involved in construction (especially contractors) (Ali and Wen 2011).

According to Ashokkumar (2014), limited time, lack of training policies, limited fund, lack of communication, obsolete methods and non-compliances are some of the reasons for the pervasiveness of poor quality in construction. Generally, to improve the quality of construction means to incur additional cost on the projects, which may be delayed. This in turn may result in unsatisfied clients and introduce different kinds of waste in construction.

Lean construction has been successful in eliminating waste and improve quality standard of construction projects. As such, it is considered as an idealised model, which aims at improving the construction schedule and eliminate problems on construction projects to provide a defect-free production (Yike and Jianbin 2015). According to Aziz and Hafez (2013), lean construction is a way to construct systems which minimise waste of materials, time and effort to generate the maximum value, it uses the same principles as lean production to reduce waste, increase productivity and effectiveness in construction through effective management.

The Lean Construction Institute defines the process of lean project management, which leads to improved quality as follows (Aziz and Hafez 2013):

- Determine client requirements and design to meet them;
- Align design to quality, schedule and budget limits;
- Manage the project by breaking it into pieces, estimating duration and resource requirements for each piece, and then put the pieces in a logical order with Critical Path Method (CPM);
- Assign or contract for each piece, give start notice and monitor each piece to assure it meets safety, quality, schedule and cost standards;
- Coordinate using the master schedule and weekly meetings;
- Cost may be reduced by productivity improvement: Duration may be reduced by speeding each piece or changing logic and
- Quality and safety get better with inspection and enforcement.

3 Research Methodology

A quantitative research approach was adopted to conduct the empirical study based on a survey research design. The survey research design was adopted as it provides an accurate portrayal of the opinions and knowledge of an individual, group or situation. The survey made it possible to collect a large amount of data under the same circumstances, making it easy to compare the information as it was easier to understand and summarise (Creswell 2014).

The sample stratum of this study was limited to the following building professionals: Construction Managers (CMs), Construction Project Managers (CPMs), Quantity Surveyors (QSs), Building Contractors and Civil Engineers. This was done to ensure different perspectives of the built environment professionals were covered, which gave breadth and depth to the study. The sampling technique was purposive in nature in that the questionnaires were merely distributed to the relevant professionals.

A questionnaire (soft and hard copy) was created to capture the responses of professionals in the industry. The soft copies were e-mailed to potential respondents and hardcopies physically distributed. A total of 37 emails were sent and 15 questionnaires were physically distributed. This totalled 52 potential responses. 21 Responses were received with a response rate of 40.4%.

Data analysis was based on descriptive statistics. Specifically, simple percentages, bar chart and mean score were used for the analysis.

4 Results and Discussion

4.1 Demographic Information of the Respondents

Table 1 illustrates the number and percentage of professionals who responded to the questionnaires, with the highest being CMs at 29 %, this is followed by the QSs and

Table 1 Number and percentage of professionals who responded to the questionnaires

Respondents	Number	Percentage (%)
Project Managers	3	14
Construction Managers	6	29
Quantity Surveyors	5	24
Building Contractors	2	9
Civil Engineers	5	24

Civil Engineers with 24 % each. Project Managers were 14%, while the Building Contractors were 9 %.

Also, it important to capture the years of experience of the respondents. As such, the results from the study indicate that majority of the respondents have worked in the industry for five or more years. This by implication means that the respondents have requisite experience to answer the questionnaire.

4.2 Factors Impacting on Quality of Construction Projects

In a bid to explore how lean construction practices could enhance the quality of construction projects, it is important to first consider the factors impacting on quality of construction projects. To this end, Table 2 illustrates the professionals' perceptions of factors that impact on the quality of construction projects in terms of percentage responses to a scale of 1 (minor) to 5 (major); and Mean Scores (MSs) ranging between a minimum value of 1.00 and a maximum value of 5.00 were computed for each factor.

According to the results in Table 2, most of the respondents ranked 'effective communication' as the highest (MS = 4.48). While 'specifying client requirements'; 'employee participation'; 'frequent site meetings' and other factors were ranked from second to eighth, respectively. One of the profound findings from the results is that all the MSs are greater than 3.00 indicating that all the factors have almost major impact on the quality of construction projects. Majority of the factors are related to the lean construction practices, which by implication means the lean construction has a role to play regarding the quality of construction projects.

4.3 Awareness of Lean Construction Implementation in Construction Projects

It cannot be ascertained whether or not the respondents 'officially' aware of the application of lean construction in construction projects. To this end, Table 3 illustrates that only 33% of the respondents were aware that the lean construction concept is being implemented in construction projects. This value is low indicating that majority of the respondents are not aware of the implementation of lean construction principle.

Table 2 Factors impacting on quality

Factor	Response (%)							MS	Rank
	Unsure	Does note	Minor			Major			
			1	2	3	4	5		
Effective communication	0.0	4.8	0.0	0.0	4.8	23.8	66.7	4.48	1
Specifying client requirements	0.0	9.5	0.0	0.0	9.5	33.3	47.6	4.10	2
Employee participation	4.8	4.8	0.0	0.0	14.3	33.3	42.9	4.00	3
Frequent site meetings	0.0	4.8	0.0	4.8	14.3	42.9	33.3	3.95	4
Increased visualisation (quality and safety signs)	0.0	4.8	0.0	4.8	19.1	38.1	33.3	3.90	5
Standardised processes	4.8	4.8	0.0	0.0	9.5	57.1	23.8	3.86	6
Stakeholder commitment	4.8	4.8	4.8	0.0	19.1	19.1	47.6	3.86	6
Continues improvement	0.0	4.8	0.0	0.0	19.1	38.1	33.3	3.81	7
Elimination of waste	0.0	9.5	4.8	4.8	19.1	33.3	28.6	3.57	8

Table 3 Respondents' awareness of lean construction implementation

Response	Number	Percentage (%)
Yes	7	33
No	11	53
Unsure	3	14

4.4 Impact of Lean Construction on Project Performance Parameters

Indirectly, respondents were asked to rank, based on their perception, the impact of lean construction on project performance parameters. Table 4 illustrates their perceptions on how lean construction impacts on the project parameters in terms of percentage responses on a scale of 1 (Minor) to 5 (Major), and MSs ranging between a minimum value of 1.00 and a maximum value of 5.00.

It is noticeable that all of the MSs are above 3.00, which implies that the professionals perceived that lean construction has a major impact on these project performance parameters as opposed to a minor impact.

4.5 Lean Construction Implementation

Table 5 illustrates the respondents' perception regarding how lean tool/techniques need to be implemented in construction (based on the various lean implementation statements) in terms of percentage responses to a scale of 1 (minor) to 5 (major); and MSs ranging between a minimum value of 1.00 and a maximum value of 5.00.

It is also noticeable that all the following statements MSs are higher than the midpoint of 3.00, which indicates that the respondents are deemed to agree as opposed to disagree with these statements. By implication, it means that lean tool/techniques are inevitable in construction projects.

5 Discussion

The findings from the study indicate that the factors identified have almost major impact on the quality of construction projects. One thing that is evident from the study is that majority of the factors are related to lean construction practices, which by implication means the lean construction has a role to play regarding the quality of construction projects. This is in consonance with the process of lean construction project management, which actually leads to improved quality (Aziz and Hafez 2013).

Majority of the respondents are not aware of the implementation of lean construction principle. As such, this is capable of impeding on the acceptance and hence the implementation of the concept for construction projects. Additionally, the professionals were of the opinion that lean construction has a major impact on project performance parameters. As such, the lean tool/techniques are inevitable in construction projects.

6 Conclusions

This study outlined how the lean construction principle can improve the quality of construction projects. From the study, it is evidence that there are many factors impacting on the quality of construction projects of which majority of those factors are related to lean construction. Lean construction not only focuses on improving the quality of project but also aims to reduce the time involved, eliminate failure and eliminate waste in construction. There are different types of lean tools/techniques that can be used in the construction industry based on the lean implementation statements that were assessed. However, the awareness level of the respondents regarding the application of lean construction principle in construction projects is limited in the study area.

Table 4 Impact of lean construction on project performance parameters

Parameter	Response (%)							MS	Rank
	Unsure	Does note	Minor			Major			
			1	2	3	4	5		
Time	4.8	0.0	0.0	4.8	9.5	23.8	57.1	4.24	1
Cost	4.8	0.0	4.8	0.0	4.8	38.1	47.6	4.14	2
Quality	9.5	4.8	0.0	4.8	0.0	28.6	52.4	4.00	3
productivity	14.3	0.0	0.0	4.8	4.8	33.3	42.9	3.86	4
Client satisfaction	4.8	4.8	4.8	9.5	14.3	19.1	42.9	3.67	
Environment	19.1	0.0	0.0	4.8	19.1	14.3	42.9	3.57	6
Health and safety	19.1	0.0	0.0	19.1	4.8	9.5	47.6	3.48	7
Waste	9.5	14.3	0.0	4.8	19.1	19.1	33.3	3.33	

Table 5 Lean Implementation statements

Statement	Response (%)						MS	Rank
	Unsure	Strongly disagree	Disagree	Neutral	Agree	Strongly agree		
A reduction of waste decrease the project costs	0.0	0.0	4.8	4.8	42.9	47.6	4.33	1
Worker participation leads to continues improvement	0.0	0.0	0.0	9.5	57.1	33.3	4.24	2
Daily site meetings help identify potential problems on the site	4.8	0.0	0.0	4.8	47.6	42.9	4.19	3
The inclusion of the suppliers in the planning process promotes on time delivery materials to projects site	0.0	0.0	0.0	9.5	66.7	23.8	4.14	4
Considering customer feedback leads to continues improvement	0.0	0.0	0.0	14.3	57.1	28.6	4.14	4
Specifying client requirements leads to improved quality	0.0	0.0	14.3	9.5	42.9	33.3	4.00	5
Employees willingness to learn new techniques leads to continues improvement	0.0	0.0	9.5	9.5	57.1	23.8	3.95	6
More effort in planning, through the last planner system promotes a smooth workflow	14.3	0.0	0.0	14.3	23.8	47.6	3.90	7
Making use of look ahead schedules increases the work flow	0.0	0.0	0.0	38.1	33.3	28.6	3.86	8
Defining end-to-end processes for a project helps establish processes that are efficient and waste-free	9.5	0.0	0.0	23.8	38.1	28.6	3.76	9
Posting signs on the site (safety and quality signs) makes workers and guests compliant with safety rules and regulations	0.0	0.0	14.3	28.6	28.6	28.6	3.71	10
Training of the stakeholders helps eliminate resistance to change	0.0	0.0	4.8	33.3	42.9	14.3	3.57	11
The inclusion of suppliers in the planning process fosters the reduction of material lead times	0.0	9.5	14.3	9.5	47.6	19.1	3.52	12
Ordering materials just before they are required reduces inventory waste	0.0	0.0	23.8	23.8	42.9	9.5	3.38	13
More effort in planning, through the Last Planner technique decreases the variability in the process	14.3	0.0	0.0	19.1	47.6	14.3	3.33	14
Including customers during project definitions and design phase leads to waste reduction	0.0	4.8	33.3	28.6	19.1	14.3	3.05	15
Reduction in non-value adding activities reduce waste	14.3	0.0	14.3	33.3	28.6	9.5	3.05	15

As such, many of the industry professionals in the Eastern Cape Province of South Africa are unaware of lean or know how to implement it.

It is recommended that lean construction should not only be adopted into construction projects as an alternative to traditional construction or when requested by clients. It should become part of the organisations' culture, goals and objective if organisations wish to strive for improved quality and performance. For professionals to experience the maximum benefits of lean construction and for lean construction to be successful, professionals need to follow the lean process and the statements as outlined. They also need to implement the correct lean tool/technique to improve a specific project parameter or the overall project performance.

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The Sources of Dispute in Construction Projects in the Mpumalanga Province

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Abstract

Construction projects are frequently held in a complex and uncertain nature, alongside claims being unavoidable. Construction projects involve processes that are complex and dynamic which at most result in disputes between the stakeholders. The study investigated the sources of disputes in construction projects in the Mpumalanga Province. The data used in this paper were derived from both primary and secondary sources. The secondary data was collected via a detailed review of related literature. The primary data was collected through a survey questionnaire which was distributed to project participants. Out of the 90 questionnaires sent out, 80 were received back representing 89% response rate. Data received from the questionnaires were analysed using descriptive statistics procedures such as Ms Excel and SPSS software. Findings from the study revealed that payment delays, poor supervision financial incapable of contractors, change of scope, delay in work progress, poor workmanship, incomplete specification design errors, delay in providing information and extension of time were the main sources of construction disputes. Therefore, client should minimise changing scope to avoid cost overrun and extension of time which contribute to dispute. Respondent believed that dispute avoidance strategies such as stakeholders management, alliancing, lean construction and partnering will reduce dispute drastically. Hence, the industry is encouraged to embrace modern management concepts and to avoid the effects of construction disputes such as loss of production, delays and profitability.

Keywords

Construction industry • Claims • Disputes and Mpumalanga • Province

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1 Introduction

Disputes are prone during the construction process due to the problem of contractual terms such as payment, variation, and extension of time and the unavailability of information (Cakmak and Cakmak 2013). Construction Projects are often delivered under a complex and uncertain environment, with claims being an inevitable part (Mashwama et al. 2016). Construction disputes materialise when construction claims are not settled in an effective, economical and timely manner (Love et al. 2007).

However, resolving disputes can be expensive and time consuming. It is, therefore, crucial to manage disputes proactively to ensure that early settlement is achieved (Bvumbwe and Thwala 2011). Any stakeholders in the construction project can generate dispute (including client, professional consultants, contractors, subcontractors) through their level of knowledge of the construction process. Furthermore, the more complex the project is, the higher the probability of dispute causation (Sinha and Wayal 2008). Disputes have become an endemic feature of the Mpumalanga construction industry. Hence, this research aims to investigate the causes of disputes in construction projects in the Mpumalanga Province of South Africa.

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2 Construction Industry

The Construction Industry (CI) in many countries is a key component of economic growth. Furthermore, the construction industry plays even a greater role in development and poverty alleviation by providing access to basic services and transport facilities in the developing countries. The CI is an important sector of the economy because of the outputs of its activities (Mashwama et al. 2016). It contributes to national socio-economic development by providing the buildings which are used in the production of all goods in the economy. The CI is one of the most diverse and unstable sectors within the economy (Cakmak and Cakmak 2013). However, anything that impacts on construction industry has potential to affect the whole economy. Since it is unique and complex to other industries as it involves many participants in all trends, due to this, conflict and disputes can easily occur, for example, through changes in plans, quantities or details of construction which are inherent in the nature of construction (US 2004).

3 Disputes in the Construction Industry

Carelessness and negligence in construction has risen to greater prominence (Cakmak and Cakmak 2013). The occurrence of construction disputes can lead to negative impact towards client organisation. The construction work progress will be slow due to disputes between the contractor and client, subsequently, the cash flow suffers terrible (Love et al. 2007). Furthermore, during the construction process personnel will change, the economy will change and technology will change. With almost 100% certainty, that won't change is the fact that something will not go according to plan during the project and dispute will arise (Latham 1994).

4 Disputes Defined

Dispute according to Cakmak and Cakmak (2013) does not exist until a claim has been submitted and rejected, a claim being a request for compensation for damages incurred by any party to the contract. Dispute is a problem or disagreement between the parties to a contract, that cannot be resolved by on jobsite or on-site project managers. Dispute can be caused by negligence in understanding the terms of the contract, for example, dispute on misunderstanding and interpretation of clauses (Jannadia et al. 2000).

5 Claim

The relationship between disputes and claim has been discussed by a number of scholars (Semple et al. 1994), hence there is ample evidence from standards forms of contract that, in a contractual sense, dispute only comes into being after a claim has been made and rejected. However, a differentiation should be made between claimed entitlement within the contract such as extension of time and a claim for breach of contract by one or several parties to the contract. Cakmak and Cakmak (2013) infers that a claim is a request for compensation for damages incurred by any party to the contract. An all-important point on the nature of claim is the question of timing, hence when a claim is submitted it must be timely resolved to avoid dispute (Mashwama et al. 2016).

6 Sources of Disputes in the Construction Industry

In the study, the sources of dispute would be classified into three categories which are uncertainty, contracts and behaviour and are discussed below.

6.1 Contract Issues

The procurement method adopted or used is very vital since it can have negative or positive influence on the contract (Ng et al. 2002). Moreover, in order to avoid construction dispute, proper contract documentation is required, furthermore, Carnell (2005) state that getting it right needs a proper and good procurement method with apportionment of risk, complying with the contract requirement and monitoring delays should be chosen.

6.2 Behaviour

Construction performance may be affected by dispute which leads to low friendliness, low trust, low respect. Conflict which mostly leads to dispute is caused or started by people or projects and process criteria. According to (Diekmann and Girard 1995), people criteria followed by process criteria has the most effect in causing construction dispute. Hence teamwork approach is ideal for a project success to avoid opportunistic behaviour by promoting cooperation and establishing good relations, and effective problem-solving mechanism (Kartam and Kartam 2001).

6.3 Project Uncertainties

According to Zack (1996), risk is also the main causes of dispute. Risk such as related risk, defective works, project funding, economic risk, labour forces, subcontractor, physical risk, act of God, latent defect, impractical/impossibility, latent site condition, taxes, insurance, suspension of works, quantity variation, supplier failure, site access, time-related risk, economic disaster, failure to pay, project funding, changes, contractor furnished equipment/material, acceleration, bonding, means and methods of construction just to name a few. The above-mentioned risks have been associated with the causes of dispute, therefore, this suggests that when risk surface in a project and not dealt with properly, somehow dispute does arises (Kartam and Kartam 2001).

7 Methodology

7.1 Research Area

Mpumalanga means the place of the rising sun and people are drawn to the province by its magnificent scenery, fauna and flora. The province is the second-smallest province in South Africa yet it has fourth-largest economy. It's situated mainly on the high plateau grasslands of the middleveld. Mpumalanga has network of excellent roads and railway connections thus making it highly accessible (Mpumalanga Provincial Government 2018). Mpumalanga is very rich in coal reserves. The province house the country three major power stations, of which is the largest in the southern hemisphere (Mpumalanga Provincial Government 2018).

7.2 Research Approach and Design

Quantitative approach method was adopted to investigate a stakeholder's perspective on the sources of disputes in the construction industry of Mpumalanga Province of South Africa. The study was carried out in Mpumalanga Province of the Republic of South Africa. 90 Questionnaires were distributed and 80 were brought back which were all valid and usable. A well-structured questionnaire was distributed to different construction companies in Mpumalanga Province, amongst construction professionals such as civil engineers, project managers, directors, quantity surveyors, construction managers and contractors who are registered on the CIDB database. The questionnaires were sent via e-mails, some were delivered to the known construction companies by the researcher and some were distributed during site clarification meetings of contractors and consultants bidders in Mpumalanga Province. The study was conducted from reliable scholarly sources such as articles, journals, books, publications, websites and site experience on the field.

7.3 Statistical Package for the Social Science (SPSS)

The quantitative data collected was analysed with Statistical Package for the Social Science (SPSS) a computer programme which is used for analysing data concerned with social phenomena. The software was used to generate various statistical, including descriptive statistic, which provides a basic summary of all variables in the data (SPSS 2004). 5-point Linkert scale was adopted for the study which gave a wider range of possible scores and increase statistical analyses that are available to the researcher.

The computation of the Mean Item Score (MIS) was calculated from the total of all weighted responses and then relating it to the total responses on a particular aspect. The mean item score was adopted to rank the factors from highest to lowest. The Mean Item Score (MIS) is expressed and calculated for each item as follows:

$$\text{MIS} = \frac{1n1 + 2n2 + 3n3 + 4n4 + 5n5}{\Sigma N} \tag{1}$$

where

n1 = number of respondents for strongly disagree
n2 = number of respondents for disagree
n3 = number of respondents for neutral
n4 = number of respondents for agree
n5 = number of respondents for strongly agree
N = Total number of respondents.

8 Findings

8.1 Sources of Disputes in Construction Projects

The respondents were asked based on their experience as to which factor has been the sources of dispute in construction projects in Mpumalanga Province. Generally, the sources were divided into six groups. Under the client related, Acceleration/Fast-tracking project was ranked first with (MIS = 4.33; STD = 1.085); Variation initiated by the client was ranked second with (MIS = 4.31; STD = 0.744);

Table 1 Sources of dispute—Client related

	Causes of disputes	$\bar{x}$	σX	R
Client-related factors	Acceleration/Fast tracking project	4.33	1.085	1
	Variation initiated by the client	4.31	0.744	2
	Payment delays by the client	4.24	0.594	3
	Change of scope by the client	4.20	0.876	4
	Unrealistic expectations of the client	4.18	1.099	5
	Late giving of possession of the site	4	1.274	6

σX = Standard deviation; $\bar{x}$ = Mean item score; R = Rank

Table 2 Sources of dispute—Contractor related

	Causes of dispute	$\bar{x}$	σX	R
Contractor-related factors	Technical inadequacy of the contractor	4.26	0.679	1
	Financial failure of the contractor	4.12	0.864	2
	Unrealistic tender pricing by contractor	4.01	1.102	3
	Time extensions by the contractor	3.99	0.980	4
	Poor quality of the works by the contractor	3.85	1.240	5
	Delays in work progress caused by poor planning	3.65	0.940	6

σX = Standard deviation; $\bar{x}$ = Mean item score; R = Rank

Payment delays by the client were ranked third with (MIS = 4.24; STD = 0.594); Change of scope by the client was ranked fourth with (MIS = 4.20; STD = 0.876); Unrealistic expectations of the client were ranked fifth with (MIS = 4.18; STD = 1.099) and Late giving of possession of the site was ranked last with (MIS = 4; STD = 1.274) (Table 1).

Table 2 represents the contractor-related factors group, Technical inadequacy of the contractor was ranked first with (MIS = 4.26; STD = 0.679); Financial failure of the contractor was ranked second with (MIS = 4.12; STD = 0.864); Unrealistic tender pricing by contractor was ranked third with (MIS = 4.01; STD = 1.102); Time extensions by the contractor was ranked fourth with (MIS = 3.99; STD = 0.980); Poor quality of the works by the contractor was ranked fifth with (MIS = 3.85; STD = 1.240); Delays in work progress caused by poor planning was ranked last with an (MIS = 3.65; STD = 0.940).

Table 3 represents contract-related group factors respondent; Risk allocation (e. g financial risk) was ranked first with (MIS = 3.49; STD = 1.170); Breach of contract by one or more project participants was ranked second with (MIS = 3.45; STD = 0.998); Exaggerated claims were ranked third with (MIS = 3.38; STD = 1.042); Ambiguities in contract documents terms were ranked fourth with (MIS = 3.17; STD = 1.089); Different interpretations of the contract clause were ranked last (MIS = 3.08; STD = 1.112).

Table 4 is representing the design-related group factors respondent, Inadequate/incomplete specifications were ranked first with (MIS = 3.87; STD = 1.085); Design errors by the design team were ranked second with (MIS = 3.68; STD = 1.174); Unavailability of information was ranked third with (MIS = 3.65; STD = 1.077); Poor Quality of design was ranked last with (MIS = 3.45; STD = 1.079).

Table 5 presents the external-related factors, Fragmented structure of the sector (Lack of consistency policy in the sector) was ranked first with (MIS = 3.90; STD = 1.109); Legal and economic factors were ranked second with (MIS = 3.65; STD = 1.021); Weather (Rainy, frosty) was ranked last with (MIS = 3.46, STD = 1.130).

Lastly, Table 6 represents the Project-related factors, unforeseen changes were ranked first with (MIS = 4;

Table 3 Sources of dispute—Contract related

	Causes of dispute	$\bar{x}$	σX	R
Contract-related factors	Risk allocation (e. g. financial risk)	3.49	1.170	1
	Breach of contract by one or more project participants	3.45	0.998	2
	Exaggerated claims	3.38	1.042	3
	Ambiguities in contract documents terms	3.17	1.089	4
	Different interpretations of the contract clause	3.08	1.112	5

σX = Standard deviation; $\bar{x}$ = Mean item score; R = Rank

Table 4 Sources of dispute—Design related

	Causes of disputes	$\bar{x}$	σX	R
Design-related factors	Inadequate/incomplete specifications	3.87	1.085	1
	Design errors by the design team	3.68	1.174	2
	Unavailability of information	3.65	1.077	3
	Poor Quality of design	3.45	1.079	4

σX = Standard deviation; $\bar{x}$ = Mean item score; R = Rank

Table 5 Causes of disputes—External factors

	Causes of dispute	$\bar{x}$	σX	R
External factors	Fragmented structure of the sector(Lack of consistency policy in the sector)	3.90	1.109	1
	Legal and economic factors	3.65	1.021	2
	Weather (Rainy, frosty)	3.46	1.130	3

σX = Standard deviation; $\bar{x}$ = Mean item score; R = Rank

Table 6 Causes of dispute—Project related

	Causes of dispute	$\bar{x}$	σX	R
Project-related factors	Unforeseen changes	4	1.081	1
	Poor Site conditions	3.87	1.089	2

σX = Standard deviation; $\bar{x}$ = Mean item score; R = Rank

STD = 1.081) and poor site conditions were ranked last with (MIS = 3.87; SD = 1.089).

8.2 Strategies to Minimise Construction Disputes

Respondents were asked on the strategies to minimise construction disputes in construction projects in Mpumalanga Province. Most respondents ranked Stakeholder management and alliancing first with (MIS = 3.45; STD = 1.151 and 1.203, respectively); Lean construction was ranked second with (MIS = 3.38; STD = 1.058); Partnering was ranked third with (MIS = 3.22; STD = 1.213); Supply chain management was ranked fourth with (MIS = 3.20; STD = 0.989); Relational contracting was ranked fifth with (MIS = 3.05; STD = 1.015); Lastly, Alignment with (MIS = 2.98; STD = 1.249) (Table 7).

9 Conclusion

Findings from the current study prove that there are higher incidences of construction dispute caused by Client and the contractor-related causes. Others emanating from the contract, design-related causes, external-related causes and lastly was Project-related causes. In terms of dispute minimization or dispute avoidance strategies have been identified, hence the industry has been cautioned and encouraged to embrace modern management concepts or management strategies such as stakeholders management, alliancing, lean construction, Partnering, with the emphasis being placed on an early involvement in the decision-making process by the key stakeholders including the clients, contractors and building users. It is also recommended that every stakeholder in the construction industry be knowledgeable about the strategies that minimise construction dispute in order to

Table 7 Strategies of minimising construction disputes

Strategies of minimising disputes	$\bar{x}$	σX	R
Stakeholder management	3.45	1.151	1
Alliancing	3.45	1.203	1
Lean construction	3.38	1.058	2
Partnering	3.22	1.213	3
Supply chain management	3.20	0.989	4
Relational contracting	3.05	1.015	5
Alignment	2.98	1.249	6

σX = Standard deviation; $\bar{x}$ = Mean item score; R = Rank avoid the effects of construction disputes such as loss of production on site, delays, profitability, loss of business viability and loss of company reputation.

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Safety Management Amongst Small Contractors in Selangor, Malaysia

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Abstract

Safety Management System (SMS) incorporates direction on the safety, guideline and documentation, safety preparing, crisis readiness and also reaction arrangement and safety approach. It is an important element to be implemented in the construction industry. Therefore, it is important for the small contractors to develop, implement and maintain the safety management system in their project. This paper aims to identify the safety management system amongst small contractors in Malaysia. Questionnaires survey was sent out to 100 small contractors of Grade G1 registered under the Malaysian Construction Industry Board (CIDB) with a thirty-five (35%) returned. As a result, it was found that the problems that occur in construction sites were improper controls machine, inadequate maintenance, unsafe of employee attitudes, unsafe conditions of materials, plants and equipment, ineffective of training of instruction, use of alcohols and drugs, lack of communication, improper motivation of operational personnel as well as improper safety rules and guideline. It is recommended that the small contractors should implement the safety management techniques or procedures during the construction to avoid and control the risk and need to develop and conduct the safety training programmes and training policy for the workers on the site. They must provide an adequate Personal Protection Equipment (PPE) for workers on site for protection and prevent from risks and accidents which may occur during construction operation.

Keywords

Safety management • Small contractors

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1 Introduction

Safety and health is a logic that recognizes and wipes out employment site dangers all through the lifecycle of any work venture. It is a logic that disheartens work hones that spot people in danger of harm and the joining of safety and health into the daily work process. According to Choudhry (2014), safety has become the most importance issues during the construction process. It is likewise the advancement of a situation where every individual in the task development progressive has a part and obligation regarding safety and health. At the point when construction undertaking of built the building, the industry of construction essential to guarantee the construction sites is being protected.

Safety management amongst the small contractors needs to know the significance of safety during construction which keeps up safety at sites. According to Fabiano et al. (2004), opposite relationship between the company size and level of occupational accidents exists. It can so be argued that small workplaces are more probable to have accidents than larger ones. The contractor ought to recognize the safety risks and prevention rehearses which every each will convey directly to construction site. Through safety administration, the employer can guarantee the safety coordination, safety orientation and practices of safety organizations.

The safety management system will guarantee the work performed to determine prerequisites is set up, reported, actualized and kept up. Safety management system, the parts of hierarchical, as far as its capacities, Personnel Protective Equipment (PPE), safety management instruments, cooperation with different divisions, safety management project and safety management hones. Previous findings revealed that the successful development and application of SMS would help in preventing the accidents from happening in the construction industry (Baxendale and Jones 2000; Wilson and Koehn 2000; Tam et al. 2001; Hinze and Gambatese 2003). According to Fewings (2013), good Health and Safety performance in the construction industries of

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developed countries are largely attributed by systematic implementation of Health and Safety management practices as stipulated in Health and Safety management systems. Hence, there is a need for a comprehensive understanding of the safety measures by all contractors and project administrators.

2 Literature Review

The Safety Management System (SMS) should be actualized to lead security approach and enhance the safety execution at every level of authoritative and person and incorporates direction on the safety, guideline and documentation, safety preparing, crisis readiness as well as reaction arrangement and safety approach. The safety management approaches can be undertaken by critically observing the company's safety policies, safety procedures and practices, particularly during its implementation on construction site (Wilson and Koehn 2000) in addition to executing a safety management programme into each of construction activities.

Projects are complex in nature, as they involve technical, procedural, organizational and human elements in an integrated manner (Ruuska and Vartiainen 2003). Hence, after reviewing the safety levels, assessment of an arrangement are ought to be created with a specific end goal to actualize the quality system. Besides that, the way towards safety management system is by distinguishing and building up the controls, forms, hardware, abilities and assets, besides it has to guarantee that all outlines, strategies and documentation are appropriate, upgrading control, testing and examination procedures, recognizing any estimation prerequisites, clearing up acknowledgment benchmarks as well as distinguishing quality records to name a few. Several control components in a quality system arrangement also need to be incorporated to the system including formal reporting, records of activities, review of the reports, problem discoveries and so forth. Moreover, in leading the strategy for executing safety in the construction process, the contractor must be a part of the safety management system. Thus, failure to implement SMS on site will lead to numerous dangers and risks. Therefore, employers and workers had to formulate and implement health and safety policies and procedures to manage health and safety risks (Bluff et al. 2004, 2010; Walters et al. 2011).

Furthermore, the significant issues in the safety management system was considered as contractor does not build up the safety inspection, the absence of data which regards to the danger control programme where the contractor did not assess the hazard and risk frequently. According to Goh and Chua (2009), construction safety risk assessment helps to improve the efficiency and quality of new hazard identification. It is the contractor's obligation to carry out the risk assessment in accomplishing an effective health and safety on site. Besides that, safety instructions and safety training should be provided at extraordinary levels as when degree of safety information stands low. It is conceivable that danger might happen during the project execution. Meanwhile, health and safety management issues in small businesses are related to lack of adequate resources to address health and safety issues, as well as lack of knowledge of the firm's health and safety risks (Champoux and Brun 2002). Therefore, it is important to note that the lack of risk-related knowledge and resources contributes to accidents on site and the aim of this paper is to recommend the best practice of safety management system amongst small contractors in Selangor, Malaysia. The next section describes methodology and analysis used in the study.

3 Methodology and Analysis

Questionnaires were distributed to 100 respondents with the feedback of 35% replied. In terms of respondent profiles, out of 35 respondents, 15 respondents (43%) is from Grade G1 and 20 respondents (57%) are contractors registered under MCIDB. Most respondents have working experience between 5 and 10 years and all respondents understood and implemented the safety management system on the site. Majority implemented safety procedures, risk control, review safety procedure and prepared health and safety policy and safety plan. They also conducted the safety inspection and safety audit of work undertakings. Majority of the respondents did conduct safety inspection and safety audit. Most of the contractors (66%) conducted the safety audit on daily basis while the remaining 34% of them did not conducting the safety audit. It shows that (97%) of the small contractors are providing the Personal Protection Equipment (PPE) to the labourers on site while carrying out the works. However, it shows that (80%) of respondents do not conduct the training programmes for labourers on site.

It shows that (91%) of the respondents implement health and safety for labourers in construction sites and majority carry out the risk assessment on the worksite and did not have the system to manage the hazardous substances. They did not do the reporting, recording and investigation of incidents, injuries and illness. Majority are not having the safety committee. It shows that (74%) of the majority are having the safety meeting on site.

Table 1 shows the main factors occurrences of accidents on the construction site. Majority of the respondents agreed to the fact that the factors of accidents are unsafe of employer attitudes with the average index value of 4.40, followed by the use of alcohol and drugs with the average index value of 4.34. The third factors of accidents agreed by respondents are improper machine controls which have the

Table 1 The main factors of accidents occurred on construction site

No	Factors	Mean	Rank
A1	Unsafe of employees attitude	4.40	1
A2	Unsafe conditions of materials, plants and equipments	3.94	7
A3	Ineffective of training instruction	3.80	9
A4	Use of alcohol and drugs	4.34	2
A5	Inadequate maintenance	4.09	6
A6	Lack of communication	4.20	4
A7	Improper motivation of operational personnel	3.91	8
A8	Improper safety rules or guidelines	4.14	5
A9	Improper machine controls	4.23	3

average index value of 4.23, followed by lack of communication, improper safety rules or guidelines, inadequate maintenance, unsafe conditions of materials, plants and equipment, improper motivation of operational personnel, ineffective of training instruction. Based on the value index, majority is agreed that the most factor that is causing accidents on the site is unsafe of employer attitudes while carrying out the works. Because the workers may lack knowledge and training programmes provided by the employee.

4 Discussion on the Findings

4.1 Understanding Safety Management System in Construction Industry

From the findings, 34 out of 35 respondents are implementing the safety management system on the site with the total of 97% of the respondents agreed in implementation of the safety management in the construction operation. However, findings also show that some of the small contractors lack in performing the safety management system. Due to lack in performing the safety management system, it can lead to risk and hazard that cause accidents. The uncontrolled of safety and health on construction sites may cause hazardous conditions to go unchecked, which can cause death or serious injuries and contractor who have bad safety records or perform their work in an unsafe manner are very culpable (Reese and Eidson 2006). Findings also signify that the majority of small contractors is not conducting the training programmes for labour on site which means that the labours are not receiving the adequate knowledge regarding the safety while undertaking the works. Arocena and Nuñez (2010) highlight the importance of good access to public support and training activities in establishments adopting more comprehensive Occupational Safety and Health management systems. It can, therefore, be concluded that lack of knowledge and resources contributes to the issue of accidents. The result of the findings can be strengthened based on the study of the ESENER data undertaken by The European Agency for Safety and Health at Work (EU-OSHA) (2002) of all establishments partaking in the survey as they recommend that a lack of resources such as time, staff or money (36%), a lack of expertise (24%) and the culture within the establishment (24%) are several of the main barriers to the application of Occupational Safety and Health management reported by the respondents.

Therefore, the small contractors need to overcome this problem through the implementation of the safety management system by way of exploring the knowledge on the safety and allocate the reasonable amount of cost for safety coverage and expenditures as outlined by the OSHA regarding the safety and health while carrying out the construction works. According to Baxendale and Jones (Baxendale and Jones 2000), the on-cost for smaller sized projects was more substantial as the cost of developing the health and safety plan as it was often disproportionate to the value of the project.

4.2 Safety Management System to Avoid and Control Risk During Construction Operation

The implementation of the safety management system to avoid and control the risk during the construction operation depends on the level of the safety management employed by the contractors. From the findings, most of the small contractors are implementing health and safety for labourers in construction sites, providing the risk assessment on the site and conducting the safety meeting. Further, by just implementing health and safety, providing risk assessment, and conducting site meeting, it is not enough to avoid and control risk during the construction operation. The contractors need also to have safety committee and a formal of the reporting, recording and investigation of incidents, injuries and illness system to enhance the effectiveness for prediction of future similar events from happening and ways to overcome. Due to the uncompleted system of safety being implemented, it will not do any better towards the safety, performance, to reduce the accident rate the small contractors need to have a proper safety management system. Based on their own research and discussions with experts, Gallagher et al. (2001) recommend that Occupational Safety and Health Management Systems can deliver more healthy and safe workplaces, but only under the right circumstances. EU-OSHA (2010) also finds that the application of Occupational Safety and Health Management Systems can lead to positive effects such as a reduction in accidents and a rise in workers' motivation.

However, it may not make sense for small companies to analyze the reasons for absenteeism formally or to appoint a health and safety representative. Many of these companies may have informal approaches and limited resources and expertise (Baldock et al. 2006). According to Hasle et al. (2009), smaller sized companies take less systematic approach to risk management and focus less on preventative measures. The exposure to risk factors at work causes real harm to the health and safety of labourers (Commission 2010). Therefore, it is an important element that the small contractors need to implement the safety management system to avoid and control the risk.

4.3 Factors of Problems in Construction Sites Without Safety Management

From the findings, Table 5.20 shows there are nine factors that contribute to the issues which occur on construction sites without safety management. Most of the respondents agreed that the major factors of problems that occur on construction sites without safety management are unsafe of employee's attitudes while commencing the work shows the average 4.40. Kaskutas et al. (2010) also found that unsafe behaviour was negatively associated with employer size. The second highest factor is the use of alcohols and drugs shows the average 4.34 which can contribute to the dangers to other people and worker itself. The third highest factor is unacceptable machine controls which shows the average 4.23. HSE (2002) also concluded that worker behaviour is a causal factor in approximately 80% of the accidents. However, the lowest factors of issues that occur on construction sites is unsafe ineffective of training instruction. Major numbers of respondents agreed that ineffective training instruction is not the major factors of issues that occur on construction sites. The reason is attitude if the employee itself. Many studies discovered that the majority of accidents and resulting injuries are accredited to unsafe work practices of the workers rather than unsafe working conditions (Garavan and O'brien 2001). Therefore, the small contractors need to implement the safety management system to reduce and avoid risk from happening in construction site.

5 Conclusions and Recommendations

It can be concluded that if all eight of the methods is used in implementing the safety into construction sites, the accidents, incidents, risks and hazardous can be minimized and avoided from taking place in construction sites. The safety management system must be developed, implemented and conducted on construction sites in order to lessen the hazards and risks, and can accomplish the objectives of the project. From the data gathered, it can be concluded that the majority numbers of respondents are implementing the safety management system as to control and avoid the risk in the period of construction, operation and also the small contractors are applying the health and safety of the labourers, providing the risk assessments and having safety meeting. Data gathered also shows that other safety management system such as system in managing the hazardous substances, safety committee and recording and investigation of incidents, injuries and illness are less to be undertaken by the small contractors might due to the reason of less knowledge and resources to implement it.

In terms of recommendation, small contractors need to apply the safety management methods on all work involved in the construction in order to preventing and controlling the hazards and risks that may happen. Besides that, the contractors need to provide and carry out the safety training programmes and safety training policy to the workers by giving the instruction, providing the knowledge and information regarding the safety management in carrying out works to ensure the workers are alerted for precaution towards emergency situation. Moreover, contractors need to implement the safety planning according to the Occupational Safety and Health management to ensure to achieve the objectives of works without any incidents.

Small contractors must provide Personal Protection Equipments (PPEs) for all of the workers on construction site according to the suitability of the works for their safety protection. Thus, the level of hazards or risks can be minimized or avoided. The contractors also need to ensure safety management system needs to be developed, implemented and conducted in a construction project to achieve the objectives of the projects as well as to avoid any accidents or incidents to the workers. Furthermore, the safety meeting and safety committee need to be developed. This is to ease the procedure to analyze the risks that occur by having the documentations from previous data of risks to be reviewed for the latest risks happened. This is to analyze the risks and suggesting the ways of preventing the risks to be happening. The study also suggests that the small contractors need to have an adequate amount of resources to implement health and safety management also increase in the level of knowledge regarding the health and safety management to be able to apply it.

Small contractors need to develop the safety meeting and safety committee, this is to ease the procedure to analyze the risks that occur by having the documentations from the earlier date of risks to be reviewed for latest risks happened. This is to analyze the risks and suggesting the ways of preventing the risks to be happening. Hence, the risk assessment needs to be provided and implement in order to ensure the risks and hazards are identified, to make sure all aspects of the work undertakings are to be reviewed, to reviewing the operation of plants, machines and equipment control and identify the possibility of the risks and hazards which might happen in construction sites. Thus, the safety inspection, safety audit and safety performance will need to be evaluated continuously to improve the safety management system in the future. The safety inspection and safety review need to be provided to evaluate the operation of safety management system and organization of the project in achieving the objectives.

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Assessing the Emerging Factors on Stakeholder Management in Public–Private Partnerships (PPP) in Malaysia

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Abstract

Public–Private Partnerships in Malaysia has become popular to both public and private sectors. Private and public sector need to know the emerging factors attaining the successful delivery of stakeholder management in PPP projects. This paper aims to identify the emerging factors that affected the successful delivery of stakeholder management in Malaysian PPP projects. In order to achieve the objectives, the data presented are qualitative interviews, observations and documentary reviews of documents related to selected case studies. Nine (9) PPP projects were selected Malaysian highway projects. Results showed that there were seven (7) emerging factors of successful delivery of stakeholder management in PPP projects. These factors include the key drivers of stakeholder management, good stakeholder engagement, built trusts between stakeholders, understanding concession agreement, bankability/availability of financial, technology transfer, fast completed and earn revenue and fast decision-making. It is recommended that these seven (7) factors are considered as the keys to successful delivery of stakeholder management in PPP projects. These factors expected to be guidelines to all stakeholder involved in achieving successful delivery in PPP project in Malaysia.

Keywords

Public–Private Partnerships (PPP) • Stakeholder management

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1 Introduction

Public–Private Partnership (PPP) has become very popularly used in infrastructure sectors such as transport, education, water and waste treatment, social and health (Liu et al. 2016). Traditionally, PPP projects were seen as a viable option for countries to provide infrastructure facilities. However, the development of infrastructure requires very large investment have an important role in the economy of delevoping country like Malaysia. PPP was first launched in the form of PFI in 1992 by UK government. The PPP model attained with the goal to obtaining infrastructure projects from the public balance sheet, reducing public spending and also reducing constraints associated with public sector lending limits (Li et al. 2005). Malaysian Government introduced PPP as an alternative procurement method, which emphasises greater involvement of private sector in providing public services (Ismail and Harris 2014). Since 1983, 500 projects have been launched by Malaysia Government with the cooperation of private sector under PPP arrangements and that has saved capital expenditure of RM 161 billion (Ahmad et al. 2017). Nonetheless, KL Sentral, Light Rail Transit (LRT), highways and medical facilities are examples of successful project which benefit the public in Malaysia through Public–Private Partnership (Alkaf and Karim 2011; Beh 2010). The PPP projects' success criteria have become very important and challenging for investors and public authorities in developing economy to assess their implemented projects whether it is successful or not (Osei-Kyei and Chan 2017). To achieve a successful project delivery, the stakeholder plays an important role in the construction industry (Eyiah-Botwe et al. 2016). Nevertheless, to see the implemented projects have become successful or not, this research endeavours to assist stakeholder to achieve successful delivery of PPP projects. Therefore, this research was aimed to identify the emerging factors on stakeholder management that link up a useful guidance to the stakeholders' involvement in PPP to handling, planning

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strategies and initiatives to be implemented towards the achievement of successful delivery in PPP projects.

2 Literature Review

2.1 Public–Private Partnerships

PPP is a partnership of public and private sector to facilitate the delivery projects and services. The purpose of PPP was to build and operate infrastructure which are delivering cost-effective and efficient projects as to meet budget constraints (Trebilcock and Rosenstock 2015). Procuring public infrastructure an effective strategy in the PPP policy should be established (Chou and Pramudawardhani 2015). Consequently, nothing new with the involvement of the private sector in delivery of public facilities and services, but in the past, it was either limited to financing or provision of long-term services (Villalba-Romero et al. 2015). Governments are seeking for PPP to develop public facilities due to limited availability of public funds for these initiatives (Carbonara and Pellegrino 2018). As a result, PPP projects received fund injections from the private sector with the efficiency of project management instead of using government funds. Generally, PPP projects' organise a Special Purpose Vehicle (SPV) or a concessionaire company to deal with contractor, lenders, investors, insurance providers and other parties especially government authority (Kurniawan et al. 2015). An effective PPP project is the key between the public and private sectors as well as in the relationship among other stakeholders (Cui et al. 2018). Collaboration between public and private sectors is required as PPP projects involve various stakeholders as the projects are large and complex. (Kolltveit et al. 2005; Smyth and Edkins 2007; Marrewijk et al. 2008; Walker and Jacobsson 2014). Many stakeholders usually involve in these projects and infrastructure (Kivilä et al. 2017; Arts and Faith-Ell 2012).

2.2 Stakeholder Management

Stakeholder management is about relationship between organisation and its stakeholders. The relationship impact among the stakeholders can be both on individuals and organisations, positively or negatively. Stakeholders need to be managed as to minimise their negative impacts and ensure that they achieve the organisation's goals. Two aspects identified for managing stakeholders in construction projects are communication with stakeholders and setting of common goals, objectives and project priorities (Jergeas 2000). Five factors are identified; analysis of stakeholder concerns and needs, communication of benefits and negative impacts, evaluations of alternative solutions, project organisation and media relations (Olander and Landin 2008). According to De Schepper et al. (2014) the application of general stakeholder analysis techniques in PPP projects determined the impact of allocating the responsibilities of the main two stakeholders that suggested unique recommendations for better stakeholder management. It is important to consider the best practices related to the life cycle of PPP projects, which are the conception, design and construction and operational and maintenance phases. Therefore, the best practices, such as communicating with all stakeholders and be honest and integrate stakeholders into the process, are all related to the construction stage.

3 Methodology

The case studies are used to test the validity of successful delivery of PPP projects related to the emerging factors for the successful delivery of stakeholder management in PPP, identified from the related literature. In order to gather the empirical data to understand the successful delivery of stakeholder management in PPP projects in Malaysia for this research, a multiple case study approach was employed. Case studies style is selected when the researcher intends to understand and analyse in depth of a phenomenon or cases which can be an individual person up to an organisation or projects. The use of case studies style is among the construction research advocate. The data presented in this paper represent the qualitative interviews, observations and a documentary review of the documents related to selected case studies (Faisol 2010; Takim 2005). Nine (9) selected PPP projects in Malaysia are highways projects namely as case study C1, C2, C3, C4, C5, C6, C7, C8 and case study C9.

4 Result and Discussion

It is clear that the project will succeed or fail for some of the same reasons. Hence, it is vital to identify the emerging factors for the successful delivery of stakeholder management in PPP projects. Based on respondents' experiences, these are the factors proposed (Table 1).

4.1 Understand the Key Drivers of Stakeholder Management

C1 and C2 highlighted that understanding the key drivers of stakeholder management is to have good understanding of each other objectives. It is important to determine

Table 1 The proposed factors for the successful delivery of stakeholder management in PPP projects

Code	Emerging Factors	Respondents	Attributes
EF1	Understanding the key drivers of stakeholder management	C1, C2, C9	• Good understanding of the projects' objectives
			• Understand group and need
			• Clear responsibilities from stakeholders
			• Clear contractual structure of stakeholder from various parties
			• Stakeholders must know their commitment
			• Clear with stakeholders scoping of work and contract obligations
EF2	Good stakeholder engagement	C1, C2, C9	Appropriate stakeholder engagement process
EF3	Build trust between stakeholder	C1, C2, C4, C5	• Stakeholders work together more easily and effectively
			• Stakeholders must be sincere
EF4	Bankability/Availability of financial	C1, C7	Strong funding
EF5	Technology Transfer	C3, C4, C5, C6, C8	• Knowledge transfer and experience
			• The use of latest technology in PPP project
			• Introducing new technologies and encouraging technology transfer
EF6	Fast completion and earn revenue	C4, C5, C9	Fast completion project delivery to end-user, concessionaire holders can earn revenue as soon highway was operated
EF7	Fast decision-making	C1, C2	• Stakeholders has the equal access to the interests
			• All stakeholders have to be taken into account when making decision

stakeholder group and understand their needs and the roles they play for project success. C2 stated that clear responsibilities from stakeholders are a way for stakeholders to understand their key drivers. C2 also added way for stakeholders to understand their key driver is to get clear contractual structure from various parties. C9 stated that stakeholders must know their commitment to monitor the works on site, and C1 stated that they must be clear with their scoping of work and contract obligations where those who simply need to be kept informed of progress, and those who will directly influence project outcomes. Therefore, it is important to identify and assess the interests of stakeholders.

4.2 Good Stakeholder Engagement

All respondents except C1, C2 and C9 agreed that good stakeholder engagement is one of the emerging factors for the successful delivery of stakeholder management in PPP projects. Therefore, it is important to designing of appropriate stakeholders' engagement as the factors for the project success.

4.3 Build Trust Between Stakeholders

C1 stated that one key element of project success is establishing trust between stakeholders. If there is trust between stakeholders, they can work together easily and effectively. C4 and C5 added that communication is one of the best ways to gaining trust between stakeholders. C2 also added that stakeholder must be sincere and build trust as good relationship is one of the success factor of the project.

4.4 Bankability/availability of Financial

C7 stated that the responsibility to obtain funds is more on the private sector. C7 mentioned that the first concenssions company failed to get funding for their project, then C7 company's take over the project to get funding by convincing the bank with feasibility study, traffic forecast, cash flow and revenue. C1 added that strong funding can ensure the success of PPP implementation. From case study, it found that they get funding through Employees Provident Fund (EPF). Therefore, bankability/availability of financial is a key factor for successful delivery in PPP projects.

4.5 Technology Transfer

C3, C4, C5, C6 and C8 agreed that technology transfer is important for project success. C3 added that the use of latest technology in PPP will bring out a greater outcome to a project. C4 also has the same opinion where introducing new technologies and encouraging technology transfer will effectively affect the success of a project. C5 and C8 mentioned that technology transfer is important to ensure the return of investment. Hence, the role of government, the academic and industrial community is to build a collaborative culture for the effective use of technology with government policies that drive the transfer of technology (Vutsova and Ignatova 2016).

4.6 Fast Completion and Earn Revenue

All respondents agreed that PPP project can achieve fast completion projects though with some challenges. C9 added if the project was fast completed to end-user, concessionaire holders can earn revenue as soon as highway operated. C4 admitted that PPP can accelerate the development of a project. However, C5 suggested that to ensure fast project delivery, relevant government authorities, particularly Unit Kerjasama Awam Swasta (UKAS), must ensure that no long delay in any process before the PPP project is awarded to the SPV or private company. Therefore, faster project completions can earn the revenue is another factor for successful delivery of stakeholder management.

4.7 Fast Decision-Making

C2 stated that the decision-making is important to ensure that every stakeholder has the equal access to the interests. Moreover, C1 added that too long to make a decision may result in delays and increase cost for a project. The theory posits that all stakeholders have to be taken into account when making decision that can affect their interests within the corporation. C1 provides an example such as top management. Therefore, fast decision-making is important for project success.

5 Conclusions

The successful project delivery release on the stakeholder plays an important role in PPP projects. PPP provides benefits for both the public and private sector, based on trust in all parties involved, openness, fairness and mutual respect. Concessionnaire holder agreed that understanding the key drivers of stakeholder management, good stakeholder engagement, builds trust between stakeholder, understanding concession agreement, bankability/availability of financial, technology transfer, fast completed and earn revenue and fast decision-making were emerging factors for successful delivery of stakeholder management in PPP projects. Therefore, PPP attempts to offer many benefits to all stakeholders who are involved in PPP project.

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BIM Awareness and Usage Versus BIM Knowledge, Importance and Future Planning: An Analysis from Malaysian Quantity Surveyors

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Abstract

The construction industry has been continuously affected by the inefficiencies and ineffectiveness in delivering its construction projects. However, BIM technology has been acknowledged to have numerous benefits in contributing towards project success. The BIM benefits include reduced project time and cost; enhanced team collaboration and communication; and improved project quality and performance. In quantity surveying practice, BIM applications also provide a platform towards producing more reliable cost estimates. However, its usage amongst the Malaysian Quantity Surveyors is still at infancy level. Thus, this paper aims to explore BIM implementation amongst the Quantity Surveyors in Malaysia. A questionnaire survey was conducted to gain their perspectives on BIM awareness and usage, versus the knowledge, importance and future planning of using the technology. The overall results show that the respondents have rated themselves as having moderate knowledge in BIM. For BIM could play a major role in their practice, they would apply BIM for their future planning. This study significantly offers input for BIM adoption in the Malaysian construction industry by focusing on the quantity surveying field. Subsequently, the information could be used as a reference to benchmark BIM development in Malaysia.

Keywords

Building Information Modelling (BIM) • BIM awareness • BIM knowledge • Quantity surveyors • Malaysian construction industry

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1 Introduction

Numerous issues such as project delays, reworks, inaccuracies, less team-coordination, limited information-integration and many more leading to many project failures have been occurred in the construction industry throughout the years. However, it has been claimed that the advanced technology of Building Information Modelling (BIM) has shifted the construction industry into a new revolution. The employment of this technology in the construction industry worldwide has brought valuable merits towards more effective and efficient practices for construction projects. Amongst the identified benefits of deploying BIM applications are cost and time saving; reduced human resource; quality and performance improvement; clash detection; improved accuracy; increased profitability; enhanced collaboration and communication; better presentation and documentation process; improved planning and design; better visualisation; and improved information.

Where BIM has been actively employed by many developed countries such as the UK, US, Europe, Australia and New Zealand (RICS 2014; McGraw Hill Construction 2014), this technology implementation is still at low adoption level in most of developing countries including Malaysia (Ismail et al. 1903). It was suggested that the quantity surveying sector in Malaysia should initiate some strategies in assessing BIM influence towards its practice (Quek 2012). Hence, the objective of this study is to examine the diffusion of BIM innovation in quantity surveying practice by focusing the awareness, usage, knowledge, importance and future planning of adopting the technology amongst the Quantity Surveyors in Malaysia.

2 Literature Review

The BIM uptake in Malaysia has been managed by the Construction Industry Development Board (CIDB) (Bernama 2014). The BIM implementation was literally started

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by the Malaysian Public Works Department (PWD) in 2007, however, has been dominated by the private sectors since 2009 (CIDB 2013). Thereafter in 2010, the National Cancer Institute Putrajaya was announced as the first national BIM project. Subsequently starting from 2011, BIM was actively promoted by the CIDB offering initiatives to promote the application of BIM in the Malaysian construction industry (Bernama 2014).

Some previous studies described the adoption of BIM technology amongst the stakeholders in the Malaysian construction industry (Mohd-Nor and Grant 2014; Rogers et al. 2015; Ali et al. 2013). Notably, the development of this technology also impacts the quantity surveying practice especially in establishing more accurate and reliable construction cost estimates. Even though the traditional roles of the Quantity Surveyors have been challenged through the existence of BIM (Olatunji et al. 2010), the BIM advantages definitely improve their flawed practice and add some more values to their current services (Crowley 2013).

BIM capabilities could enhance Quantity Surveyors' performance in relation to time, cost and quality by providing automated measurement (Wong et al. 2014), additionally leading to producing more reliable cost estimates. BIM could also overrule the traditional method by providing more reliable sources for quantity take-off and cost estimating processes (Nagalingam et al. 2013). Thus, it is worthwhile to further explore the BIM adoption level amongst the Quantity Surveyors in Malaysia. This study could lead to more research on how BIM assists the construction industry players particularly the Quantity Surveyors towards more successful construction projects.

3 Methodology

Data collection for this study employed close-ended questionnaire survey. It was conducted through online as it is considered cheaper having comparable response rates to other approaches. As this cross-sectional study also has limitation of cost and time allocated, survey by questionnaire method is more suitable rather than conducting direct observation, yet furnishing this study with broader information similar to other comparison methods.

After pre-tested, the questionnaire was distributed to the Quantity Surveyors registered with the Royal Institution of Surveyors Malaysia (RISM). From about 1140 Quantity Surveyors listed with RISM registration, only 295 were selected randomly as study samples (Krejcie and Morgan 1970). Ultimately, this study obtained 202 responses from the conducted survey after raw data being cleaned and screened. Considering unusable responses, the overall response rate was 68.47%. For this study, SPSS software was used to analyse the surveyed results using descriptive analysis on the respondents' background information, followed by evaluating BIM awareness, usage, knowledge, importance and planning of the respondents for using BIM application in the future.

4 Results and Discussions

As for the respondents' background information, majority of respondents (37.1%) have more than 10 years in estimating construction costs. 94.6% of surveyed respondents were from a quantity surveying background with most of them are Quantity Surveyors (83.7%) and 52.0% work with quantity surveying firms. The respondents were divided into three groups of whether they are currently using BIM, have used BIM but not for cost estimating and have not used BIM at all. They were all either aware or not aware of the existence of BIM technology in the construction industry. Figure 1 shows the distribution of respondents based on their BIM awareness and usage. The majority (90.6%) of the respondents are aware of BIM, while the rest (9.4%) are not aware and not using BIM at all. From the 90.6% of respondents that are aware of BIM, only 22.3% use BIM (12.9% currently using BIM in cost estimating; 9.4% have used BIM but not in cost estimating). The majority of respondents (68.3%) do not use BIM in their practice even though they are aware of the technology.

BIM knowledge, its importance and future planning of its usage were next assessed in line with the level of awareness and usage of BIM amongst the respondents as described in the following Figs. 2, 3 and 4. Figure 2 interprets that most of the respondents who are aware and use BIM in their practice have rated themselves as somewhat knowledgeable about BIM technology (highest mark of 6 and 7 of rating scale). However, those respondents who are aware but do not use BIM considered themselves as barely knowledgeable about BIM technology (highest mark of 3 of rating scale). It becomes apparent that the BIM users are expected to have more BIM knowledge as compared to non-users, since they are practically using the technology, giving them more hands-on technical experience, rather than only learning through reading materials and so on.

Meanwhile, in evaluating BIM importance in their practice, the respondents that are aware and use BIM often, rated the technology as mostly important (at level 8 on the rating scale) in assisting them in their current roles. While those who are just aware but not using BIM in their practice, mostly rated the BIM technology as somewhat important (at level 5 on the rating scale). The different perception towards BIM importance between these two groups is predictable given that the actual use of BIM technology has the high possibility to improve users' performance with its many benefits, hence increases the importance level of its usage. In

Fig. 1 BIM awareness versus BIM usage

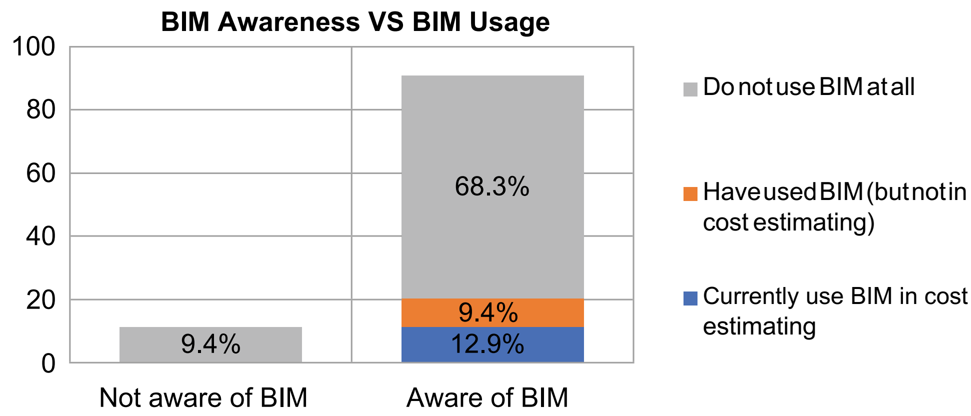


Fig. 2 BIM awareness and usage versus BIM knowledge

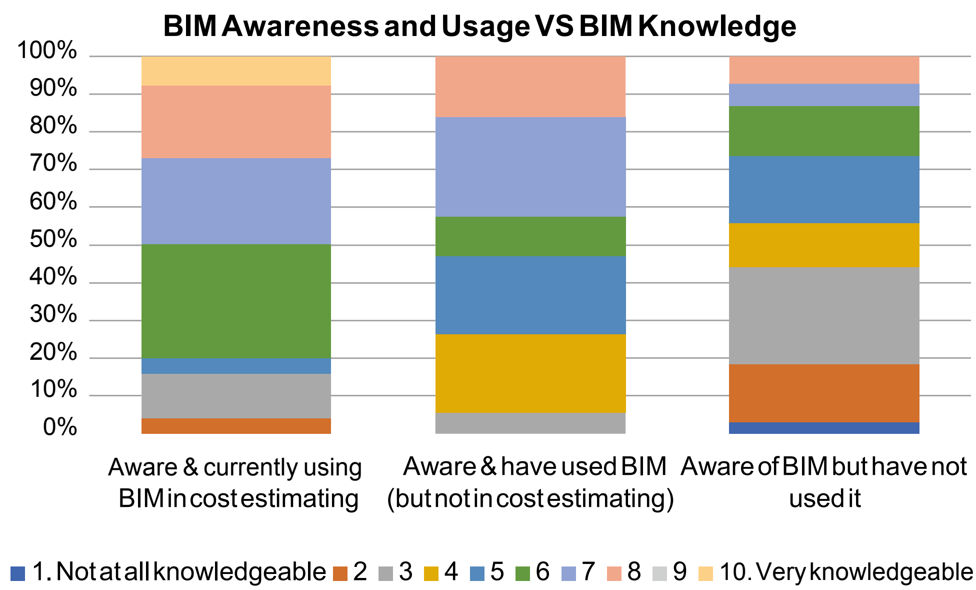
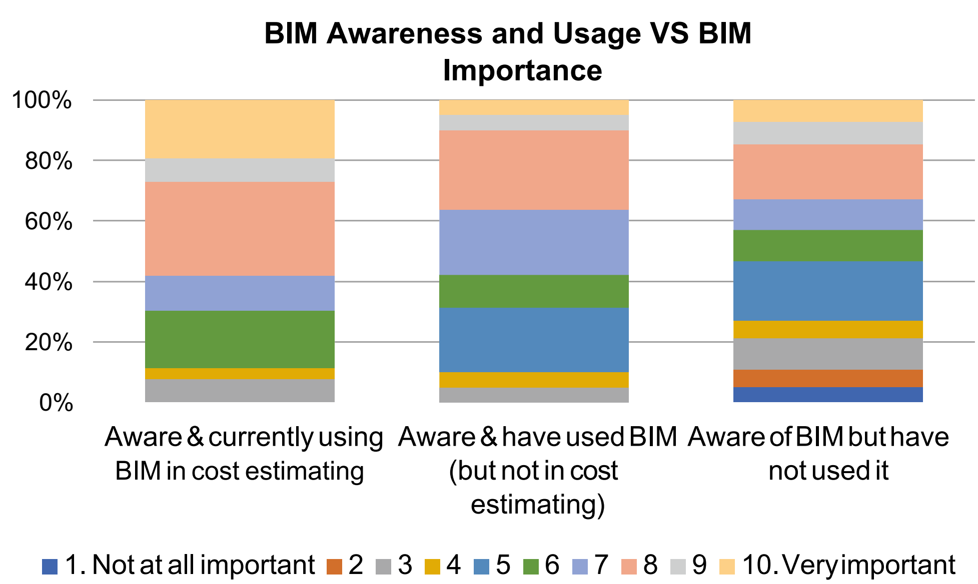


Fig. 3 BIM awareness and usage versus BIM importance



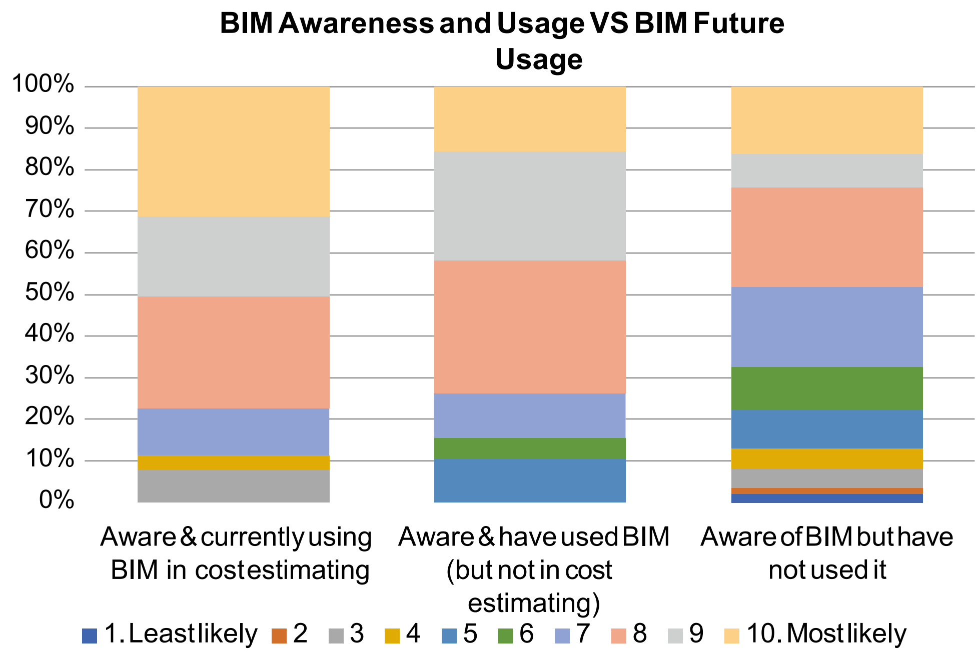


Fig. 4 BIM awareness and usage versus BIM future usage

contrast, the limited BIM knowledge without the actual application of the technology restricts the evaluation of BIM significance in the respondents' practice, leading the non-BIM users to moderately rate BIM as important. Figure 3 depicts the results of BIM importance perceptions amongst the BIM and non-BIM users.

Other than BIM knowledge and BIM importance being determined amongst respondents that are aware of BIM, they were also examined on their planning of using BIM for their future practice (refer Fig. 4). Figure 4 portrays those respondents that are aware and currently using BIM in their cost estimating practice have a very high probability of using BIM in the future. It is evident that BIM technology has significantly assisted them in establishing more reliable cost estimates, leading them to continuously use BIM for future projects. In the meantime, respondents that are aware and have used BIM but not in cost estimating are most probably planning to use BIM in their next practice. By not specifically adopting BIM technology for current cost-estimating practice, it can be said that many undiscovered benefits towards cost estimate reliability and accuracy are not yet explored by the respondents. Subsequently, this affects judgements towards the planning of BIM usage onwards. Likewise, the respondents that are aware of BIM but have not used it provide similar results of being more likely to use BIM for their future practice. Even though without any experience of using BIM technically, they might envisage BIM furnishing benefits towards their practice from various sources, such as reading materials or other experiences.

5 Conclusions

From the overall results, it can be concluded that the respondents who are aware and currently using BIM in cost estimating have fair BIM knowledge, rated BIM as influential in their current practice. They are very likely to implement BIM in their next projects, reflecting that the BIM technology they are currently adopting is beneficial for their cost-estimating practice. By that, they regarded BIM as important in developing more reliable cost estimates and are looking forward to using the technology continuously to constantly improve their cost-estimating practice.

Whilst, the respondents who are aware and have used BIM (but not in cost estimating) have fair BIM knowledge in which they considered BIM as significant in their current practice and may adopt the technology in their future projects. With BIM being employed not specifically for estimating costs, to a certain extent this has provided different perspectives towards future implementation of the technology. The respondents may possibly not have gained all the BIM benefits specifically related to their cost estimating practice, hence leading to undecided future planning for BIM utilisation.

Finally, the respondents that are aware of BIM but have not used it have limited BIM knowledge, however, rated BIM as quite important towards their current practice, might adopt BIM in the future. The results indicate that despite not using any BIM applications in their projects, they credit BIM with being able to assist them to perform better to improve their current practice, therefore achieving more successful projects.

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Augmented Reality (AR) for Utility Infrastructure: An Experiential Development Workflow

Poorang Piroozfar, Alex Judd, Simon Boseley, Amer Essa, and Eric R. P. Farr

Abstract

The process and product development phase of the research instrument for experiential action research is crucial in the success of the research. Due to time, space and resource limitations, fewer studies have concentrated on this development process. In this respect, research on Augmented Reality (AR) in the Architecture, Engineering and Construction (AEC) industry is no exception. This is more evident in subsurface, urban utilities and infrastructure sector. Furthermore, a limited number of studies on AR/VR have utilized mobile devices as their enabling technologies. This paper sets out to contribute to the state-of-the-art in AR research for urban utilities and infrastructure by outlining a generic procedural workflow to be used for designing AR experiments for experiential research in this area. Given the fact that workflow development research in AR is still limited, this research presents a unique contribution in this area to date.

Keywords

Augmented reality • Construction industry • Handheld devices • ICT application • Infrastructure • Urban utilities

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1 Introduction

The process and product development phase of the research instrument for experiential action research is crucial in the success of the research because it (re)defines the researcher-subject relationship and promotes the role and facilitates engagement of the subject as a co-researcher in such studies. Therefore, the importance of the design of such experiments as the backbone of the research instrument remains undebatable in experiential studies. Due to time, space and resource limitations, fewer studies have concentrated on this development process. In this respect, research on Augmented Reality (AR) and Virtual Reality (VR) in the Architecture, Engineering and Construction (AEC) industry is no exception. A limited number of studies on AR/VR have utilized mobile devices as their 'Enabling Technologies'. In the case of AR/VR research for urban utilities and infrastructure, the impact of the choice of device on Health and Safety (H&S), as well as legal and liability concerns, are issues that have driven the choice of device away from HMDs towards handheld devices. This makes it difficult to generalize the knowledge claims of such studies as they remain context-specific with limited scope for triangulation of findings. Therefore, this paper sets out to contribute to the state-of-the-art in AR research for urban utilities and infrastructure by outlining a generic procedural workflow to be used for designing AR experiments for experiential research in this area. Literature review on AR and its associated aspects and areas is presented first. The paper then carries on with the AR experiment, developed to be applicable to a variety of mobile devices available on the current market. Depending on the devices used (and their respective operating systems), minor adjustments to the experiment might be inevitable. Given the fact that workflow development research in AR is still limited, this research presents a unique contribution in this area to date.

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2 Literature Review

In comparison with VR, AR is relatively new and as such its definitions are still subject to transformation. The most widely agreed definition of AR seems to be what Milgram and Kishino(1994)) have proposed, where they place AR on a spectrum between physical reality and virtual reality, taxonomizing it as a form of 'Mixed Reality'. However, the term is now more likely to refer to any case in which an otherwise real environment is 'augmented' by means of virtual or computer graphic objects.

2.1 Data Availability

Utility asset data availability determines the approach to, precision and effectiveness of the AR instrument devised to assist in upkeep, maintenance and repair of the utility network. The current status of utility data is in need of some improvements. Previous researchers highlighted the lack of digital formats (Roberts et al. 2006) and inaccuracy of as-built information (Talmaki et al. 2013). The need for a shared geospatial platform is suggested to be key to handheld AR applications (Schall 2009), especially with reference to mobile market hardware developments (Nicholls and Powertech 2013). This has been suggested to the extent that utility data will eventually become as accessible as Google™ (Fenais et al. 2018), where asset owners and in particular local authorities have been encouraged to make their data more accessible to enable safe excavation (LSBUD 2017). Doing so also enables AR technologies to link with large quantities of information, hosted by BIM-enabled platforms, streamlining and simplifying its application (Chi et al. 2013). Other countries such as Singapore have begun to make their infrastructure data more accessible, where various benefits to procurement of such projects are being realized (Son et al. 2018) with some direct benefits for quality assurance as well as facilitating visualization methods. Although with increased use of GPS technologies, data collection and storage are beginning to merge (Talmaki et al. 2013), interoperability and encapsulation of non-asset data remains a challenge and may affect excavation and space planning practices (Yan et al. 2018).

2.2 Data Accuracy

With regard to data and information quality, the accuracy of the source data is a matter of concern in almost every research on subsurface utilities in conjunction with AR (Roberts et al. 2006; Talmaki et al. 2013; Behzadan et al. 2015; Côté and Mercier 2018), where the role that experts can play in public safety (Côté and Mercier 2018) and complexity (Jung 2012) have been highlighted. PAS128:2014 (BSI 2014) recommends Ground-Penetrating Radars (GPRs) high accuracy of 150 mm which has been adopted by some researchers (Junghanns et al. 2008) with others suggesting 300 mm (Schall 2009; Schall et al. 2013) or even 500 mm (Behzadan et al. 2015). Other elements associated with accuracy relate to capturing, visualization and positioning. For instance, GPR limitation in capturing data of dead power cables; low pressure gas and water pipes (LSBUD 2017); and new plastic pipes (Roberts et al. 2006) have been discussed in previous research. Technology development will allow for more reliable data capture such as pit photogrammetry and gyroscopic mapping with accuracy well in succession of 150 mm (Son et al. 2018), while utilizing a variety of surveying methods has been proposed to enable accurate data capture (Talmaki et al. 2013; Yan et al. 2018). Human errors and surveyors' skill and competence (Talmaki et al. 2013) and their ability to locate the pipe on site (Roberts 2002) are, however, not to be undermined.

2.3 Model Content

The requirements of augmented utility model contents have been broadly discussed, highlighting the importance of factors such as size and shape (Talmaki et al. 2013); colour (Schall et al. 2013); and transparency (Côté and Antoine 2015). While Talmaki et al. (Talmaki et al. 2013) advocate that the shape of utilities should differ as per cross-section type, review of other research suggests, to the contrary, that modelling objects should be kept at a lower level of detail (Li 2018). Regardless, it is important that objects are projected to scale and have a coherent colour coding schema (Meehan 2017). In order to negate the negative effects of occlusion, a semi-transparent visualization can be used (Côté and Antoine 2015). Filtering the data (Schall 2009) and simplifying the visualization can avoid misperceptions (Li 2018). Therefore, a suitable working range must be implemented, for which 5 m has been suggested (Roberts 2002; Côté et al. 2014). It is suggested that as well as the utility objects, the models also need to consider scene composition plans (Schall et al. 2013), or a rendered 3D terrain (Talmaki et al. 2013). Others do not concur with this opinion pointing at cost implications (Behzadan and Kamat 2009) or increasing chance of clash with real-world features (Côté and Mercier 2018). Communicating the uncertainties associated with visualization accuracy was discussed as an essential requirement for operators (Talmaki et al. 2013), which could cause model over-complication. One suggested solution is meta-information labelling (Schall 2009), permitting informed field decisions (Talmaki et al. 2013) and allowing for rapid cloud-enabled access to data (Fenais et al.2018). Previous research also highlights requirements for geophysical meta-data to inform excavation techniques (Jung 2012). Others have found that informing field workers of extra tasks and tools provides little benefit (Schall 2009).

2.4 Platform

A robust platform is essential for hosting the visualization. AR is often hosted on a mobile or a wearable device. However, due to dynamic and high-risk environment of construction sites, mobile technologies are favoured (Fenais et al. 2018); with benefits highlighted as portability, cost and availability (Chi et al. 2013), while their ability to convey more detailed information has been disputed by others (Fenais et al. 2018). However, there are some downfalls including their inability to be hands-free (Meehan 2017) and their apparent depth perception issues (Schall et al. 2013). The platform also needs to be ergonomic (Li 2018) while daylight affecting the user's experience has also been widely discussed (Schall 2009; Roberts 2002; Côté et al. 2014), suggesting that methods to eradicate glare and reflection need to be considered. It is suggested that a laptop or a screen can resolve these problems. However, they would require two hands. Therefore, they need to be mounted and screen interactivity should be kept at minimum (Schall 2009). Stable localization technologies need to be implemented for higher accuracy (Chi et al. 2013). Registration is still highlighted as a shortcoming for AR (Côté and Mercier 2018). To achieve good registration, some propose using a Simultaneous Localization and Mapping (SLAM) system which will enable continuous data transmission in the instance of a sensor failure (Chi et al. 2013).

2.5 Procurement

Even with highly coherent and accurate augmentations, its application needs to be justified to ensure correct use. Therefore, the procurement of the system has been investigated during planning, analysis and excavation stages while analyzing its implications on people and site technology. Insufficiently planned construction work can be hazardous (Li 2018) especially where the work sequence is counter-intuitive. The UK government recognizes this in urban utility sector and to respond to this need, produced PAS 128:2014 (Specification for underground utility detection, verification and location) in 2014. Previous research raises awareness of an evident gap between construction practices and mapping disciplines (Talmaki et al. 2013; Chi et al. 2013; Yan et al. 2018). AR could close this gap by allowing field workers to connect with remote colleagues (Nicholls and Powertech 2013; Meehan 2017) either through screen sharing or through attribute editing/redlining. There is some debate as to the responsibility of producing 3D geometric assets on-site, where Schall et al. (2013) propose model interaction and allowing on-site digital asset production and changes to meta-data will facilitate this. The benefit of on-site model control is in the inclusion of adjustments to existing utilities (Talmaki et al. 2013), often not picked up in the back office. A concern of modern-day utility excavation practices is the process of imagination that surmounts from the lack of persistent visual guidance (Talmaki et al. 2013) and the undetermined distance of the excavator bucket to the pipe crown. Behzadan et al. (2015) suggest the use of real-time forward kinematic algorithms to accurately calculate this distance as well as a combination of audio-visual alert systems to the operator, while Talmaki et al. (2013) suggest proximity analysis. A criticism of such an AR system is that it may give the operator a false sense of accuracy (Roberts et al. 2006) giving the impression that reducing these safety nets due to advanced technologies will result in the same H&S levels. LSBUD (2017) suggests that 44 % of works in the UK take place without a utility search. Previous research suggests that an AR system may improve this statistic through increasing awareness of utilities by excavation teams (Fenais et al. 2018). However, even if the AR system is robust, safety concerns can occur from personal behaviour and attitude of the AR operators (Li 2018). It is suggested that although even well-trained workers may have a negligent attitude towards safety, visual literacy skills should be improved to allow effective AR usage (Li 2018). Simultaneous use of the platform by more than one user can ensure safe procurement. Some researchers suggest that interactivity provides a more meaningful overlay visualization (Junghanns et al. 2008), facilitating improved performance in users tasks (Talmaki et al. 2013) while raising safety concerns (Chi et al. 2013), thereby suggesting that the excavator operator should have minimal interaction. AR helps contractors with discovery-based learning methods (Behzadan and Kamat 2009), allowing operators to understand how to avoid utility strikes as well as how to deal with a strike if it occurs; essential for modern complex engineering projects (Li 2018).

3 Research Design and Methodology

To carry out experiential or applied research in AR, the initial stage is to develop an experiment tool. After the preliminaries were carried out an experiment was designed to ensure objectives would be achieved, fulfilling the research questions. The aim of this paper is to expand on the development process of the experiment. The experiential nature of the research enquiry required that the experiment be designed, accounting for the research participants where separation of the researcher's and the subject's roles dissolves to enable those involved to become co-researchers and co-subjects, to devise, manage and draw conclusions from the research, but also to undergo the experiences and perform the actions that are being researched (Heron 1982). Therefore ease of use, practicality, interactivity and active engagement were the most important criteria in the research design, among more common factors such as replicability, validity, reliability, reproducibility of the instrument and the process of data enquiry and analysis. In doing so, special attention was given to the value of human experience; focusing on the wholeness of experience; searching for meanings and essences of experience; obtaining descriptions of experience through first-person account; regarding the experiential data as imperative; formulating questions and problems that reflect the interest, involvement, and personal commitment of the researcher; and last but not least, viewing experience and behaviour as integrated and inseparable discourses as indicated by Piroozfar et al. (2018).

4 Experiment Development

4.1 Model Development

A 3D model representing urban utilities assets was required and accordingly devised based on aspects of the literature review and as specified in PAS128 Quality Level B. Utility survey data was optimized in Autodesk Civil 3D using the pipe network features. Civil 3D allows for pipes and structures to be generated from this data, however, to save time the plug-in 'PipesToolBox' was utilized to batch-swap the imported objects into their correct layers and networks. These were then exported as AutoCAD 3D Objects for integration with the Unity platform, where the development of the application could be initiated (Fig. 1).

4.2 Application Development

In developing the experiment, an investigation was first carried out to establish the most suitable solution regarding AR for urban utilities. The initial solution was to identify a multi-platform application (including Android and iOS) to display GPS-located 3D AR models. Previously, an application called 'LayAR' was used to this effect (Piroozfar et al. 2018), however, as of 2019, LayAR no longer supports this level of functionality. The solution, therefore, was to instead develop an in-house standalone application that provides all required features. 'Unity' game engine was chosen to build the app, due to its multi-platform accessibility and support for the desired features, as well as being free to use and

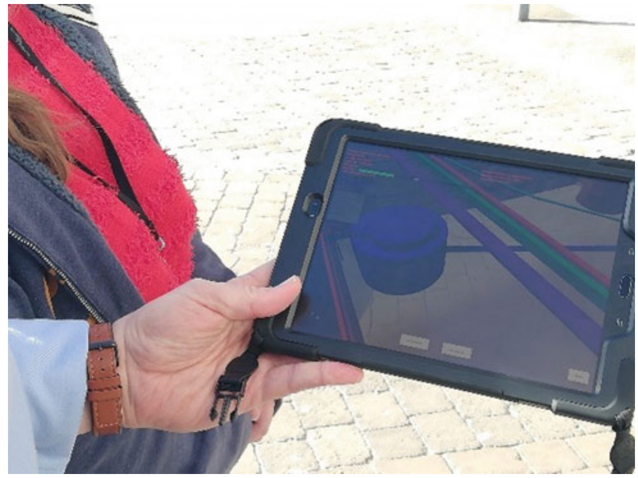

Fig. 1 Developed app

frequently updated. Next, several Application Programming Interfaces (APIs) for AR were trialled; the selected API would serve as the 'AR engine' to provide 3D AR functionality utilizing the mobile device's camera. The APIs tested include Wikitude, Mapbox, Vuforia, AR Foundation and ARCore. After trialling these APIs, the application was developed with Vuforia with the aim of developing a script to provide GPS functionality. Due to time restraints, it was not possible to develop such functionality in-house and so, third-party plug-ins were explored of which, 'AR + GPS' plug-in was deemed most suitable. Initially, there were software compatibility issues between Vuforia and the GPS plug-in. As a result, GPS was temporarily abandoned as an app feature. At this point, the ARCore API was chosen to replace Vuforia. ARCore allowed for 'surface-tracking' AR (Fig. 2a, b)—using ground surface planes to detect and augment utilities—without GPS functionality. Given that GPS was a desired feature of the application, the AR + GPS plug-in was revisited and trialled with a different API: AR Foundation. This combination worked and so GPS-based AR was possible and with Unity this meant the app could be used on a variety of mobile platforms. With a rudimentary app developed, features were added to improve performance, user experience and feedback. To provide debugging information so that the app could be improved and also serve as a user feature, a compass as well as relative GPS data were built-in. From this, we could analyze how accurate the GPS data was. The next step was to include multiple 3D models in the app to represent utilities at different sites/locations. The aim was to have these 3D elements overlaid with GPS synchronized. After trialling this, there were issues with lost performance and overlaying of multiple site models in one instance. To address this, a User Interface (UI) system was developed so that only a single model would be shown at any particular time, where the user could switch between

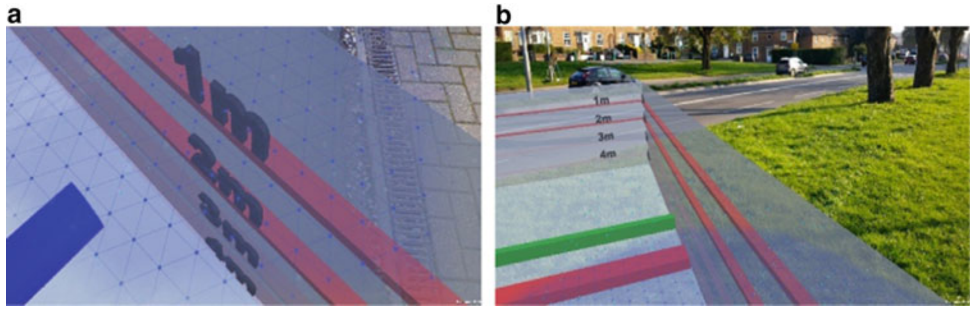

Fig. 2 **a** (left) Surface tracking of ground plane using ARCore Grid, and **b** (right) SLAM-like grid (represented by scattered magenta dots)

different geo-tagged models. The app was modified to display hotspots[1] indicating site locations based on global positioning (Fig. 3), at each location, where the user could switch to the relevant site model and at the appropriate size (a 20 × 20 or 50 × 50 m trench). The final stage of application development looked into inclusion of layer functionality and meta-data of the associated pipework. A separate UI was developed to allow for navigation and enabling the relevant utilities as and when deemed required, including main supply (e.g. gas, electric, water mains); drainage network and communication infrastructure (Figs. 4a, b). To enhance the geo-locationing feature of the application, a Global Navigation Satellite System (GLONASS) GPS enhancer device was procured to pair up with the mobile device and help with real-time locationing. This intended feature did not work due to the plug-in limitation in allowing for the GPS enhancer to take over the internal mobile GPS. Further work would be required to explore if the device or the plug-in can be coded or configured in order to take over the device GPS via Bluetooth™.

Fig. 3 Hotspot indicating site location

5 Concluding Comments and Future Research

Due to new development of affordable, user-friendly and open-source applications, conducting such level of research and development is now possible; what was not even conceivable a decade or so ago. However, this still looks more or less like a 'black box' to many and is worth shedding some lights on. This gap has been indicated in previous experiential research on application of both AR and VR in the AEC industry especially where a user-centred research instrument has been intended. It was noted that in such approaches to action research, no longer does traditional division between the researcher and the subject exists and the participants will be promoted to the role of co-subjects/co-researchers and, therefore, it is of paramount importance that every measure is taken to improve their engagement, enhance their experience, protect their H&S and other individual or social interests. To help bridge this gap, a series of experiments has been developed with ease of use, applicability and fitness for purpose of the developed experiment in the centre of focus. To serve the specific purpose of this paper, the experiment has been revisited and redesigned to ensure that it stays generic and presents a

[1]This is an AR/VR development technical term and differs from what it may denote as mobile network.

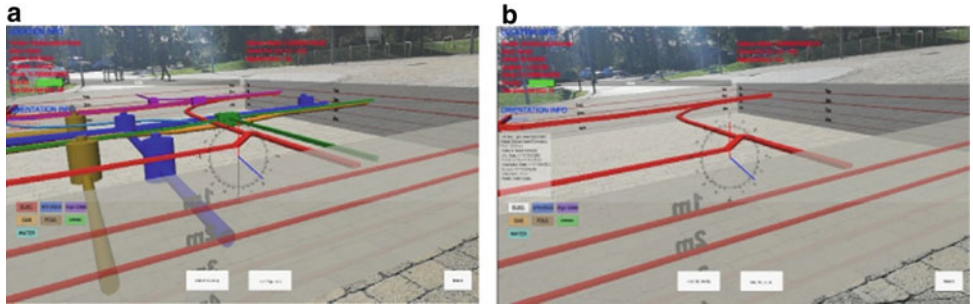

Fig. 4 **a** (left) layered view of all augmented utility types, and **b** (right) meta- data of the isolated utility type (chosen utility: electricity duct network)

customizable workflow which can be adopted and adapted to the specifics of similar research in the field. An intensive trial and error exercise was carried out which, although seminal to this development process, was kept to a minimum to avoid discouraging the readers. Most areas of concern were related—directly or indirectly—to software-to-software and/or software-to-hardware interoperability. Therefore, it is advisable to maximize the use of open-source software in case coding was deemed required as the only way forward, if possible at all, to improve on this aspect. The next point worth mentioning is coding skills required. Again with more and more coding languages moving towards Visual Programing Languages (VPLs) protocols, this task has become much more easily manageable with limited to no previous experience required. The next problem was that GPS is not as accurate as needed for the specific purpose of this research. This was expected as GPS can only provide certain levels of accuracy. This, however, was still within the accuracy limits for AR application in urban infrastructure and utility research and practice as suggested in previous research, hence the chosen method in this study. To tackle this problem, the use of local positioning systems seems to be the way forward, either on their own or in combination with GPS. However, the practicality of linking the two might be problematic. Another outstanding issue to resolve is altitude and height, where relying merely on GPS data does not suffice and requires an additional layer of sourcing and inclusion of data. The need for meta-data to complement the data visualization was another important requirement which was uniformly picked up in the pilot study and was added to the final prototype. Coupled with meta-data was the capability to annotate which was mentioned as a much-needed capability within the application. This was kept for further development to avoid over-complication of the task flow and process, and also for the fact that it could contribute to data or information overload; what was not limited to annotation and imposed a significant hurdle in many other areas. Therefore, the general advice is to avoid inclusion of any feature or data/information categories unless they are absolutely necessary, reducing the risk of distraction and threat on H&S. Distraction and H&S were also highlighted—as in previous research—to be associated with other areas such as the type, the size and the ease of use of the device; its location; the type, time, frequency and pace of the user's interaction with the device; device data update; refresh rate and effectiveness; Wi-Fi and Bluetooth™ effectiveness; screen brightness and readability in daylight, to name but just a few. One of the other solutions to overcome the problem of data clutter we suggest is to add a 'Section Box' where sections of the visualization—vertical or horizontal—can be cropped from view to speed up the application. Links to GIS databases were also picked up as beneficial aspects to include and improve on. Although many of the above-mentioned areas were concentrated and improved during the several rounds of iteration for application development in this study, there is still more work to be done in those areas, which will set the target for future research in many of those areas.

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Augmented Reality for Urban Utility Infrastructure: A UK Perspective

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Abstract

Research on Augmented Reality (AR) in the Architecture, Engineering and Construction (AEC) industry is still new. As part of a comprehensive study on the application of AR technologies for urban utility infrastructure, this paper sets out to contribute to the state-of-the-art in this area by presenting the results of an industry survey in the UK. The results of the survey conformed, in principles, to majority of findings of the previous research in the field, but also revealed some new or contradictory patterns. Geo-locationing and geo-tagging are still major concerns and have not yet been completely resolved. Relying on global systems does not look like the most reliable option and local systems are required to either replace or jointly work with global systems. With respect to non-AR issues, it is crucial that the quality and content of infrastructure and utilities data are improved and ideally stored centrally in a nationally procured database.

Keywords

Augmented reality • Construction industry • Handheld devices • ICT application • Infrastructure • Urban utilities

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1 Introduction

Research on Augmented Reality (AR) in the Architecture, Engineering and Construction (AEC) industry is still new and more so compared with Virtual Reality (VR). Therefore, its definitions are yet very much subject to different views and to some extent disagreement. Milgram and Kishino's (1994) definition places AR on a spectrum between actual and virtual reality, taxonomizing it as a form of 'Mixed Reality'. It seems to be the most established and widely referenced definition of AR ever since it was proposed.

As part of a comprehensive study on application of AR technologies for urban utility infrastructure, this paper sets out to contribute to the state-of-the-art in this area by presenting the results of an industry survey in the UK. Firstly, a critical review of literature on AR and its associated aspects and areas is carried out. The paper then reports on the findings of a survey which was conducted after the participants partook in a hands-on trial of the AR experiment primarily developed for this study. The experiment was intended to be applicable to a variety of mobile devices. The results of the survey conformed, in principles, to majority of findings of the previous research in the field, but also revealed some new or contradictory patterns which are discussed in this paper. As a part of the comprehensive study and once the questionnaire survey was concluded, a series of expert interviews were carried out to enhance the depth of this study and increase validity and reliability of its knowledge claims. The results of interviews are not presented in this paper due to restrictions on paper length.

2 Literature Review

2.1 Data Availability and Accuracy

The key to handheld AR applications is geospatial data (Schall 2009). Asset owners and local authorities are making

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their data more accessible (LSBUD 2017), comparable to Google™ (Fenais et al. 2018). Lack of [uniform] digital formats (Roberts et al. 2006), inaccuracy of as-built information (Talmaki et al. 2013) and need for a shared geospatial platform (Schall 2009) to link with large quantities of BIM hosted information, streamlining and simplifying its application (Chi et al. 2013) have been highlighted in previous research. Previous research on AR for subsurface utilities has raised concerns about the accuracy of source data (Roberts et al. 2006; Talmaki et al. 2013; Behzadan et al. 2015; Côté and Mercier 2018), with proportionate correlation to the level of complexity (Jung 2012) and public safety (Côté and Mercier 2018). Accurate GPS would be required (Nicholls and Powertech 2013) which can facilitate data collection and storage merger (Talmaki et al. 2013) signifying that AR could assist with refining the detail of a geospatial model on-site, where live visual links to the back office allow for real-time attribute editing and redlining (Nicholls and Powertech 2013). Accuracy tolerances range from ± 150 mm (BSI 2014) to 300 mm (Schall 2009; Schall et al. 2013) or even 500 mm (Behzadan et al. 2015). It is suggested that this variation may be the result of geo-locationing reducing accuracy levels to 450 mm (Talmaki et al. 2013) and possibly even more within street canyons (Schall 2009; Côté and Mercier 2018). This has also been attributed to limitation associated with Ground-Penetrating Radars (GPR) in capturing data pertaining to new plastic pipes (Roberts et al. 2006), low-pressure gas and water pipes, and dead power cables (LSBUD 2017). However, developing technologies such as pit photogrammetry and gyroscopic mapping can provide accuracies well in succession of 150 mm (Son et al. xxxx), or multiple surveying methods to enable accurate data capture (Talmaki et al. 2013; Sciences 2018). The encapsulation of non-asset data (Sciences 2018) and the lack of control of human errors and surveyors' skill (Talmaki et al. 2013) impose some significant challenges. For AR to work in unprepared environments, it is important to have accurate tracking information (Roberts et al. 2006; Côté and Mercier 2018). This can be achieved by tracking the precise position and orientation of the user and their relative position against the hardware plans (Schall et al. 2013; Yan et al. 2018).

2.2 Model Content and Platform

Due to dynamic and high-risk environment of construction sites, mobile technologies are favoured for hosting AR (Fenais et al. 2018). Mobile device benefits have been highlighted as portability, cost and availability (Chi et al. 2013), while their ability to convey more detailed information has been picked up by others (Fenais et al. 2018) with the possibility of pixel-level accuracy (Yan et al. 2018). Size and shape (Talmaki et al. 2013), colour and colour compliance with company drawing protocols (Schall et al. 2013), while following utility disciplines (Schall 2009), being to scale and having a coherent colour coding schema (Roberts 2002), and transparency (Meehan 2017), displaying data quality (Roberts et al. 2006; Côté and Mercier 2018) as meta-data (Schall 2009) have been discussed as content requirements of an augmented utility model. It has been suggested that the shape of utilities should differ according to cross-section type (Talmaki et al. 2013). Others have suggested a lower level of detail (Côté and Antoine 2015) to improve the processing speed. Depth perception has been picked up (Schall et al. 2013), with a 5 m x 5 m virtual hole (Yan et al. 2018; Li 2018) to enhance it (Côté et al. 2014), and prevent the virtual layer 'floating' on top of the real environments, especially in monocular displays (Schall 2009). It is suggested that, as well as the utility objects, the models also need to consider scene composition (Schall et al. 2013), or a rendered 3D terrain (Talmaki et al. 2013). Conversely, others point at cost implications (Junghanns et al. 2008) or increasing chance of clashes with real-world features (Côté and Mercier 2018). Although field workers may wish to see all underground assets buried at one spot (Schall 2009), this can be difficult due to large areas covered by utilities (Schall et al. 2013). Appropriately filtering the data (Schall 2009) and simplifying the visualization can help avoid misperceptions (Côté and Antoine 2015). Occlusion has been picked up with relation to on-site safety (Meehan 2017) and surrounding environment (Roberts et al. 2006) and a semi-transparent visualization has been suggested to address it (Meehan 2017). As discussed previously, communicating the uncertainties associated with visualization accuracy is an essential requirement for operators (Talmaki et al. 2013). This, however, could cause model over-complication. One suggested method is to use meta-information labelling (Schall 2009), permitting informed field decisions (Talmaki et al. 2013) and allowing for rapid cloud-enabled access to data (Fenais et al. 2018), including geophysical meta-data to inform excavation techniques (Jung 2012). Others have found that informing field workers of extra tasks and tools provides little benefit (Schall 2009). As for platform, ease of use and convenience have been discussed, with respect to platform ergonomics (Côté and Antoine 2015) and daylight impact on user's experience (Schall 2009; Yan et al. 2018; Li 2018). A laptop or screen cover can resolve these problems, but interactivity should be kept at minimum and the device needs to be mounted to keep hands free (Schall 2009). Over a decade ago it was believed that 4–5 satellites would be able to enable accurate positioning (Roberts et al. 2006). However, registration is still highlighted as a shortcoming for AR (Côté and Mercier 2018). Using a Simultaneous Localization and Mapping (SLAM) system has been suggested to enable continuous data transmission (Chi et al. 2013), particularly when combined with a magnetic orientation sensor (Junghanns et al. 2008). Stable localization technologies (Chi et al. 2013) need to effectively be associated with a grid for future data retrieval and analysis (Talmaki et al. 2013).

2.3 Planning and Analysis

Institute of Civil Engineers (ICE) in collaboration with British Standard Institution (BSI) developed PAS 128:2014 to ensure H&S for underground utility detection, verification and locationing. According to PAS 128:2014, Table 1 (BSI 2014) Quality Level A (QL-A) accuracy is achieved through trial holes prior to which, QL-B data is reflected by painting on the road surface. Previous research highlights issues with time consumption (Li 2018), disruption to the public (Roberts et al. 2006), error rates (Côté and Mercier 2018; Roberts 2002) and the lack of persistent visual guidance once the markings are destroyed (Junghanns et al. 2008). AR has been suggested to be applied to assist with this scenario. The use of a mirrored pre-captured environment with 2D surface lines associated with it has been proposed, highlighting accuracy advantages in areas of non-flat topography (Li 2018). Conversely, others have suggested that the main benefit of AR is its use in real world/time and not a pre-capture (Côté et al. 2014). Arguably, a system has been suggested to integrate interactive scene modifications to update QL-D information to QL-C (Li 2018) arguing that the system works well for virtual excavation methods (Meehan 2017). For planning purposes, this 2D overlay system could assist with standard surveying tasks where AR can be used to take measurements (Schall 2009) which could be more accurate than manual methods (Côté and Mercier 2018). However, both systems focus on 2D representation without 3D geometry which was a concern for some others (Sciences 2018).

2.4 Excavation

AR can increase the excavation teams' awareness of utilities (Fenais et al. 2018), especially in 44 % of works in the UK that take place without a utility search (LSBUD 2017). Lack of persistent visual guidance (Talmaki et al. 2013) and the undetermined distance of the excavator bucket to the pipe crown (Junghanns et al. 2008) have led to debates around the process of imagination in excavation practices. The use of real-time kinematic algorithms to accurately calculate this distance as well as a combination of audio-visual alerts for the operator (Behzadan et al. 2015) and proximity analysis (Talmaki et al. 2013) have been suggested to address this. However, high-tech AR systems may give a false sense of accuracy (Roberts et al. 2006), resulting in negligence towards H&S in site operations. Even with the most robust AR systems, safety concerns can occur due to personal behaviour and negative attitudes of the AR operators, even if they are well trained (Côté and Antoine 2015). To ensure that inexperienced or untrained workers are not disadvantaged, visual literacy skills should be improved and more than one user should use the platform to ensure safe procurement (Côté and Antoine 2015) where a supervisor can observe the AR visualization (Behzadan et al. 2015). While concerns have been raised as interactivity may deter the users' attention from their tasks, (Chi et al. 2013), some researchers suggest that interactivity provides a more meaningful overlay visualization (Côté et al. 2014) and allows for better performance (Talmaki et al. 2013). Either way, the excavator operators should have minimal interaction with AR technologies. Having a reference screen within the excavator cabin (Junghanns et al. 2008) may be a way forward to reduce H&S risks.

2.5 Socio-Economic Impact

Jung (2012) asserts that the use of subsurface utility engineering has potential savings of 10–15 % in the US and that the earlier this is implemented, the higher the benefits would be. AR has shown the potential to eliminate the need for surface excavation, reducing environmental damage and its associated costs (Schall et al. 2013). Moreover, it shows potential in utility strike avoidance, reinforcing the connections between people and objects through an intuitive mixed reality (Junghanns et al. 2008), and reducing the need for interpretation and imagination (Côté and Mercier 2018), leading to less error-prone decisions (Côté et al. 2014). As a result, there are potential savings in project time and financial resources (Behzadan et al. 2015). It has been suggested that the ratio of indirect to direct cost of repair is 29:1, which does not cover costs associated with back office time and plant costs (LSBUD 2017). Besides, there are other dimensions associated with social implications of utility strikes which will always be assumed as the asset owner's responsibility from the general public perception even if they are not at fault (LSBUD 2017). AR helps contractors with discovery-based learning methods (Junghanns et al. 2008), allowing their operators to understand how to avoid or deal with utility strikes if they occur, essential for modern complex engineering projects (Côté and Antoine 2015).

3 Research Design and Methodology

This study investigates the applicability of AR technology and its associated tasks for urban utilities and infrastructure in the UK, with an aim to gauge users' perceptions of benefits and limitations of the concept and the technology. A literature review was carried out to build an extensive knowledge base associated with the application of AR especially for urban utilities to then be used in the design of the research instrument for this study. A mixed-methodology approach was used in primary research to overcome limitations which may have otherwise been inevitable if a single-method approach were used. Quantitative and qualitative methods were applied using a questionnaire survey after the participants took part in an experiment developed for this study, followed by an expert interview to add depth to the study. Particular care was taken to adapt primary research methods in the most appropriate manner in order to avoid giving the impression that AR is a complex or confusing concept especially to those who may have had limited exposure to the concept in its intended context of application. A less considerate approach could have resulted in misrepresentation of, or at best case scenario an unintended bias in, the findings. Pivotal to the data collection instrument of this study was the experiment design which was developed following the break-down of the tasks and intentions required to be fulfilled for the specific purpose of this study. Due to limitation of the space, this paper only presents the questionnaire survey data. The findings of the expert interviews will be presented separately.

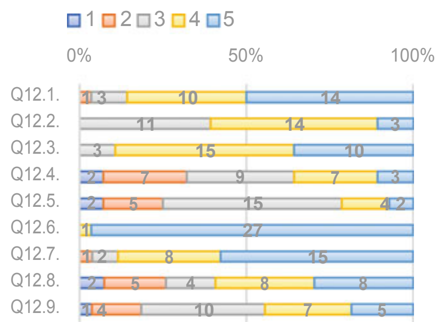
4 Data Collection and Analysis

The questionnaire survey was distributed by email using a mixture of two-tiered non-random sampling: purposive and snowball, to ensure that the AEC industry professionals with the most relevant experience are included in the survey. The potential participants were approached through the professional network of the researchers' and were asked to forward the request to those relevant professionals in their own network. Professionals with less than 1 year experience, students who were undergraduates with no experience in the AEC industry and those that had no work experience in the AEC industry were deemed ineligible, hence excluded. Of total 115 survey questionnaires which were issued (23 professionals, 14 colleagues, 5 academics, 11 peers, 28 social media and 34 through snowball sampling), 29 responses were returned (25.22 % response rate) of which one was considered invalid due to mismatched criteria, hence excluded. The questionnaire started with general questions about the age (with 18–24 yr: 21 %, 25–34 yr: 14 %, 35–44 yr: 14 %, 45–54 yr: 25 %, 55–64 yr: 25 %, and + 65 yr: 0 %), gender (F/M: 21 %/78 %) and the years of relevant industry experience (1–5 yr: 18,625 %, 5–10 yr: 17 %, 10–15 yr: 12.5 %, 15–20 yr: 12.5 %, 20–25 yr: 8 % and More than 25 yr: 25 %). There were four mature students between respondents with some relevant industry experience including placement year. Those were excluded from the count of years of relevant industry experience but were included in the rest of this research. When asked if they use CAD software packages, out of 28, 11 answered no and the rest indicated use of AutoCAD (N = 14), Revit (N = 9), SketchUp (N = 8), Civil 3D (N = 6), ArchiCAD (N = 20), Bently Microstation (N = 1), Vectorworks (N = 1) and others (N = 4).

Next question concentrates on the existing knowledge of AR between the participants where 64 % stated that they had previous knowledge of AR in gaming such as PokémonGo (N = 5), professional applications (N = 4), general (N = 4), reading about the subject (N = 2) with media, education and phone applications (N = 1, each). Of the participants, 12 stated that they had some knowledge of PAS128 of whom most were expert users in their professional practice. The participants then were shown a short video and asked to express their opinion about the positive and negative aspects of AR for urban utilities. Many highlighted benefits in relation to visualization aspects, suggesting that a 3D overlay gives a 'clear picture of underground services', with some suggesting that this can 'de-risk' an area. Other themes included convenience and simplicity of the model proposing that this method can sufficiently identify 'hidden' utilities with ease. Some underlining themes included its aspects around safety and planning, suggesting that this could 'prevent service strikes' through its use at a pre-construction/planning stage as an advisory measure. The least appealing aspect was the accuracy of visualization, with some suggesting that this was due to GPS, hardware registration and real-time rendering. Others suggest these inaccuracies can occur due to an individual's interpretation of original utility records. Next question aimed at gauging users' perception about importance of the meta-data attributions to be included in the AR tool using a Likert scale (with 1 = Not Important to 5 = Exceptionally Important). The results indicated that positional aspects (i.e. accuracy, coordinates and grids) were ranked the highest while the contact details were perceived as the least important (Fig. 1).

54 % of respondents said they would add to this list with the majority alluding to the date of the source data being required. Others suggested that the ground conditions (water tables, foundations, etc.), survey types (PAS:128 Quality Levels) and safety zones should also be reflected to better advise the user of the data. Some minor accentuations alluded to positional data in terms of GPS coordination and referring to highways chainage nodes. Next question asked about participants' perception about the type of projects where AR technology for infrastructure and utility was deemed most suitable with tunnelling, urban regeneration, highways, new build and finally agriculture ranking from the most to least suitable.

Fig. 1 Meta-data Importance



	Total Respondents	RII	Average	Rank
XYZ coordinate of the object	28	0.864	4.321	2
Material	28	0.743	3.714	5
Diameter/Size	28	0.85	4.25	4
General tel of network operator	28	0.614	3.071	8
General email of network operator	28	0.593	2.964	9
Accuracy of the data	28	0.993	4.964	1
The grid being used	26	0.885	4.423	3
Next service date	27	0.711	3.556	6
Service Life	27	0.681	3.407	7

Scenario suitability was the next feature which was gauged. 'Planning new utility networks', 'training' and 'planning buildings/structures around assets' were the three highest ranks while 'excavation of the utility asset' was ranked at the bottom of the list of seven scenarios (Fig. 2).

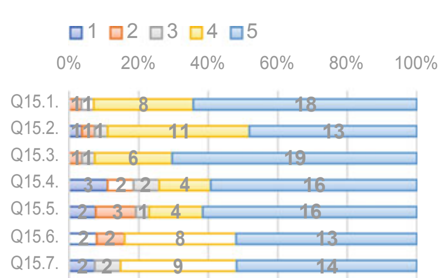
Next question was intended to measure users' perception of how application of AR may affect the existing practice in urban infrastructure and utility sector using a 1–5 Likert scale (with 1 = Strongly Disagree to 5 = Strongly Agree). 10 questions were formulated to investigate this aspect around time, health and safety, incurred costs as well as effectiveness and ease of use of the technology. There seemed to be a consensus about using AR to help people better understand location of underground utilities which ranked the first with 96 % agreeing or completely agreeing to it. This followed by AR's role in meeting QA standards and improving site H&S. The least favourable aspects were those associated with cost and time (Fig. 3).

Next question was a free-text question and asked about potential barriers the participants perceived on the way of wider implementation of AR in utility sector where the majority of respondents pointed towards accuracy of data. They associated this with the source data and its reliability from desktop searches through to trial hole information. Other underlined trends were associated with tolerances, signal, software updates and data management. Users also highlighted their training requirements, site behaviours, resistance to change, detachment from reality as well as legal and liability issues. To conclude the questionnaire, respondents were asked if they would have liked to add any further comments. 35 % of participants completed this section. Suitability for the intended project or activity was amongst the raised issues while some participants commented positively on promising future for AR in the sector. In addition to some further concerns surrounding accuracy, one response highlighted nausea and dizziness while watching the video.

5 Discussion of Findings and Conclusion

The findings of this study corroborate those of previous studies such as accuracy and reliability of the source data (Roberts et al. 2006; Talmaki et al. 2013; Behzadan et al. 2015; Côté and Mercier 2018), and the need to include additional information as meta-data (Schall 2009; Jung 2012). Model content and platform have been picked up by many researchers before (e.g. Schall 2009; Fenais et al. 2018; Talmaki et al. 2013; Chi et al. 2013; BSI 2014; Schall et al. 2013; Meehan 2017; Côté and Antoine 2015; Li 2018) and the fact that the majority of users in this study did not have any major concerns regarding the experiment, confirms that the platform and model content were successful in achieving the aim of this study. Issues associated with skill shortage (Talmaki et al. 2013) did not seem to be a serious concern for the participants of this study as it was believed to be easy for someone with no previous AR experience to

Fig. 2 Scenario suitability



AR scenario suitability for:	Total Respondents	RII	Average	Rank
Training purposes	28	0.907	4.536	2
Planning buildings around assets	27	0.852	4.259	3
Planning new utility networks	27	0.919	4.593	1
Excavation of the utility asset itself	27	0.807	4.037	7
Trench-less utility construction	26	0.823	4.115	6
Emergency excavations	25	0.824	4.12	5
Managing the asset	27	0.844	4.222	4

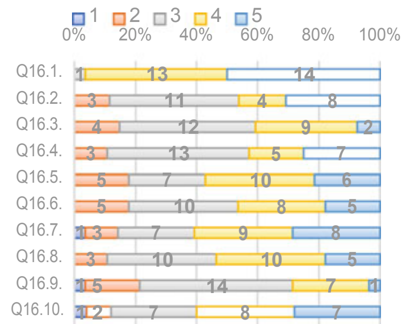


Fig. 3 AR impact on existing urban utilities professional

Using/Applying AR/AR model…	Total Respondents	RII	Average	Rank
Helps understand location of UG utilities	28	0.893	4.464	1
Is easy with no previous experience	26	0.731	3.654	4
Speeds up utility procurement	27	0.667	3.333	9
Save on planning costs	28	0.714	3.571	7
Saves on excavation costs	28	0.721	3.607	6
Saves on maintenance costs	28	0.693	3.464	8
Improves site health and safety procedures	28	0.743	3.714	3
Decreases length of road/footpath closures	28	0.721	3.607	5
Decreases darwing/modelling time in b/office	28	0.614	3.071	10
Helps companies meet QA standards	25	0.744	3.72	2

become skilful at it. Participants believed that having an AR model would improve site H&S procedures. This may be true as carrying out AR-assisted tasks will reduce H&S risks. It may, however, trigger false impressions of safety given by AR; professional negligence; confusion between virtual and actual environment; and finally increased distraction as a result of use of unfamiliar technologies. Some of our findings did not seem to concur with previous reports and researches. This was chiefly associated with cost. While previous research suggests—directly or indirectly—that the use of AR technology for subsurface utility engineering has potential to reduce the direct financial (Behzadan et al. 2015; Jung 2012) or indirect social (LSBUD 2017) and environmental (Schall et al. 2013) costs, for our participants' cost-related issues were not the most positively impactful factors of AR for urban utility. In conclusion, development of new affordable, user-friendly and open-source applications has made the level of R&D performed in this study possible; something which was not even imaginable a decade ago. Despite being an overall success, the developed experiment for assessing the AR technologies in urban utility infrastructure proved to be a challenge in regard to app development and interoperability. Geo-locationing and geo-tagging are still major concerns and despite long-term promises and hopeful expectations have not yet been completely realized. Therefore, relying on global systems (including cloud-based services and GPS) does not look like the most reliable option and more R&D is necessary to develop local systems to either replace or jointly work with global systems to enhance the accuracy and reliability of AR. As expected, raising awareness, education and training need to improve. These are key to facilitate a major leap forward in exploiting the full benefits such technologies have to offer to the AEC industry and to subsurface utility engineering. With respect to non-AR issues underpinned by this study, it is crucial that the quality and content of infrastructure and utility data are improved and ideally stored centrally in a nationally procured database.

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Sharing Knowledge via Ubiquitous Technology to Enhance Safety Awareness: Willingness and Actual Experience in Hong Kong

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Abstract

Recently, various ubiquitous technological advancements have benefitted knowledge sharing in different sectors. As there is a close relationship between safety knowledge and awareness, this paper examines the use of Web 2.0, Internet of Things (IoT) and mobile applications in construction safety knowledge sharing for enhancing safety awareness at work. The use of such technologies can improve internal and external communication as well as collaboration. A quantitative survey was conducted to investigate the willingness and uptake of advanced technologies in the Hong Kong construction industry. Out of 23 respondents, 16 were eager to use mobile applications to share safety information. Regarding safety knowledge sharing via Web 2.0, respondents perceived a variety of barriers for not using it, such as the need to protect their company's privacy issues made them hesitant to share knowledge regarding safety issues; others were of the opinion that Web 2.0 was managed by the elite in the organisation. Only three respondents have used Web 2.0 platforms. The willingness to apply IoT was relatively negative due to the perceived extra operation costs.

Keywords

IoT • Mobile apps • Web 2.0 • Knowledge sharing • Construction • Safety

1 Introduction

Gone are the times when knowledge sharing depended entirely on face-to-face encounters (Li and Poon 2011). Recent ubiquitous technology advancement has provided new approaches for communication. Wireless communication and cloud infrastructure increase the power and reach of information to anybody, anytime and anywhere. Advancement in technology has become an inseparable part of our daily experience. Revolutionary improvements in microprocessor cost-performance ratios have forced the knowledge sharing activity forward while drastically reducing computing-device structure elements, enabling the inclusion of computers in many aspects of our environments. In 40 years' time, change will have transformed the past large technological machines into compact devices that enable, mediate, help and coordinate our everyday actions (Lyytinen and Yoo 2002). The development of the internet is changing the conventional expert hierarchies and shifting ways of distributing data. In construction safety knowledge management, the internet is enabling new ways of gathering, preparing and distributing knowledge. Safety information mining enables the use of better techniques of information structure and memory as well as investigation of huge datasets, leading to the discovery of previously undiscovered knowledge and relationships (Cooper 2014). While the global telecommunication capacity per capita doubled every 34 months and the world's storage capacity per capita takes 40 months to double (Hibert and Lopez 2011), researchers discovered that use of mobile apps strongly correlates with the individual's position and daily experience (Ventola 2014). This paper aims to investigate the willingness and actual usage of ubiquitous technology for construction safety.

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2 The Application of IoT

The Internet of Things (IoT) is a form of technology conceptualised by smart and intelligent objects. IoT allows devices to interact automatically without human control, for example, personal items such as glasses, medical devices and wearables (from fitness trackers to baby socks); the smart home (digital assistants such as Google Home, smart thermostats, boilers, light bulbs, home security, fridges, televisions, etc.), connected car systems (evolving into autonomous vehicles) and smart communities where electricity grids, traffic systems and street lights incorporate sensors to collect data continuously (Deursen and Mossberger 2018). IoT is also used in several other sectors such as banking (Bareisis 2017) and education (Hu et al. 2013; Bremer, 2015). Ashton (2009) opine that IoT is a smart network that can detect, control and programme objects automatically. Due to the characteristics of the construction industry as reported by McKinsey, the huge number of people and the profusion of construction equipment, sites are becoming denser with vast amounts of data. On a construction site, the IoT would allow construction workers, materials and machinery to communicate with a common data platform that captures critical performance parameters.

One common example is the use of smart hard hats on construction sites. These hats monitor heart rates of workers against the outside temperatures to predict and prevent heatstroke in extremely high temperatures. Through this wearable device, workers can prevent injuries by predicting health concerns in real time and alerting managers instantly when they occur. E-tendering is also one of the tools of information technology in the construction industry that uses an internet connection (Lavelle and Bardon 2009). The e-tender concept makes the distribution of information easier to bidders and the document delivery process is faster because the distance is no longer an issue in the use of this system. In terms of management, Scan Marker, a digital pen capable of scanning any printed text and transmitting it into any device such as computers, tablets and smartphones via Bluetooth connections, saves typing time, translating around 40 languages and text scans can produce sound (Regev 2019).

The late supply of materials can disrupt the smooth running of a project and often occurs on-site due to delays in the delivery process. Recently, supply units have been labelled with Radio Frequency Identification (RFID) tags for automatic counting of supplies. When the count falls below a certain level, the system provides information to the central system to place more orders (Burger 2019).

Indeed, the adoption of IoT could benefit the construction industry level since it can alleviate the production costs. For example, IoT could be used to identify where materials, such as a window panel, should be placed, thereby reducing the costs arising due to wrong window placement. However, some IoT practices are still in the experimental stage, making it difficult to adequately convince the public of the benefit of IoT application. Consequently, this provides the basis for researching the real intentions of users in adopting IoT, especially in construction since the industry is currently focusing on technological advancements.

3 The Application of Mobile Applications

In terms of feasibility, mobile apps are anticipated to enhance knowledge sharing, with the possibility for further development and implementation. Lu et al. (2014) reported that many construction practitioners have smartphones and use the apps for work purposes. Indeed, there are thousands of smartphone applications advertised as 'construction apps', however, the most popular smartphone applications offered by software providers to the construction industry are in field data collection, project management, bidding, Building Information Modelling (BIM), accounting, customer relationship management and estimating (Barbarosoglu and Arditi 2016). The image and video capturing capabilities of mobile apps can be used for record keeping and documentation purposes, not just for communication.

It is estimated that there are approximately 13,000 construction-related development and design apps presently on the market (Park et al. 2016). An empirical study conducted by Liu et al. (2017) indicated several areas of app use in the construction industry, including site photos, health and safety reporting, timekeeping, RFIs, progress tracking, change orders, communication and punch list. Similarly, research conducted on USA sites found that mobile solutions impacted on the quality, subcontractor management, site coordination, safety, productivity, material procurement, project duration and budget (Azhar and Cox 2015). The use of these apps can greatly improve efficiency as well as the accuracy of site inspections and reporting (Bowden et al. 2006).

Nonetheless, the motivation to use such apps by construction professionals in Hong Kong is unknown. The purpose of this study was to examine the willingness of construction professionals to share safety knowledge using mobile apps and the actual usage of such apps.

4 The Application of Web 2.0

Web 2.0 is a web-based platform with simple-to-use interfaces that enable users to collectively contribute and share large amounts of information. It harnesses collective intelligence by engaging users to publish, tag, link, choose and comment. Basically, Web 2.0 is a web application (technologies and websites) which makes use of the internet in a collaborative way to provide services to users. Examples of Web 2.0 are blogs and wikis, as such, Web 2.0 relies heavily on users as a publisher model allowing content to be created by many people. These technologies are increasingly being used by companies for better staff collaboration and communication.

Web 2.0 impacts on data and information exchange, knowledge management, improved internal and external communication as well as collaboration. With the expansion of modern web services, it is easy to read email attachments on mobile phones, publish information on internal or external company pages, and send pictures from distant construction site locations directly to the concerned parties using web-based services. These are features for valuable learning, implying that individuals will be more active to participate in learning processes on Web 2.0 platforms. Despite the benefits of information technologies, the construction industry is in a relatively early phase of adopting web-based technology. Social media are considered perfect examples of Web 2.0 applications, which people use to communicate and collaborate. With the rapid development of Web 2.0 applications, knowledge, communication and sharing has moved beyond face-to-face exchanges to social media contexts such as YouTube, Facebook and Twitter (Li and Poon 2009).

Compared with the application of IoT and mobile applications, Web 2.0 provides a certain and discrete benefit to knowledge sharing because the conceptual framework of Web 2.0 endeavours to improve information circulation.

5 Research Method

The study employed a quantitative research approach. Questionnaires were distributed to construction practitioners in Hong Kong via LinkedIn.

6 Results and Discussion

Generally, respondents were interested in adopting Web 2.0 and mobile applications in practice, however, they were neutral in adopting IoT. There was a lack of experience in the application of these advanced technologies among respondents. The following sections present the results and discuss the willingness and actual usage (application) of the indicated advanced technologies.

From Fig. 1, it is evident that most respondents were generally willing to share safety knowledge across the various mentioned technologies, particularly mobile Apps and Web 2.0 platforms as opposed to IoT. However, the general expectation that their willingness might translate to actual usage was proven to be false for construction professionals in terms of using the technologies. Figure 2 shows that there is a huge gap between those who actually use the technologies and those who do not, as out of 23 participants, only 3 used Web 2.0 platforms. Most respondents (6 out of 23) made use of mobile apps to share safety knowledge compared to IoT and Web 2.0. Respondents were asked in an open-ended question to indicate (1) the willingness to use advanced technologies to share safety knowledge, and (2) why willingness has not resulted in actual use of these technologies to share safety knowledge.

6.1 Web 2.0

Those who used Web 2.0 to share safety knowledge in construction organisations provided positive and valuable insights into its application, believing that it can effectively reduce the number of accidents: '*I believe the usage of Web 2.0 stimulus the information sharing process, therefore, with sufficient knowledge, it can reduce the accident rate'*. However, there were various concerns regarding the implementation of Web 2.0 in practice as some respondents claim accident figures are confidential and sensitive in a competitive market such as construction.

There are foreseeable incentives in using Web 2.0 such as convenience and efficiency. Also, two of the three respondents who used Web 2.0 for knowledge sharing also used WhatsApp for intra-team communication. Respondents claimed that face-to-face and emails are the usual communication tools to share information among practitioners, these traditional methods are particularly used in the construction industry.

Regarding safety knowledge sharing through Web 2.0, respondents perceived various barriers for its application, such as the need to protect their company's privacy made them hesitant to share knowledge on safety issues. Others were of the opinion that Web 2.0 was managed by the elite within the organisation: '*I (the respondent) believe that Web 2.0 technology is only applicable in educating personnel and management level'*.

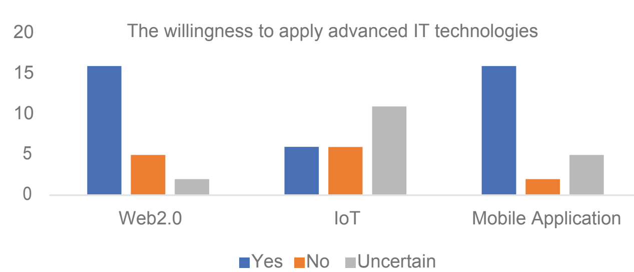

Fig. 1 Willingness to apply advanced IT technologies

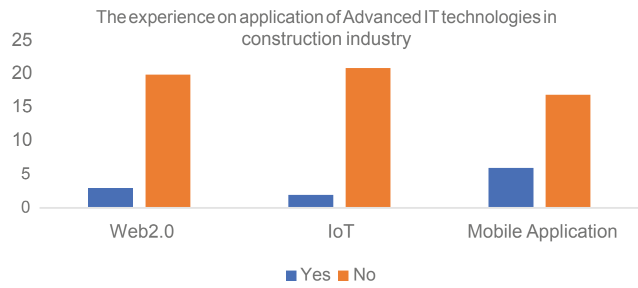

Fig. 2 Application of advanced IT technologies in the construction industry

Taken together, these insights can be summarised as barriers to the use of Web 2.0 as (1) lack of content in practice for sharing, (2) time and (3) on-site internet connection issue.

6.2 Mobile Applications

Regarding the use of mobile applications in construction safety knowledge sharing, 2 out of 23 respondents were not agreeable to use mobile applications to share safety information. Six respondents indicated that they were already using mobile applications to share information with colleagues, while 17 had no such experience in using mobile applications to facilitate work. Although respondents had less experience in using mobile applications, 16 out of 23 respondents reported their willingness to use mobile applications to share safety information. Importantly, those respondents who refused to use mobile applications tended to anticipate the development of specific mobile applications, while it can refer to general mobile applications such as Messenger, WhatsApp and WeChat.

In summary, of the barriers perceived by respondents, internet connectivity was the major concern. Another barrier is that workers considered reporting safety information through these mobile apps as doubling their workload. From the data analysis, the main motivation to use mobile applications was to alleviate the accident rate if the safety information could be transferred effectively and efficiently. However, some respondents were worried that the information could not be effectively transmitted to the target audience (on-site workers). In the worst-case scenario, mobile applications cannot guarantee that the workers read and understand the message, so they are not an alternative approach to face-to-face communication, even though most construction workers use a smartphone daily. Liu et al. (2017) conducted a study on the perceived benefits of Apps by construction professionals, showing that about 92 % of the respondents used mobile technologies and smartphone applications were utilised by construction professionals for site photos, health and safety reporting as well as timekeeping.

6.3 IoT

With regard to the application of IoT, compared to the previous two IT tools, respondents reported that IoT would be more appropriate for presentation but not in on-site practice. While some respondents claimed they had no idea about IoT, there was relatively high negative feedback in comparison to both Web 2.0 and mobile applications. They perceived that the IoT system has the potential to be hacked, which increases the potential risk in operation. Furthermore, only one respondent reported that he had used the technology before, however, he did not specify how he made use of it. The respondents were relatively unwilling to apply IoT as they considered it to be costly to set up, as well as the previously mentioned concerns regarding potential hacking. The respondents' motivation to apply IoT was rather ambiguous, for example, safety improvement was unclear in their view. Interestingly, there was ambivalence towards the application of IoT, some respondents were worried about increased costs, while others believed IoT could reduce the cost, albeit the cost was not well defined among respondents.

In summary, overall the respondents have no idea whether to apply IoT and they appeared confused about this technology, with only one respondent truly understanding the meaning of the application of IoT on construction sites, such that he expressed concerns regarding the hacking problem and data leakage in implementation.

7 Conclusions

This study highlighted the following critical factors which are crucial to motivate practitioners to adopt those technologies: first, practitioners are reluctant to use technologies that may violate their privacy commitment or if there is a potential risk of data leakage; second, the practitioners are willing to use applications if they consider that they will have a significant positive effect on safety management.

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Measuring the Needs for the Special Property Development Entity (SPDE) for Waqf Property Development in Malaysia

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Abstract

This paper aims to enhance the approach for developing the waqf properties in Malaysia. A Special Property Development Entity (SPDE) in the context of this article refers to a dedicated development actor that holds the responsibility to develop waqf lands. The intended role of the SPDE is to become the property development arm of State Islamic Religious Councils (SIRCs) in developing the waqf lands. This is expected to overcome the current limitations of SIRCs in entering into the property development while bringing a new model to deal with the issue of undeveloped waqf lands, as well as a better platform to penetrate the property market. The objective of this article is to measure the needs for the establishment of SPDE by SIRCs. By adopting a structured interview technique with fourteen informants from SIRCs throughout Malaysia, the study was able to quantify the needs for the SPDE. The quantification process for the need to establish the SPDE was conducted using the Guttman Scaling, which galvanises the need for versatile SPDE in contribute to the waqf institution.

Keywords

Special Property Development Entity (SPDE) • Waqf institution • Property development • Malaysia

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1 Introduction

A Special Property Development Entity (SPDE) refers to the development actor that functions as a dedicated development arm owned by State Islamic Religious Councils (SIRCs) which holds the responsibility to develop lands or assets under the control of SIRCs, including waqf lands. The concept replicates the establishment strategy of Warees Investment Pte. Ltd. (Warees) by the Majlis Ugama Islam Singapura (MUIS) to revive the waqf institution in Singapore through professional management and driven by market and commercial considerations (Osman 2014). Sharing the same vision, the SPDE is a strategy to professionally manage the development of waqf lands and focus on dealing with the issue of undeveloped waqf lands. It aims to fill the gap that most SIRCs are unable to attend due to various limitations.

Waqf or religious endowment started from the act of the Prophet Muhammad (peace be upon him) himself after he built a Quba Mosque in Medina soon after his arrival from Mecca. Waqf has existed in parallel with the Islamic civilization itself. It functions to support the social welfare of society through the general good while seeking compound rewards in the hereafter (Mohsin 2013). Waqf has been perceived as a very influential charitable institution that exists in the Muslim civilisation. Despite that, it faces threats from colonisation (Alias 1957; Mahamood 2006), persistent neglect by the public and authorised bodies (Mohammad and Mar Iman 2006), and an unfavourable administration and legislative framework in the country (Syed Abdul Kader and Dahlan 2009) which is a remnant of the past. This has resulted in what can be termed underperformance or under-development of the waqf institution today.

The development progress of waqf properties in Malaysia is still not at an optimum level. A report from the Malaysian Awqaf Foundation reveals that Malaysia has 30,888.89 hectares of waqf land, both general and specific (Yayasan Waqaf Malaysia 2016). That latest figure is showing a tremendous increase from the previous official records of

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11,091.82 hectares from the Department of Waqf, Zakat and Hajj (JAWHAR). However, due to various impediments and improper records that are sometimes beyond the control of SIRCs, the amount of developed waqf land is only about 3,504.72 hectares or 11.35% of its total (Yayasan Waqaf Malaysia 2016). Income generations from the waqf properties, specifically the non-religious type of waqf are also weak with only one-fifth of it is producing significant revenues (Kamali 2014). This indicates that waqf institutions in Malaysia require bold moves by their stakeholders to rectify this, especially the SIRCs who hold the responsibility as sole trustees of waqf assets in the country. Effective and efficient efforts to revitalise waqf institutions are desperately needed in order to fulfil the intentions of waqf donors to deliver benefits to the stipulated beneficiaries.

Despite continuous efforts, the results are still subject to discussion because the expectations from the public are relatively high and do not match the capacity of SIRCs due to various impediments. While stopping short of accusing SIRCs of failing to carry out their responsibilities adequately, there are a number of problems that affect them, such as an imbalance in the number of staff, unequal treatment of internal units, limited administrative and development budget, and a lack of professional staff with adequate property development backgrounds (Mahamood 2006; Syed Abdul Kader and Dahlan 2009; Majid and Said 2014; Syed Abdul Kader 2013). Some of the specified problems are actually beyond the control of SIRCs because they may require approval from a higher authority such as the Board Committee, State Government or the Royal Highness Sultan or King. In addition, some SIRCs' employment schemes are subject to approval from the Public Service Department that controls the employment of staff. The rigid structure of employment control by the Public Service Department having no equal to the enlargement of contemporary roles and functions of SIRCs. It definitely holds back the transformation process of SIRCs.

Moreover, as addressed by Çizakça (2008) and Mat Rani and Abdul Aziz (2010), waqf management between states in Malaysia lacks standardisation of legislation, management and implementation due to the exclusive power of the state to manage Islamic religious affairs. SIRCs are protective about this exclusivity and prefer others not to interfere in their business. This situation means that there is little opportunity for the consolidation or unification of waqf institutions across the whole of Malaysia, which would garner the greatest possible advantages from waqf. Neither does the JAWHAR at the federal level have the power to impose standardisation among states, except to facilitate, coordinate and promote the waqf agenda at the national level but without harming the exclusivity of SIRCs.

Taking into consideration that SIRCs suffer from certain limitations which prevent them from developing waqf land and at the same time are sensitive about their role as the sole trustee for waqf in the state, this study is attracted to the strategy of Selangor SIRC to establish its own SPDE based on the Singapore waqf institution. The initiative looks viable, especially when dealing with waqf property development which requires specialist knowledge and experience to handle matters related to land development.

2 Methodology

The study aims to enhance the perpetual benefits of waqf properties through a proactive property development approach. The objective is to measure the needs for the establishment of SPDE in every state and Malaysia generally. The study is a piece of mixed-method research of an exploratory nature. The data collection instrument was mainly the structured interview involving all 14 SIRCs in Malaysia that focused on a waqf development approach specifically. All the informants were selected from high-level officers who hold the highest waqf management position in the respective state.

There were ten interview questions that related to the probability of having SPDE in their state. It requires the informants to recall their experiences and expectations when dealing with developers, contractors or any development actors. All of the informants were responsive and cooperative in giving good answers.

Employing the gathered information from the interview, this study then was conducting the quantification process to measure the level of need for SPDE establishment based on a few dimensions that derived from the gathered information. The process adopted the 'yes/no' unidimensional scaling method known as the Guttman Scaling. The idea was to see the single-dimensional continuum for the concept to measure and reveal the hierarchical pattern of the result (Abdi 2010; Neuman 2014). The Guttman Scaling has helped the study to produce a growing pattern for the need of SPDE establishment by the SIRCs based on the identified dimensions that were asked in the form of yes/no questions. However, this study must use the 'reverse scale' for four out of ten available questions in order to turn any disadvantages experienced by the SIRCs into the contributing score to the need for the SPDE establishment.

The 'yes' or 'no' answers then had been translated into 0 and 1 score and will be used to produce the growing pattern through the accumulated results. The focus of the questions was mainly on the subsidiary provisions, the SIRCs' subsidiaries, professionals team availability and development finance availability, which further were asked in the following questions in Table 1.

The questions were sent prior to the interview session and properly sought the permission for the interview

Table 1 The interview questions

No.	Question
Normal score questions (To show that the item is contributing to the need for spde establishment)	
1.	Would you agree on the idea of establishing the SPDE?
2.	Are there any provisions allowing for the establishment of subsidiary company under the SIRC?
3.	Does the subsidiary company related to the development (project intermediary/project coordinator) is established under the SIRC?
4.	Does the SIRC has established any subsidiary company? (Searching some clues for the SIRC to consider corporatizing any of its functions)
5.	Is the state has high number of strategic waqf lands?
6.	Is the waqf land under the general deeds (suitable for any non-religious type of development) dominating the number of waqf land in the state?
Reverse score questions (To show that any disadvantages are contributing to a higher need for SPDE establishment)	
7.	Does the SIRC has the full-fledged development subsidiary company complete with development technical professionals?
8.	Has the SIRC gets enough and constant development budget from the government?
9.	Does the SIRC has several waqf development financing alternatives?
10.	Does the SIRC has enough in-house development professionals to do the waqf development?

appointment. All the interview sessions were conducted face to face with the informants and audio recorded.

3 Results

The answers have been arranged according to Table 2, like a scalogram and the results for each question then have been calculated per states' rows and questions' columns. Based on the results, the order of the questions had been rearranged from the highest to the lowest score. It was to produce a trend of how the state was able to fulfil the dimensions asked in the questions. The overall score of 91 from the maximum of 140 has indicated a strong altitude for the need of SPDE establishment in the state. The different scores for the states would indicate different altitude for the SPDE establishment, but it would take much consideration from the SIRCs.

Table 2 The measurement for the needs of SPDE establishment according to states

State	Q2	Q7	Q4	Q8	Q6	Q10	Q1	Q5	Q9	Q3	Score
A	1	1	1	1	1	1	1	1	0	1	**9**
B	1	0	1	1	1	0	1	1	0	1	**7**
C	1	1	1	1	1	0	0	0	0	0	**5**
D	1	1	1	1	0	0	0	1	1	0	**6**
J	1	1	1	1	1	1	0	1	0	0	**7**
K	1	1	1	0	1	1	0	0	1	0	**6**
M	1	1	1	0	1	1	0	0	1	0	**6**
N	1	1	1	1	0	1	1	0	1	1	**8**
P	1	1	1	1	1	1	1	1	0	1	**9**
Q	1	0	1	1	0	0	1	0	0	1	**5**
R	1	1	0	1	0	1	1	0	1	1	**7**
S	1	1	0	1	0	1	0	0	1	0	**5**
T	1	1	0	0	1	0	0	1	1	0	**5**
W	1	1	1	1	0	0	1	1	0	0	**6**
Score	**14**	**12**	**11**	**11**	**8**	**8**	**7**	**7**	**7**	**6**	**91**

Normal score Indicator: 0 = No, 1 = Yes; Reverse Score Indicator: 0 = Yes, 1 = No

4 Conclusions

The SPDE is an additional approach for the SIRC that complements the existing development approaches. The establishment of SPDE would give more options to develop waqf properties in Malaysia. It is possible to avoid certain governmental bureaucracies in the SIRCs and increase flexibility to secure the financing facilities and to hire good talents into the organisation. The SPDE could become more responsive to the market condition and make strategic sustainable decisions. Given in any structure or statutory framework, the establishment of SPDE recognises the crucial function of property developer as one of the prescribed actors in shaping the growth of the built environment through the production of real estate products. The idea is to bring synergy to waqf institutions in Malaysia and become a sustainable sector that can generate high incomes and at the same time safeguarding the social well-being.

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Assessing the Intrinsic Value of Construction Stocks: An Empirical Evidence from the Price Earning Models

Muhamad Saiful Alizan Nordin, Norbaya Ab Rahim, and Hamimah Adnan

Abstract

The encouraging performance of Malaysian construction industry requires a holistic understanding of the intrinsic values in order to practically invest in this sector. The paper aims to assess the intrinsic values of Malaysian construction stocks using price earning-valuation models. Quantitative content analysis has been employed to the top 20 construction companies based on total market capitalisation identified as Malaysian Construction Company (MCC) 1 to MCC20. Based on the data derived from the Bursa Malaysia, annual reports and stock-related websites, the intrinsic value of the construction stock is assessed using two fundamental methods of valuation comprising Price Earnings Multiple and Relative Price Earnings. The results suggested that there is a positive consistency of intrinsic values across two methods of valuation where 11 MCCs were recorded as undervalued stocks, 4 MCCs were recorded as overvalued and 2 MCCs were recorded at fairly valued in relation to its stock opening prices. Only 3 stocks recorded inconsistent findings where the Relative P/E were unable to effectively countercheck the intrinsic values derived from P/E Multiple. Overall, the results literally suggest that the 20 MCCs lie within the semi-strong form of market efficiency. This research is expected to provide preliminary evidence on the intrinsic values of construction stock in relation to the existing market efficiency.

Keywords

Construction stock • Intrinsic values • Price earning models

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1 Introduction

The construction industry is one of the preferred sectors among stock investors as its encouraging investment performance is backed by the development activities by numerous construction companies. Generally, construction companies carry out their development activities through the acquisition of land banks in potential areas to be developed with various construction projects according to the needs and the demand at the respective locality. The construction activities entail public project which focuses on infrastructure, institutional and affordable housing as well as private projects that covers all property sectors. One of the options can be taken by the construction companies is to list as a public listed company which legally allow them to issue share in the market.

In order to encourage public to invest in their shares, the company's performance needs to be scrutinised. The variation and volatility in the construction sectors are largely driven by its underlying performance of the previous, existing and proposed development. In addition, the construction-related Research and Development (R&D) in the context of property market research, consumers' preference and construction products' quality play an important role. According to Garcia and Oliveira (2018), the company that emphasising the R&D will have a rapid growth of development and earnings than other companies in the market. The establishment of construction stocks allows public to indirectly participate in the national construction industry even with the small initial cost of capital.

Numerous studies pertaining to the construction and other stock sectors are related to the effects of the stock prices in respond to the macro and micro-economic factors, risk and returns structures, stocks management as well as portfolio diversification for example by Hiang et al. (2005), Zull Kepili and Masron (2016), Kan (2017) and Ung et al. (2018). Other studies in identifying the effects of taxation on Malaysian stock market index volatility, Haron and Ayojimi

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(2018) found that the volatility of the Malaysian stock market index is persistent during the GST announcement and highly persistent after the implementation. The study, however, generalises all market sectors. Another example from Indonesia, Simbolon and Purwanto (2018) found that interest rate, inflation rate, exchange rate and GDP growth rate, as composite variables, have a significant influence on real estate and property companies' stock price.

This study, however, presents the application of fundamental valuation particularly in valuing the construction stocks. It served as an alternative to the technical analysis of the stock by focusing on the real value of the company that simultaneously minimising the speculative elements in the analysis.

2 Literature Review

The Efficient Market Hypothesis (EMH) assumed that the stock is accurately priced by the market so that the return is justified by the number of risk bears by the security. In other words, investors would not be able to obtain an abnormal return as the public information reflects the intrinsic value of the stock. The stock market is categorised as the best investment that meets the criteria of the efficient market hypothesis. In line with this feature, indices that related to the stock market have been regarded as a leading indicator to predict economic performance. The market is efficient where there is a large number of rational investors, relatively low transaction costs as well as relatively costless and availability of timely information (Pyeman et al. 2013).

There are three levels of market efficiency starting from lowest which is weak-form, semi-strong form and strong-form. According to Hadi et al. (2011), the weak-form EMH states that the market is efficient in such a way that price, volume information and stock price movements cannot be predicted using historical information. This weak-form EMH asserts that the stock returns are time-invariant, that is, there is no identifiable short-term-based pattern (Pyeman et al. 2013). Therefore under this level, the higher the ability of people to assess the stock information, the greater the profit they can earn.

However, the market is not always efficient. The achievements of Warren Buffets in sustaining the returns as well as strategies in acquiring a mispriced asset based on an intrinsic value thus denying the principles of EMH. Besides that the lack of long time series data and infrequent trading make the valuation of the stock market quite challenging especially when involving an initial public offering. For example, Yamashita et al. (2010) stated that the crisis in 1988 did not allow for the development of the stock options in Malaysia as much as in Japan. This may be due to the slow responsiveness to the stock information. In comparing the Malaysian stock with Japan, Yamashita et al. (2010) also reveal that the issues related to stock options in Malaysia are not that big as in Japan because the amount is not large and material. However, in the case of semi-strong efficiency, both fundamental analysis and technical analysis enable investors to produce excess returns as the stock prices response quickly to the newly available data in the market (Garcia and Oliveira 2018).

Stock valuers, analyst or even investors can assess relevant information via a stock exchange, to see the trading prices (opening price and closing price) as well as company's website or annual report to see any updates on the organisational or business structure that may affect the stock performance in the market. The application of intrinsic values as indicators to the stock prices would benefit investors in choosing the right stock to be invested. The intrinsic value of stocks is determined by a careful fundamental analysis of the historical accounting and financial data. This information can be obtained freely from the published annual report, official announcements and company's website. However, certain information such as investment and financial plan of a company is privately available where it only can be obtained through private enquiries on a company.

According to Wang and Ahammad (2012), accounting information, especially the annual reports, and direct contact with company management, represent the most important and most useful sources of information to financial analysts, although there is a clear shift in the relative importance of these sources over time. Survey-based studies on financial analysts indicate that analysts consistently emphasise the long-term view over the short-term in stock evaluation and selection (Wang and Ahammad 2012). In investigating the relationship between accounting information and stock returns of selected Indian stocks, Venkates et al. (2012) found that all individual accounting signals have a positive correlation with future stock returns. However, the functionality of fundamental analysis might differ in the different market places. In contrast, another study by Iqbal et al. (2013), however, found that the fundamental analysis cannot predict stock returns in Pakistani listed companies. This is because the market information in Pakistan is not efficient as it cannot reflect the true value of the stock. By assuming the market information is efficient, many models have been constantly developed and improved over time in determining the intrinsic value of the stock. However, the authors only discuss on two main approaches that will be used in analysing the selected share namely P/E Multiple and Relative P/E. The application of these models is briefly explained in the methodology section.

3 Methodology

Quantitative content analysis has been employed to the 20 property developers listed in Bursa Malaysia and identified in this study as Malaysian Construction Company (MCC) 1 to MCC20. The company was selected based on the highest market capitalisation and have been randomly sorted in this study. Based on the data derived from the companies' annual report, Bursa Malaysia and stock-related websites, the intrinsic value of construction stock is assessed using two fundamental methods of valuation comprising Price Earnings (P/E) Multiple and Relative P/E. The date of valuation is taken as at 30 April 2019 where data on opening prices, P/E and EPS are concurrent with the period of the study.

The list of top 20 Malaysian construction companies by market capitalisation are identified as S P Setia Bhd (RM8.99bn), Gamuda Bhd (RM8.64bn), IJM Corporation Bhd (RM8.51bn), Sunway Bhd (RM8.22bn), Sime Darby Property Bhd (RM7.55bn), IOI Properties Group Bhd (RM7.54bn) Malaysian Resources Corporation Bhd (RM4.53bn), UEM Sunrise Bhd (RM4.22bn), UOA Development Bhd (RM4.17bn), Eco World Development Group Bhd (RM2.72bn), Mah Sing Group Bhd (RM2.33bn), Ekovest Bhd (RM1.88bn), WCT Holdings Bhd (RM1.50bn), Matrix Concepts Holdings Bhd (RM1.45bn), Tropicana Corporation Bhd (RM1.28bn), Eastern & Oriental Bhd (RM1.27bn), LBS Bina Group Bhd (RM959.02 m), Paramount Corporation Bhd (RM918.69 m), KSL Holdings Bhd (RM881.88 m) and YNH Property 142Bhd (RM878.14 m).

3.1 Price Earning Models

The P/E is a good indicator of the financial strength of the firm. By using the simple earnings capitalisation model to investigate the association between price and earnings across profit and loss firms, Papadaki and Siougle (2007) signify a negative P/E relation for the company that reports losses and a positive P/E relation for the company firms that report profits. Price Earnings (P/E) Multiple is a popular technique where the company's expected EPS is multiplied by the average P/E ratio for the industry to estimate the company's share value. The methodological strength of P/E Multiple is considered superior to the use of book and liquidation values since it considers expected earnings. According to Wang and Ahammad (2012), analyst compares the market P/E and share price in the same industry to come out with an estimated reasonable price interval before recommendations on investment being made. If the intrinsic value of the share is higher than the share price, it implies the shares are undervalued. As mentioned earlier, the expected earning is the main determinant under this method. The expected changes in EPS, expected returns on equity and prospects for the relevant industry are also considered the most important variables over the long- term besides giving the greatest weight over the short term (Wang and Ahammad 2012). Valuation of stock using P/E Multiple can be calculated as follows:

$$V_{\mathrm{P}}/\mathrm{E}_{\mathrm{Multiple}} = \mathrm{EPS} \times \bar{x}\,\mathrm{P/E}_{\mathrm{Industry}}$$

where $V_{\mathrm{P/EMultiple}}$ is intrinsic value of stock using P/E Multiple while $\bar{x}\,\mathrm{P/E}_{\mathrm{Industry}}$ is the average P/E of construction industry that can be assessed as follows:

$$\bar{x}\mathrm{P/E}_{\mathrm{Industry}} = [(\mathrm{P/E}_{\mathrm{MCC1}} + \mathrm{P/E}_{\mathrm{MCC2}} + \mathrm{P/E}_{\mathrm{MCC3}} \ldots \mathrm{P/E}_{\mathrm{MCC20}})/n*]$$

where $\mathrm{P/E}_{\mathrm{MCC1} \ldots \mathrm{MCC20}}$ refers to the P/E of each MCC and $n*$ the number of the company analysed, i.e. 20. Meanwhile, Relative P/E is a measure of stock performance in relation to the average performance of the market. The method suggested that $1.00 is the relative value of stock in the market. Therefore, if the relative P/E is exceeding $1.00, the stock is said to be undervalued and otherwise it is less than $1.00. Relative P/E can be calculated as $\mathrm{P/E}_{\mathrm{Stock}}/\bar{x}\,\mathrm{P/E}_{\mathrm{Industry}}$ while the intrinsic value using Relative P/E can be arranged as follows:

$$V_{\mathrm{RelativeP/E}} = P_0 + [V_{\mathrm{Relative}} - (\mathrm{P/E}_{\mathrm{Stock}}/\bar{x}\mathrm{P/E}_{\mathrm{Industry}})]$$

where $V_{\mathrm{Relative}\ P/E}$ is intrinsic value using Relative P/E, P_0 is the current price of stock as well as V_{Relative}, the relative value of stock indicated at RM1.00 per share.

4 Results and Discussions

Table 1 depicts the summary of intrinsic values derived from the P/E Multiple and Relative *P/E*. Based on the data analysed, eight companies were reported at issuing a penny stock where the opening prices are less than RM1.00 per unit (MCC4, MCC7 and MCC13 to MCC17). However, these stocks mostly are in the state of undervalued and fairly valued except for MCC16 which shows an overvalued figure. The undervalued intrinsic values are ranging from RM0.8830 to RM3.6998. This figure signifies the information transparency of seven penny stocks in the study. The results also reported that, by excluding MCC1, there is a positive consistency of intrinsic values across both methods of valuation as Relative P/E can serve as a countercheck method to the P/E multiple model and vice versa. These were supported by Yoo (2006) where the application of simple multiple methods of valuation is likely encompassed the common and incremental information that is beneficial for the improvement of the valuation accuracy. Incremental

Table 1 Intrinsic values of selected Malaysian construction companies using P/E models

Company	Stock opening price	Method 1: P/E Multiple			Method 2: Relative P/E		
		EPS	$\bar{x}$ $P/E_{Industry}$	Intrinsic value	P/E	Relative P/E	Intrinsic value
MCC1	1.1100	0.0178	16.81	***0.2992 [−73.04%]	−31.2	−1.8531	*3.9631 [+257.04%]
MCC2	1.3700	0.1378	16.81	*2.3163 [+69.08%]	9.95	0.5919	*1.7781 [+29.79%]
MCC3	2.2600	0.2114	16.81	*3.5535 [+57.24]	10.69	0.6359	*2.6241 [+16.11%]
MCC4	0.9250	0.0584	16.81	*0.9817 [+6.13%]	15.85	0.9429	*0.9821 [+6.17%]
MCC5	1.0600	0.0793	16.81	*1.3330 [+25.75%]	13.37	0.7954	*1.2646 [+19.30%]
MCC6	1.9200	0.2607	16.81	*4.3822 [+128.24%]	7.36	0.4378	*2.4822 [+29.28%]
MCC7	0.6150	0.0618	16.81	*1.0388 [+68.91%]	9.95	0.5919	*1.0231 [+66.35%]
MCC8	2.1200	0.2218	16.81	*3.7283 [+75.87%]	9.56	0.5687	*2.5513 [+20.34%]
MCC9	2.2700	0.1259	16.81	***2.1163 [−6.77%]	18.03	1.0726	**2.1974 [−3.20%]
MCC10	3.5000	0.1774	16.81	***2.9820 [−14.80%]	19.73	1.1737	**3.3263 [−4.96%]
MCC11	1.0300	0.0172	16.81	***0.2891 [−71.93%]	59.95	3.5664	***1.5364 [−249.17%]
MCC12	0.9300	0.0529	16.81	**0.8892 [−4.38%]	17.60	1.0470	**0.8830 [−5.06%]
MCC13	0.9600	0.0783	16.81	*1.3162 [+37.10%]	12.26	0.7293	*1.2307 [+28.19%]
MCC14	0.8800	0.0500	16.81	**0.8405 [−4.49%]	17.59	1.0464	**0.8336 [−5.28%]
MCC15	0.8700	0.1166	16.81	*1.9600 [+125.29%]	7.46	0.4438	*1.4262 [+63.93%]
MCC16	0.8750	0.0440	16.81	***0.7396 [−15.47%]	19.90	1.1839	***0.6911 [−21.01%]
MCC17	0.8500	0.2201	16.81	*3.6998 [+335.27%]	3.86	0.2296	*1.6204 [+90.63%]
MCC18	1.6600	0.0293	16.81	***0.4925 [−70.33%]	56.60	3.3671	***0.7071 [−142.60%]
MCC19	2.3400	0.0520	16.81	***0.8741 [−62.65%]	44.96	2.6747	***0.6653 [−71.57%]
MCC20	1.6700	0.1318	16.81	*2.2155 [+32.66%]	12.67	0.7537	*1.9163 [+14.75%]

Notes

1. Data on stocks' opening prices, EPS and P/E are taken as at 30 April 2019
2. $\bar{x}$ $P/E_{Industry}$ of 16.81 is derived from the average P/E of all 20 companies
3. Construction stocks are in the state of *undervalued, **fairly valued and ***overvalued
4. All values in the cells are in the currency of Ringgit Malaysia (RM) per unit/share
5. Percentage changes [± %] at each intrinsic value's cells represent the variance (σ^2) of the intrinsic values from the stocks' opening prices

information in this study refers to the intrinsic values derived from the second method of valuation, i.e. Relative P/E.

The results also suggested that only two stocks, i.e. MCC12 and MCC14 were recorded at fairly valued which signals transparency of information distribution. Fairly valued stock is a stock that possesses intrinsic values that is equivalent to the stock prices or having a relatively lower variance to the traded prices in the market. The variance of fairly valued stock is recorded at the range of −4.38 to −5.28 % which are consistent for both methods. However for MCC9 and MCC10, even though valuation scores are inconsistence (first method recorded at overvalued, second method at fairly valued), intrinsic values only recorded at a smaller variance of −3.20 to −6.77% as well as −4.96 to −14.8% for Relative *P/E* and *P/E* Multiple, respectively. These findings further support the idea of Tiwari and Singla (2015) where no single procedure is conclusively precise and, therefore, combined valuation model is more informative by providing better and more accurate estimations of stock values.

Meanwhile, 11 out of 20 stocks identified as MCC2 to MCC8, MCC13, MCC15 as well as MCC17 and MCC20 are in the state of undervalued. Even though it is good stock to invest, the huge variance recorded within the range of + 6.13 to + 335.27% shows that it has slightly deviated from the EMH where there is a huge potential for investors to excessively outperform the stock market performance. The prolonged condition may lead to the stock bubble derived from irrational expectations of return by the investors. Investors are willing to pay more to buy growth stocks, which causes them to reflect higher price ratios in order to reflect the market expectations (Garcia and Oliveira 2018). The similar pattern was recorded for the overvalued stock (MCC11, MCC16, MCC18 and MCC19) where the variance to the opening prices ranging from −15.47 to −249.17%.

From fundamental perspectives, the undervalued stock is a good stock to acquire as the market has yet to realise its real value besides its future potential growth and vice-versa for the overvalued stock. Pertaining to the relationship with EMH, it is interesting to note that the Malaysian construction stocks represented by these 20 selected companies are literally in the state of semi-strong form market efficiency where there is a combination of fairly valued stocks that comply the EMH theory besides undervalued and overvalued stock. However, according to Mehra (2018), the turnover and earning statistics only reveal the quantitative expansion of the market and, therefore, a few relevant market efficiency testing methods such as Financial Market Efficiency Index by Mehra (2018) would be useful in assessing the market efficiency levels for each stock.

5 Conclusions

This study has presented an estimate intrinsic values of the top Malaysian construction stocks based on market capitalisation. As the study involving the application of price earning models, the intrinsic values derived are highly dependent on the available information of stock prices, P/E and EPS as at the period of the study. The assumption on the average P/E is being made after taking into considerations P/E values of all companies to reduce bias in obtaining the valuation multipliers. Therefore, it should be noted that the result only provides preliminary evidence on the intrinsic values of construction stocks in relation to its opening prices and should not be treated as a consultation to the specific investment decision. The volatility nature of the stock market also provides an active lagging-effect to the valuation output as it requires an up-to-date valuation based on the newly available market data. Future studies might explore the intrinsic values using the dividend models as it would be useful in identifying the construction stock that lies within the value investing strategy.

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Deployment of Building Information Modelling (BIM) for Energy Efficiency in the UK

David Oloke

Abstract

Continuing advancement in digitalised technology has brought about constant changes and innovations in several industries. In construction, Building Information Modelling (BIM) is one of these key technologies that seeks to lessen the impacts of global warming and growing environmental concern. BIM also positively contributes to sustainable life-cycle decisions for building procurement and management. The dynamic digital environment provided by BIM facilitates the effective storage, sharing and integration of all the essential building information throughout the entire life-cycle of a building within a three-dimensional computer model. Despite the major technical opportunities and benefits, however, BIM has not been fully adopted and capitalized upon yet by industry stakeholders worldwide. The lack of widespread uptake engaging by all team members and more practical and achievable policies and other initiatives, substantial cost of software equipment, high training and consultancy fees, personal user behaviour, mostly regarding difficulties in changing traditional work processes and other factors represent the major barriers impeding the full BIM-productive potential which leads to many drawbacks, such as lower performance in building`s energy efficiency and qualitative properties, higher cost, resource losses, delay in time for project completion. To this end, some interviews were conducted for the purposes studying the sustainable ways of using BIM and the dissemination of its adoption in planning, consulting and contracting companies and organizations in the UK was conducted in this research. A more feasible integration of BIM for energy simulation, but there are still many gaps to be fulfilled. Although UK-based companies appear to be willing to implement BIM, in real terms it is more likely that BIM is not being used in its full potential.

Keywords

Building • Energy efficiency • Refurbishment • Sustainability • BIM

1 Introduction

The construction industry is expected to reach over 70% growth by 2025 (Petri et al. 2017). Thus representing a prominent sector where energy use could be decreased, several countries have already set this target out in order to reduce their carbon emissions and to achieve improvement in energy efficiency. The aim of the UK, for instance, is '(a) 33% reduction in both the initial cost of construction and the whole life cost of assets; (b) 50% reduction in the overall time from inception to completion for new build and refurbished assets; (c) 50% reduction in greenhouse gas emissions in the built environment; (d) 50% reduction in the trade gap between total exports and total imports for construction products and materials' (ibid).

Continuing advancement in digitalised technology is bringing about constant changes and innovations in each industry (Chong et al. 2017). As one of these key technologies aimed at lessening the impacts of global warming and growing environmental concerns, Building Information Modelling (BIM) is designed to positively contribute to sustainable life-cycle decisions with significant impact on our environmental, social and economic needs (Azhar et al. 2010) and Chong et al. (2017). The dynamic digital environment provided by BIM manages to effectively store, share and integrate all the essential building information from conceptual design and pre-construction stages throughout the entire life-cycle of a building within a three-dimensional computer model (Pärn et al. 2017). Such

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information technologies enable the collation of exceptionally detailed but fragmented aspects and systems of a facility, and simultaneously managing to retain all the ongoing processes together within a single model, thus aiming to purposefully achieve a set target (Azhar 2011; Turk 2016). The very valuable virtual process of BIM for design, construction, operation and maintenance of buildings allows professionals to create and reinvent sustainable designs that improve cost-savings of a built facility, and, what is tremendously important. All the project team members (owners, architects, engineers, contractors, subcontractors, suppliers) can collaborate more intensely and efficiently together, compared to the impractical traditional processes (Azhar 2011; Cho et al. 2012; Bryde et al. 2013). Various authors have reported significant return on investments over time. This is a significant economic benefit that stresses the importance of BIM-assisted designs. The use of BIM is also perceived to be advantageous owing to 'higher-quality deliverables', excellent time management, accurate cost estimation, reduced project costs and higher net savings, better understanding through real-time visualization, instant conflict detection and low percentage of documentation errors, contingencies, risks and unexpected alterations (Azhar 2011; Cho et al. 2012; Howard et al. 2017; Ghaffarianhoseini et al. 2017).

Despite its major technical opportunities and benefits, though, BIM has not been fully adopted and capitalized yet by industry stakeholders worldwide. According to a research from National Building Specification (NBS), which indicates a high level of BIM-awareness in the UK, Canada, Finland and New Zealand, compared to a much lower level of current BIM-use; only in the UK is the discrepancy`s percentages highest the suggesting that 94% are aware of BIM and just 39% are actually implementing BIM. The results of the mentioned study above only confirm that due to linking challenges, obstructing its effectiveness, BIM appears to be deployed much slower than it has been anticipated in the UK (Ghaffarianhoseini et al. 2017). The lack of widespread uptake engaging all team members and more practical and achievable policies and other initiatives, substantial cost of software equipment, high training and consultancy fees, personal user behaviour, mostly regarding difficulties in changing traditional work processes, low profitability for stakeholders, software or hardware issues and insufficiency in the desirable level of integration and interoperability represent the major barriers impeding the full BIM-productive potential which leads to many drawbacks, such as lower performance in building`s energy efficiency and qualitative properties, higher cost, resource losses, delay in time for project completion (Azhar 2011; Cho et al. 2012; Howard et al. 2017).

To address this issue, a qualitative assessment was conducted for the purposes of studying the sustainable ways of using BIM and the dissemination of its adoption in planning, consulting and contracting companies and organizations in the UK. This was with the particular focus on examining the process of improving energy efficiency through developing cost-effective smart buildings. The findings of this research are envisaged to be of special interest to a wide range of UK stakeholders, interested in the use of BIM in regards to optimisation of energy efficiency in operating built environment, with important insights on the current level of uptake in the development of BIM for energy efficiency in buildings, its competitive advantages and existing obstacles, associated with the implementation of BIM, as well as some featured recommendations on how future BIM-adoption could be developed (Howard et al. 2017).

2 An Overview of BIM Towards Energy Efficiency

Due to the rising demand for energy, the public and private sectors are progressively requiring planning and construction of sustainable buildings, (i.e. with minimal environmental impact, so that next generations could be able to meet their own needs) (Petri et al. 2017). Significant efforts have been made with regards to reducing the use of fossil fuel as the most common and incredibly polluting source of energy. Such efforts include the adoption of different sustainable processes like BIM, other planning and simulation software, effective building codes and standards. Sustainability assessments, green building rating systems such as BREEAM and LEED and a range of governmental policies and incentives (Chong et al. 2017; Cho et al. 2012).

The two major components which when combined efficiently save considerable time and resources, based on the BIM-work process, are high level of integrated design approach and an intense/collaborative team commitment (Ibid).

Due to the increasing importance of decisions needing to be made early; BIM gives the great advantage of the possibility for decisions in the design and pre-constructional stages to be made by the different team members involved in the project, especially when recognizing if any implications evolve during the process (Cho et al. 2012; Bahar et al. 2013). The integration of data during the entire project can be fluid when all of the project participants use the same software to achieve the lowest possible energy consumption and to evaluate the cost and environmental impact, so undoubtedly this is one of the BIM`s greatest benefits (Azhar 2011; Cho et al. 2012). Once the model is created, all stakeholders are able to constantly refine, adjust and change the project specifications and to be instantly detected if any collisions might appear between all major systems, as BIM automatically checks for possible interferences so the team members can be ensured that the model is as accurate as possible (Azhar 2011).

The use of BIM from the very beginning also enables the creation of design that can analyse the impact of buildings and the prediction and optimisation of their energy performance through multidisciplinary analysis for cost-avoiding and prevention of time-consuming alterations at later stages in the project (Cho et al. 2012). During the early or pre-design stage, BIM-based simulation is important for developing a sustainable building design combining many factors so that specialists could finally determine building`s internal gains and set energy consumption targets (Azhar 2011). In this regard, collaborative accomplishments toward an improvement of building`s energy evaluation process and facilitation of teamwork are noted, as it is, for instance, the Object-Oriented Physical Modelling approach, developed by Kim et al. (2015), which meliorates complex data exchange between building design and energy-simulation software (Chong et al. 2017). Another excellent example represents one of the most effective ways to reduce carbon emissions through the renovation of existing buildings in order to reduce energy consumption, for the purpose of which during the post-occupancy stage Motawa and Carter (2013) have established a conceptual systematic BIM-based model to monitor building behaviour as a means of improving the post-occupancy evaluation process and meet the industry standard requirements for sustainable buildings (Chong et al. 2017). Implementing software programs for sustainable analysis, as well as installing energy-efficient systems and optimizing strategies for minimum energy losses, such as heating systems that are power-generated from renewable energy sources, inclusion of sustainable materials and insulation from recycled or recyclable resources with high thermal properties, natural cooling and ventilation systems for best delivery efficiency are recent measures. Also, a well-orientated building design and corresponding glazing and solar shading devices for most proper daylighting and solar incidence, water-efficient systems in favour of lowering water consumption and creating more green spaces around or as a part of the building`s envelope (Azhar et al. 2010; Azhar 2011; Cho et al. 2012; Krygiel and Nies 2008; Lu et al. 2017). Manual calculations at every particular location within a building to measure or to elaborate all of these factors and finding the right thermal comfort is almost unattainable. BIM-based energy-simulation programs (capable of calculating all of those values accurately) can analyse thermal performance of buildings in the most practical and optimal manner. Thus, the inextricably linked data integration and interoperability are an extremely important asset when discussing BIM (Pärn et al. 2017).

Through the opportunity of using data exchange in thermal simulation software and selected thermal tools that integrate such analysis building geometry (surfaces and volumes), internal loads (operating systems, equipment and occupants), weather and climate conditions and other essential input data affect energy consumption and cost can now be modelled thereby clearing the interoperability`s challenges between BIM and energy-simulation tools. This can increase the workflow between the analysis applications and the project`s deliverables (Maile et al. 2007). According to Turk (2016), the goal has always been to ‘make building information models understandable and model data sharable across multiple design disciplines and heterogeneous computer systems’.

Several technical barriers that BIM-based thermal simulation tools continue to face are long analytical model preparation times, missing or invalid data in architectural models and inconsistent conversion of architectural models to thermal models (ibid).

Not having the capacity to simultaneously analyse all the aforementioned green building features and systems, thus not providing sufficient analytical data for an assessment with green building rating systems like BREEAM, LEED, DGNB, Green Star and other, is a very significant disadvantage that certainly needs to be amended (Lu et al. 2017). If all required documentation for certification toward the level of building` sustainability could be incorporated in BIM-based analysis software, this would diminish time and resource prerequisite and simplify the assessment method, compared to the conventional approach (Chong et al. 2017).

Another persistent obstacle is that BIM is mostly used during the design phase, but comparatively rarely for facility management and throughout the commissioning and operational phases, and also with highly challenging direct application in existing buildings (ibid). Hence, during the development of BIM, there must be a linking of retrievable data within the model for all the subsequent post-construction phases (Pärn et al. 2017). Although existing BIM-based software is still limited to the project design phase, there are some supporting detailed energy performance analyses designed for the operation, maintenance and post-occupancy phases, and more multidisciplinary BIM applications are indispensably expected to experience growth. The development of such extensive green BIM applications would allow a systematic analysis of the whole environmental impact of a building (Lu et al. 2017).

Last but not least, there is another shaping moderation in the ongoing adoption of BIM, affecting the user-technology relationship, namely personal attitude and perceptions, depending on factors like age, experience, motivation, voluntariness of use, social influence, terms of support and expectancy, so in order to accelerate the diffusion of BIM there should be primary focus on the individual level (Howard et al. 2017).

In general, the BIM-process needs better standardization in order to define strict guidelines for its implementation. Therefore, the data exchange process for performing energy and environmental simulations engines need to become more reliable, combined with a more user-friendly interface, more capable and much quicker, more up-to-date and with more advanced functionality towards current computer science technology, so that the users can integrate them more smoothly into practice (Maile et al. 2007). Simplification and compatibility of input parameters and enhancement of data exchange solutions with more reliable data conversion based on BIM, as well as deep knowledge of thermal processes in a building, are mandatory for a meaningful and accurate energy simulation (Lu et al. 2017). Closer integration of energy simulations with the operational performance of buildings in real terms will thus not only improve existing simulation tools, but will also enable a more energy-efficient operation of buildings.

In order to reduce data inconsistencies and to increase the number of projects where energy simulation within BIM can be not only productively used but, more importantly produce reliable results. It is thus hereby suggested that practitioners should engage themselves in further research and development process for finding such BIM-based solutions. Hence, software vendors should be encouraged to improve tools that support practical needs (Eadie et al. 2013). Furthermore, professionals willing to effectively integrate BIM in their designs should commit to its widespread implementation and to the development of standards, enabling continuous improvement not only toward the conceptual modelling, but also into deeper research into more efficient integration of energy simulation during commissioning and operational level (ibid). Accordingly, companies should also invest more in training their employees, so they could acquire indispensable and valuable skills and learn how to take full advantage of all BIM-benefits. As building industry shifts towards finding a way to successfully adopt BIM, the education system should also take as well a more thorough and collaborative educating approach towards the way of teaching and assessing sustainability topics in undergraduate and graduate degrees, as well as research objectives for doctoral programs. This will facilitate the attainment of the benefits of BIM alongside the progressive benefits from the UK Government`s mandate relating to the use of ‘fully collaborative 3D’ BIM in all contracts awarded since 2014 in order to reduce costs and errors (Bryde et al. 2013). Although the dissemination of BIM constantly rose during the past decade and it is likely to continue its growth as long as the challenges could be overcome. Research opportunities, therefore, continue to abound as a precursor to stimulating the supply chain to start working more collaboratively through the use of BIM in order to achieve higher levels of energy efficiency and sustainability of projects.

3 An Exploration of Industry Perspectives

The literature reviewed formed the basis for this study. It helped to identify existent gaps and challenges in the overall dissemination of BIM in the UK. The research thus set out to establish the extent of the current BIM-adoption for energy efficiency within the UK construction industry, with relation to project delivery.

An interview of the willing organizations was conducted to obtain opinions and information on the current level of BIM-use for improving energy efficiency in the UK-based construction companies and organizations. For the intended purpose, an online questionnaire was first distributed through e-mail invitations sent to randomly selected architects, designers, engineers, surveyors, contractors, officially operating on the UK territory. The prepared questionnaire included basic questions that allowed the consenting, voluntary participants to indicate a willingness to participate in a structured interview.

Based on the responses from the survey, three interviews were conducted as part of this phase. The interviews sought to provide information on issues such as how profitable and compatible is BIM for optimizing energy efficiency in the UK built environment, what are the major barriers toward such BIM-uptake and how these obstacles can be overwhelmed. After the data was collected it was processed for further analysis and then through discussion and stated assumptions, as well as with the aid of utilizing the option ‘analyse results’, provided by the built-in platform of SurveyMonkey.

A systematic review approach was adopted to analyse the feedback from the survey. Although the three respondents believe that BIM offers advantages to overall sustainable building design and that the sustainable construction practices are of importance within their company, they all considered that the energy efficiency aspect does not primary apply in their BIM projects as a pre-determined performance target, but rather as a design applying to environmental performances standards, such as BREEAM and LEED. They also believe that BIM helps to properly define the client’s brief requirement and ensure compliance to Building Regulation Part ‘L’ requirement. The interviews also revealed that BIM can significantly and effectively, or at least satisfyingly, aid in performing complex building energy performance analysis to predict and ensure an optimized building design.

With respect to BIM-interoperability, two of the respondents agree that energy-simulation tools strongly support BIM, but both agree that that there is significant room for improved BIM-support. There appears to have been a lot of excitement about the potential of BIM, but as per being an enhancement of best practices for energy efficiency in the conceptual, design and construction and operational stages this opportunity is limited. Full unanimity is observed when answering what the major barriers within the respondent`s organization are to the uptake of BIM with regards to energy efficiency improvement, where everyone stated ‘no client's demand’. It is mostly agreed that respondents positively will or probably may suggest innovative upgrades of the BIM-process in order to optimize energy efficiency in buildings. They also affirmed that it is absolutely essential, or worth considering, that the government should actively encourage the use of BIM through policies and other initiatives in the private sector similar to the 2016 UK Government BIM Mandate for centrally procured government projects.

Furthermore, interview results revealed that the determining characteristics and conjectures about BIM are mainly positive experience, advantages in sustainability and prediction of energy performance of buildings, satisfying level of operability and ease of use towards energy-simulation tools. However, BIM does not appear to be desirable enough in implementing best practices for energy efficiency throughout the building`s life-cycle, diversity among stakeholders in attitude, expectancy and benefits toward BIM. More upgrades should be in focus, more subsidized policies and incentives should be applied by the government in order to facilitate the adoption of BIM in the UK construction industry. Findings of the research are revealing that BIM is expanding within the construction industry and practitioners think it is the future, while moving to sustainable buildings. Overall, the collected data from the survey show that the disadvantages when using BIM towards energy efficiency and sustainability are generally less relevant than the positive effects of implementing BIM. Many obstructions were identified, though, in BIM-adoption for higher energy efficiency, and the most important barriers to uptake are: low level of awareness, difficulties in embracing innovations, lack of strict policies, lack of training and experience and relative disconnection between different construction industry`s branches.

Substantial efforts were carried out in order to obtain a more feasible integration of BIM toward energy-simulation tools, but there are still many gaps to be filled. UK-based companies and organizations are presumably willing and trying to implement BIM in an effort to meet the government deadlines, but in real terms it is more likely that BIM is not being used in its full potential. The results from this study (though limited) reveal that although there has been a significant amount of research and development about the use of BIM during various project phases, little work has been conducted about how it could be more effectively applied in order for energy efficiency in buildings to become a driving aspect in new designs and refurbishments BIM-processes. Finally, the research indicates that the main reason for slowly deploying BIM relates to the lack of client`s demand and clear and strict requirements, which in turn leads to lack of expertise within private and public companies and organizations.

Although of good quality the number of respondents to the interviews introduces a limited scope to the findings. With this relatively low number of responses, drawing sensible conclusions is very difficult, and so the reason could be postulated as a result of either apparent disinterest, or low adoption percentage of BIM by professionals in the UK. The relationship between all the variables characterizing BIM evidence in general terms how individuals in the industry are currently perceiving the BIM-concept, thus the outcomes of this survey prove a lack of interest in pursuing energy efficiency.

4 Conclusion and Recommendations

Although energy efficiency measures are recognized as an important matter and the possibilities of their application are expansive; it appears that the task of assuring stakeholders of the BIM-benefits remains a challenge. Due to the many identified barriers faced as part of the process, such as lack of time, internal capacity and resources to explore energy efficiency options; it is proving more difficult to adopt and implement energy efficiency measures. The necessity to balance profitability and competitiveness with limited resources is even tougher for many SME`s focusing on energy efficiency and other environmental concerns. Moreover, energy efficiency is indeed rarely viewed as a priority, especially among people with low income. If the investment will result, though, in other improvements beyond a sustainable way of life, such as savings, productivity, value, quality, safety, then people are more likely to be attracted and motivated to increase their investments towards energy efficiency practices.

Nevertheless, the industry is not clear enough yet on the application of BIM for optimizing energy efficiency, which urges the need more significant actions to be taken by the government and to be provided more stimulating incentives to all construction value chain stakeholders regarding the benefits of BIM towards achieving higher energy efficiency. BIM-process adaptation offers great opportunities for encapsulating rich data within the model at the earlier stages of the building life-cycle (design and construction) and such data as well for asset maintenance, so higher education institutes and other providers of educational and training courses must also collaborate more closely with practitioners to fully embrace this concept of a life-long learner in order to avoid knowledge redundancy and should be augmented with far greater industry–academic collaboration and education.

Transforming and decarbonizing the built environment is entirely possible with significant processes like BIM through which using their full potential can be predicted and facilitate the optimal energy performance of buildings and to improve best practices for energy-efficient and high-quality construction can be improved—thus improving the quality of life. Despite the significant barriers of implementation, BIM will ultimately be driven by clients, and since acceptance is an individual act based on personal perceptions, we have to know that raising awareness about environmental challenges, leading to behavioural change. Likewise, as of a perspective, computers will continue to become faster which could allow representations of more complex relationships and futuristic BIM-approaches.

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Project Control Through Disincentivisation: A Case Study of Hong Kong–Zhuhai–Macao Bridge Project

Liuying Zhu, Sai On Cheung, Xinglin Gao, Qian Li, and Gang Liu

Abstract

Incentives and disincentives (I/D hereafter) arrangements have been regularly used as project control measures. Incentives aim to enhance performance through reward provisions, whereas disincentives penalise performance below agreed targets. Use of incentives are based on motivation theories and has been well recognized as a catalyst for performance. Disincentives are relatively less studied even though it is also commonly used to deter underperformance. Compared with incentives, disincentives are less costly and can function well when the monetary reward is not the sole performance motivator. This proposition is discussed and illustrated through a case study on the Hong Kong–Zhuhai–Macao Bridge (HZMB) project. In the HZMB project, disincentivisation was integrated with the Reputation Evaluation System (the System hereafter). The System has four parts: (1) Goal Commitment; (2) Reward/Responsibility reallocation; (3) Monitoring method application and (4) Performance Assessment. Through focus group discussions, it is found that (1) The System is a useful project control tool; (2) The desire to maintain reputation underpins the effectiveness of The System; and (3) The System is instrumental in relationship building. Disincentivisation is effective in the HZMB when it is linked with the performance status of the contracting organizations. The importance of maintaining a reputation in signature projects like the HZMB makes disincnetivisation a less costly and viable project control measure.

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Keywords

Hong Kong-Zhuhai-Macao bridge • Disincentives • Project control • project performance

1 Introduction

Mega projects are usually (1) large-scale; (2) complex; (3) high value; (4) long-period and (5) having significant social impacts (Flyvbjerg 2017). The success or failure of a mega project affects the development of a region or even a country. For project management, how to handle multi-tasks and coordinate engaged parties to work together are key challenges. Based on transaction cost economics theory, opportunism is a major threat when project uncertainty is high (Williamson 1985). Incentive and disincentive (I/D hereafter) arrangements have been regularly used as project control measures to alleviate opportunism. Furthermore, incentives aim to enhance performance through rewards whereas disincentives penalize performance below agreed targets. Use of incentives is based on motivation theories and has been well recognized as catalyst for performance (Baker 1992; Bresnen and Marshall 2000). Through years of research, many studies analysed the effects of positive incentive mechanisms and found it can enhance project performance, reduce dispute and nurture innovation (Hughes et al. 2012). The working of disincentives is relatively less studied even though it is also commonly used to curb non-performance. Valid cases and general guidelines are needed to substantiate how it is operated and what purposes it can also achieve. The study aims at investigating the value of disincentivisation for project performance planning. Efficient selective incentive planning. The research objectives are organized as follows:

(1) Identify the project control functions of disincentives,
(2) The project prerequisites for the use of disincentives.

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2 Literature Review

Incentives and/or disincentives have been used as the standard project management tool to engender project performance (Meng 2015). It is believed that motivation can be derived from incentivisation, disincentivisation or combination of both (Bubshait 2003). These arrangements are typically described as 'risk–reward' or 'gain share–pain share' arrangements (Bresnen and Marshall 2000). 'Carrot or stick' is used to describe client using incentive and/or disincentive (I/D hereafter) arrangements to reward or penalize the contractor for above or underperformance, respectively (Bubshait 2003). Project performance is often identified by cost, schedule and quality. Schedule-incentive planning is seen as the most common type of a combination of I&D (Jaraiedi et al. 1995). Client sets financial bonus as a reward for early completion and liquidated damages for delay. From the perspective of project performance, I&D are both possible contractual tools to serve project control purposes (Hughes et al. 2007). The primary purpose of applying I/D is to establish agreed targets that are acceptable to both client and contractor. With that, both contracting parties do their utmost to enhance project performance (Bubshait 2003). Accordingly, incentives are used to motivate the contractor for above-normal performance and disincentives are used to discourage below-normal performance. Figure 1 shows the spectrum of I/D.

Incentives and disincentives can be used either separately or together. The integration for project objectives and incentive planning is one of the key issues for efficient project management. For example, Hauck et al. (2004) analysed the case of the National Museum of Australia Project. As the client is only aimed to ensure on-time completion, pure disincentives are sufficient for pushing timely completion. Based on the nature and complexity of the project, the selection of I/D also reflects the different expectations for project results. For cost management, the intention to shift cost-overrun risks by setting cost-ceiling or to reward contractor for cost-saving reflects two different expectations for the project.

Oliver (1980) analysed the dynamics of disincentives by comparing these two strategies. It was found disincentives take effect for motivating unanimous cooperation while incentives are effective more 'elite' actions. Disincentivasation also have its value when dealing with multiple agents (Hosseinian 2016). It is costless compared with positive financial bonus. In an ideal situation, if everyone cooperates, the only cost of disincentives is that of threatening to use it (Oliver 1980). Meng and Gallagher (2012) further analysed the role of disincentivasation in project monitoring. In that case, disincentives in terms of time, cost, safety and quality were integrated into the performance control system. Disincentivisation strengthens the client's controlling power and ensures the dominant position in the middle stage of the project. The effectiveness was also confirmed as it played a driving role in encouraging the best practice and ensuring project success. To present a clear view of the functions of disincentivisation, the comparison of I&D is summarized in Table 1.

3 Case Study: The Hong Kong-Zhuhai-Macau Bridge Project

3.1 Project Background Information

To promote economic exchanges and cooperation among Hong Kong, Guangdong Province and Macau, a mega cross-sea transportation channel was started in 2007 and envisaged. The Hong Kong–Zhuhai–Macau Bridge (HZMB hereafter) project is considered as one of the largest highway projects in China. HZMB is also one of the 10 major infrastructure projects of Hong Kong (Hong Kong Zhuhai Macau Bridge Authority 2009; Hong Kong Special Administrative Region Government 2007, 2010). The total length of the crossing is around 55 km, which includes a 29.6 km main bridge, a 6.7 km undersea tunnel, two artificial islands and ports in three cities. After 8 years of construction, the HZMB was opened for use in October 2018. Notable accomplishments were reported in terms of time, cost and innovations. Along with achieving all the project targets, over 400 patents were harvested (Hong Kong Zhuhai Macau Bridge Authority 2017). All the technical accomplishments together with the management experiences have greatly promoted the development for construction supply chain development in high-tech material manufacturing, reclamation and underwater tunnel construction in China (Hong Kong Zhuhai Macau Bridge Authority 2017). This project is also

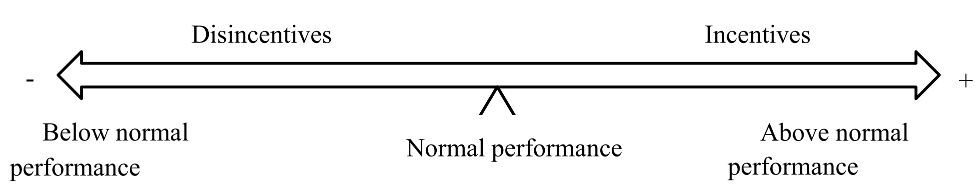

Fig. 1 Incentives and disincentives on a spectrum (Adapted from Meng (2015))

Table 1 Comparisons of incentives and disincentives in construction project

No.	Content	Incentives	Disincentives	References
1	Objective	Motivate better performance apart from the contract	Demotivate underperformance to safeguard the contract	Meng (2015)
2	Manifestation	Financial Bonus	The penalty of fine	Chan et al. (2010)
3	Advantage	Attractive	Costless	Oliver (1980)
4	Expectation	Additional value apart from the contract	Contractual safeguards	Hauck et al. (2004)
5	Essence	Encourage contractor to finish their expectations	Force contractor to comply with their requirements	Meng (2015)
6	Function	Motivate small numbers of co-operators and generate pressures toward smaller, more 'elite' actions	Motivate unanimous cooperation for multi-agents	Oliver (1980)
7	Sphere of application	Objective and interest alignment	Project monitoring	Meng and Gallagher (2012)

considered as a key demonstration project. All the accomplishments of new technologies, project experiences and innovations such as rapid island formation will be passed on too many similar planning cross-sea tunnel projects such as Shen-Zhen and Zhongshan Oversea Tunnel Project.

3.2 The Use of Disincentivisation in HZMB Project

The Hong Kong–Zhuhai–Macau Bridge Authority (HZMBA hereafter) was established by the Three Governments in 2010. It directly takes the responsibility of construction, operation and maintenance of the project. HZMBA proposed the following project pledges at the beginning of the project:

(1) Build a world-class cross-sea channel;
(2) Provide high-quality services for users;
(3) Become a landmark bridge in China.

Along with these project objectives, it is also noted that to accomplish this project, there are also complicated challenges need to be overcome (Hong Kong Zhuhai Macau Bridge Authority 2017):

(1) Construction challenges: no unified construction standards and previous experiences for this type of project;
(2) Technical challenges: Multiple risks need to be managed for the construction of the undersea tunnel, over-sea bridge, artificial islands.
(3) Environment protection: Apart from the common environmental protection issues, it is needed to attach great importance to the impact on marine ecology and white dolphin protection.
(4) Difficulty in coordination: Apart from the negotiation under different legal systems, it is also difficult in coordinating multiple project participants in this mega project.

In this way, an effective contractual tool is needed to align HZMBA's project expectations and deal with the challenges with all project participants. In this project, HZMBA transfers all these requirements into the contractual language and developed the Reputation Evaluation System (the System hereafter). The System has four parts:

3.2.1 Goal Commitment

This System for project management contains six goals:

a. Quality management: Ensure this project has a 120 year's life span, and meet all the qualifications of required standards.
b. HSE: Health, safety and environment management.
c. Procedure management: The project needs to be completed on time.
d. Cost: Cost control within the investment budget.
e. Information management: Maintain the openness of the system and to adopt industrial standards to promote the interoperability of data exchangeability.

f. Innovation: Cultivate a series of excellent scientific and technological innovations on technology and management.

3.2.2 Disincentives/Responsibility Reallocation

Around 2% of the contract value was set aside as a special fund for operating this system. The contractual requirements were set based on previous project experiences collected from different departments of HZMBA. Because of the specialty of the project, some clauses such as white dolphin protection are added.

3.2.3 Monitoring Method

A comprehensive evaluation is carried out quarterly by the HZMBA. An evaluation committee was established with members coming from a different department. There was a quarterly assessment (every 3 months) for the project performance. A meeting was held for all the project participants.

3.2.4 Performance Assessment

The evaluation committee conducted an independent evaluation on contractors according to the implementation rules and grading standards. The total score is 100 and the score distribution is concluded in Table 2.

The evaluation is by way of mark deduction according to a pre-set scales included in the contract. When the project inspectors observe misbehaviours, they would deduct points according to the requirements in the contract. When the contractor makes major errors or major deviations stipulated in the contract, the assessment shall be 0 points, and the punishment shall be given in accordance with the relevant provisions. The performance is directly linked to the payment ratio. Table 3 shows the relationship between the evaluation level and bonus payment ratio.

A contractor who receives two consistent "D grades will be counted a breach of contract. In such a situation, the client can terminate the contract.

3.3 The Project Control Functions of the System

Focus group discussions were conducted to understand the functions of the System. In this discussion, ten senior managers from HZMBA, main contractor, sub-contractor and supplier who are familiar with the System participated in two rounds of discussion. It is found that (1) The System is a useful project control tool; (2) The desire to maintain reputation underpins the effectiveness of the System; (3) The System is instrumental in relationship building:

(1) **The System is a useful project control tool**. The setting of the System basically involves all major project key targets. Because of that, the scores provide an overall view of contractors' project performance. Through the System, all the misbehaviours have been clearly shown through quarterly reports. It also provides a clear vision for project controlling and next-stage project planning.

(2) **The desire to maintain reputation underpins the effectiveness of the System**. Through discussion, it was found that motivation for better performance is not hinged on the threat of losing money, but mainly on how to maintain their reputations in this highly concerned project. The significance of a decent record and the threaten of 'losing face' underpin the efficiency of The System in the HZMB project. The score rankings for all the project participants were announced in each quarter. It also promotes a benign competitive environment for all project participants.

(3) **The System is instrumental in building a relationship**. All the interviewees confirmed that the System has more value for inter-organizational communication. At the beginning of the project, due to different organizational management style conflicts, deductions help demonstrate the intentions from HZMBA and attract the contractor to come to the negotiation table. After several rounds of assessments, as both parties are more familiar with each other, there is a significant decreasing of deductions in these areas. The interviewees agreed that this system is effective for project management, especially for inter-organizational communication. The communication and the sense of involvement are enhanced when negotiating the scores for each quarter.

4 The Project Prerequisites for the Use of Disincentives

The importance of maintaining reputation under a signature project like the HZMB makes disincnetivisation a less costly yet viable option to maintain project performance even for projects are having high risks and facing immense uncertainties. The followings are necessary actors for the use of disincentivisation:

Table 2 The score ratio of different targets

Item	Quality	HSE	Procedure	Cost	Information	Innovation
Score (%)	35	35	15	5	5	5

Table 3 The evaluation level and corresponding payment ratio of the fund

Comprehensive evaluation score: L	Evaluation level	Bonus payment ratio
$L \geq 90$	AA	100%
$85 \leq L < 90$	A	90%
$80 \leq L < 85$	B	70%
$75 \leq L < 80$	C	50%
$L < 75$ or The qualification is cancelled	D	0

(1) **Projects can instigate stringent supervision**.
From the literature review, it can be seen that disincentivisation works well when stringent project monitoring is exercised. In HZMB, the System contains all major project objectives and provides detailed quarterly performance report. The scores are indicators of underperformance that are below the acceptable norms. Contracting organizations received these feedbacks from HZMBA and were expected to take necessary action to avoid penalties.

(2) **Monetary reward is not the singular performance motivator**.
Offering monetary rewards is often used when project conditions are not well defined, risks and uncertainty are high. Incentives are used to provide a buffer for these contingencies. Moreover, for signature projects like the HZMB, maintaining reputation may well be of the highest priority for the participating contracting organizations. In HZMB, the System served as a performance ranking exercise. The contracting organizations were very concerned about their positions on the performance rankings. Keeping face was of vital importance for them. Disincentivisation took effect when performance improvement acts were taken by contracting organizations to save face.

5 Conclusions

I/D arrangements have been regularly used as project control measures. Incentives are performance motivators due to the embedded monetary rewards. Disincentives on the other hand push performance when contracting organizations seek to avoid penalties attached with underperformance. Disincentives are usually used for projects achieving well-defined scope and programmable tasks. Disincentives thus usually do not involve. Extra monetary rewards. The HZMB project was a high-risk and complex project and prima facie not suitable for use of discentives. This study found that the HZMB project used a Reputation Evaluation System (the System) to incorporate disincentive arrangements. The System worked well to control the performance of the contracting organizations not because of the penalties attached. It is the position of performance rankings that drove performance. The HZMB is a signature project and the participating units all found pride in taking part in such a project. Performance rankings were taken as records of achievement and contributions in the making of a record-breaking project. The desire to be part of the record-making team turned out to the most influential performance motivator.

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Relating Quality of Service to Customer Satisfaction in the Nigerian Automotive Service Sector

John Aiyesehinde and Clinton Aigbavboa

Abstract

Service quality and customer satisfaction are two management concepts that have transformed the operational productivity and competitive standards of businesses across industries. While several operational strategies are developed as a result of these two concepts, operational productivity will depend on the effect on specific quality attributes that influences the consumer's judgment on their service experience. In developing countries, where unstructured and unregulated business practices sum up the characteristics of the automotive after-sale industry, it is then difficult for service providers to employ operation strategies developed to only suit structured business organizations. Instead, a customer approach provides a simplified approach to improving operational productivity. This study evaluates the relationship between service quality and customer satisfaction in the Nigerian automotive industry in a bid to recognize the perception of auto-repair clients through their service experience(s). Primarily focusing on four-wheeled automobile maintenance services, 200 respondents were obtained from passenger vehicle owners and make patronize auto-repair operators in Lagos State, Nigeria. Quantitative data analysis employed a mean item score and regression analysis. The findings revealed that while service quality related to satisfaction, attributes such as empathy, reliability and assurance were responsible for their relationship. This studies outcome intends to create awareness for quality parameters that improve productivity and spark more discussion on the applicability of these service concept in the Nigeria automotive after-sales sector.

Keywords

Service quality • Customer satisfaction • After-sales • Vehicle repairs

1 Introduction

The quality of services and the satisfactory level attained in businesses have been widely discussed for over three decades as the two primary contributors to explaining consumer's response to service experience and the profitability or success of service-oriented businesses (Zeithaml et al. 2006). While the practice of quality and satisfaction strategies in businesses across industries, projects and in small enterprises have been found to create a distinction amongst service providers and competitive edge, the impact of these two concepts also reveal gaps or limitations in the operational structure of service-oriented businesses (Bennett et al. 2003; Salerno 2009).

Interestingly, several studies have shown the importance of service quality attributes and customer satisfaction to the productivity and profitability of business ventures in the after-sales sector of the automotive industry. While some studies have focused on measuring these concepts, other discussions have been expected on suggesting performance optimization strategies, focusing on the operational sections of service businesses rather than from a customer approach (Brito et al. 2007; Dombrowski et al. 2011; Saccani et al. 2006). Studies that have concentrated on tackling performance optimization through a customer behavioural approach have equally agreed and argued that service quality and satisfaction presents far better solutions and provide innovative strategies toward improving businesses in the automotive after-sales sector (Grigoroudis and Siskos 2010; Izogo and Ogba 2015).

For these reasons, this study is focusing on identifying the relationship between service quality and customer satisfaction in the after-sales sector. Particularly in the Nigeria

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automotive industry where the upstream sectors, research design and manufacturing areas have been hampered by ill policies, poor government backing and high importation of automobile since its inceptions leaving the after-sales sector as the last surviving area for indigenous business stakeholders to practice (Raimi et al. 2015; Ohwojero and Ede 2013).

1.1 Service Quality and Customer Satisfaction

There exist several definitions to clearly explain service quality, many of which have a similar direction towards the mindset of a customer and their judgement on the service consumed and their perception of the efforts of the service provider (Fisk et al. 2008; Martinez and Martinez 2010). Customer judgement was explained as a subjective evaluation of the inferiority or superiority of a service provider's effort and the quality of the service consumed based on their expectations or previous experience (Zeithaml et al. 2006).

A review of studies showed that several researchers have driven deep into identifying the impact of service quality, designing measuring models and identifying its critical quality attributes that are responsible for influencing customer attitudes towards services. These studies have produced several models for measuring service quality and unending arguments on their applications and legitimacy (Martinez and Martinez 2010). Many of these arguments have brought about some generally acceptable conclusion one of which is the discussion of service quality instrument SERVQUAL is credible for identifying the critical factors of service quality (Ladhari 2009).

Conversely, the SERVQUAL has been employed in several studies to identify the quality attributes that influences auto-repair service customers, some of which the research suggested were responsible for explaining the satisfactory level of service delivery (Sivadas and Baker-Prewitt 2000; Grigoroudis and Siskos 2010; Izogo and Ogba 2015; Yan and McLaren 2010).

The literature on customer satisfaction has also pointed out that service quality amongst other factors were determinants of the customer's fulfilment response to the outcome and process of a service consumed (Oliver 2008; Giovanis et al. 2015). For instance, a study conducted on the after-sales services in Ebonyi State, Nigeria identified the technical quality of service workshops and its technicians were the key causes of low customer satisfaction (Izogo and Ogba 2015). In agreement, other studies across different countries also pointed out some service quality attributes such as staff attitude, empathy, service tangibility and reliability qualities were responsible for the outcome of customer satisfaction in automotive after-sales services (Giovanis et al. 2015; Jian-Ling et al. 2008; Shuang et al. 2013; Stevanović et al. 2013).

While these quality attributes have been said to play a primary role as the determinants of customer satisfaction, other studies argued that the emotional influence of perceived values has a stronger effect of consumer's response to service than service quality (Brito et al. 2007; Giovanis et al. 2015; Larsen 2013). Studies on the juxtaposition of service quality and customer satisfaction clearly revealed that while these two concepts appear very similar in their conceptualization, definitions and implementation, their difference can be viewed as an attitude and consequence structure (Zeithaml et al. 2006; Oliver 2008; Sureshchandar et al. 2002). Another study explained their differences in individual structure and determinants. While one places emphasis on expressing the productivity of a firm's effort delivering an expected service, the other was established on the profitability of service provider based on the acceptance and service performance judgement made by the customer (Iacobucci et al. 1995).

When relating both concepts, researchers argued that a causal relationship exists between service quality and customer satisfaction that the former holds the helm as an antecedent variable while the later, a precedent variable (Zeithaml et al. 2006; Iacobucci et al. 1995; Dedeke 2003).

In conclusion, the most effective approach towards service quality and customer satisfaction are those employed through a customer focus because of its direct impact on the most important element of services; the customers themselves (Aboltinsa and Rivzaa 2014). While it provides simplistic insights to challenging issues, irrespective of the size and nature of the service, industry or firm.

2 Methodology

The rationale of the study was designed to provide practical insights to service providers of customer's behavioural response to auto-repair services as well as an addition to the body of knowledge that is quite limited in the region of focus, Nigeria.

The study employs a descriptive quantitative approach, one that is applied to research focused on relating variables, understanding the unique traits of a group or groups of factors and comparing the capability these factors to explain a real phenomenon (Thomlison 2001). Similar studies have used the same approach to this approach (Izogo and Ogba 2015; Yan and McLaren 2010). Survey questionnaires regarded as the most conventional method for quantitative studies used to gather the primary data, a well-structured close-ended questionnaire designed with a five-point Likert scale was employed as the data collecting instrument to gather respondents auto-repair experiences and the quality perceptions of their service providers (Donsbach and Traugott 2008). The questionnaire was structured similar to that of the SERVQUAL instrument as its usefulness was justified in an extensive service quality study for identifying customer's perceived quality attributes of services (Ladhari 2009).

The research was conducted in Lagos for its high population density, extensive relevance as a business capital city and has the highest presence of automobiles in comparison to other regions in Nigeria (Ebhomele 2016; PwC 2016; World Population Review 2016). With regards to the fact that customer-centred nature of the study requiring a wide coverage capability, and time sensitivity of the study, random sampling was employed to for questionnaire distribution (Donsbach and Traugott 2008; Vogt 2005). Questionnaires were distributed to respondents who are owners and regular users of a four-wheeler passenger vehicle in the Lagos metropolis. Questionnaires were distributed and collected between October and November 2016.

3 Analysis of Results and Discussion

Out of 300 distributed questionnaires, only 200 were deemed valid and used for data analysis, producing a response rate of 66.67 per cent. SPSS version 21 was used to run data analysis for the demographic analysis and standard multiple regression analysis to evaluate the relationship between service quality and customer satisfaction.

3.1 Demographic Analysis

The demographic analysis which consists of 16 items in the questionnaire was designed to capture the nature of the respondent's service regularity and their vehicle condition when bought and also in use. Amongst the outcomes of the demography, a crux finding showed that the highest percentage of owners and vehicle users are male. Demography also revealed that majority (57 per cent) of the respondents owned only one vehicle, most of which were purchased at a pre-owned state (Fig. 1) with at least 5 years in use (Fig. 2) and were bought without service warranties. These findings all correlate with the previous study in Nigeria about the dominance of pre-owned cars in circulation (PwC 2016). In agreement with the aforementioned, another finding revealed that most respondents take their cars for services and repairs much more regularly than the standard annually service frequency expected due to the high age distribution of cars when bought and in use.

Demography study also revealed while that a higher percentage of respondents claim to make use of more than

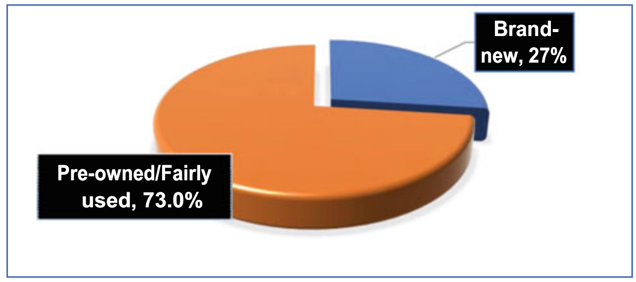

Fig. 1 Distribution of state of a car when purchased by respondents

one service option, most prefer the patronage of the unauthorized independent service operators and roadside vendors than to the authorized service centres. The aforementioned findings thus resonate with previous studies of the prevailing importance of independent automotive services in both developing and developed countries (Brito et al. 2007; Larsen 2013; Kleimann et al. 2013).

3.2 Standard Multiple Regression

Analysis: A multiple regression analysis is employed to evaluate the relationship between two constructs by exploring the correlation between their variables (independent and dependent) (Pallant 2007, p. 146). Multi-regression model equation to evaluate the relationship between service quality and customer satisfaction was established below.

$$Y_{CS} = X - X_2 - X_3 - X_4 - X_5$$

The five dimensions of service quality, Reliability, Empathy, Tangibility, Assurance and Responsiveness, as constructed using studies SERVQUAL was inputted as the independent variables denoted by (X), while customer satisfaction items were used as the dependent variables denoted by (Y).

Tabachnick et al. (2007, p. 172) argued that establishing regression preliminary assumptions ensures the regression analysis produces an explainable and reliable outcome without complications. These assumptions include assessing the sample moulds, assessing whether multicollinearity or singularity patterns exist, and checking the residuals of the model and the presence of outliers (Pallant 2007, p. 144). The outcome of the preliminary analysis and the multiple regression analysis was discussed below.

(a) Sample Size: The study's sample size was met following the guidelines of the assumptions of the standard multiple regression with respect to the quantity of the minimum acceptable size of the independent variable 2007, p. 23).

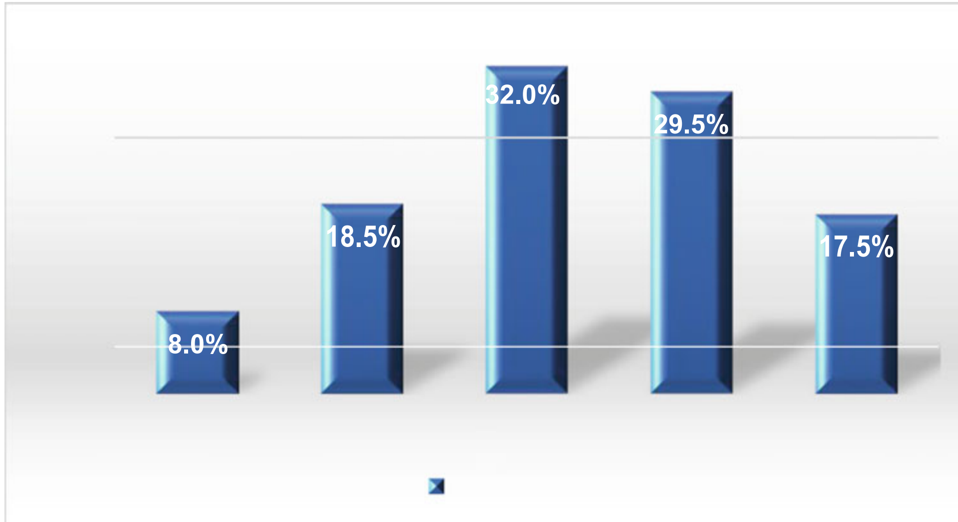

Fig. 2 Distribution of vehicle period of manufacture

(b) Independent Variable Loaded: In accordance to the guidelines of a standard multiple regression, the assumptions for the level of correlations of each independent variable and the dependent variable was checked 2007, p. 140). The preliminary analysis revealed only three independent variables; Empathy, Reliability and Assurance showed significant correlation with the independent variable as revealed in Table 1.

(c) Multicollinearity, Singularity and Normality: To ensure a relationship exist between the independent and dependent variable, the multicollinearity and singularity analysis carried out on the data by passing it through the collinearity matrix (Pallant 2007). Data preliminary analysis revealed values fell in an acceptable range in both the value of Tolerance (1-R) and Variance Inflation Factor (VIF). Followed was the test for normality, linearity and homoscedasticity between the variable scores. This is undertaken to identify or predict the type of relationship formed between the variables through the patterns formed on the scattered plot graph 2007, p. 125).

(d) Evaluating Each Independent Variables: On the coefficient matrix table, the outcome of Beta values (β) is used to compare the relational impact of each dependent variables towards the independent variable (Pallant 2007, p. 159). thus, the highest β coefficient explains the dependent variable with the most substantial contribution towards explaining customer satisfaction. Data Analysis showed that empathy (β, −0.471) had the highest impact on customer satisfaction when compared to the reliability (β, −0.265) and assurance (β, −0.210).

(e) Multiple Regression Analysis: Following the positive feedback from the preliminary analysis validating the data for regression analysis, the model employed was passed through validity test to explain the rate (R square) at which the independent variables can explain the dependent variable (Pallant 2007, p. 158). ANOVA analysis was also performed to validate the statistical significance of the model employed. According to Pallant (Pallant 2007, p. 155), the model is considered statistically significant if the P-value falls below 0.1. The outcome of the model verification showed that the three independent variables, Reliability, Empathy and Assurance, were responsible for explaining 71% (R square is 0.710) of the customer satisfaction variable. P-value (0.000) also verified the statistical significance of the model as revealed in Table 2 and Table 3.

The outcome of the multiple regression analysis does share some insightful finding. Firstly, relationship structure between service quality and customer satisfaction was identified, however, showed a nonlinearity pattern which does suggest the presence of mediating effect factor which correlates with studies that have argued on a mediating effect

Table 1 Variation retained/removed

Model	Variables entered	Variables removed	Method
1	Empathy	Tangibles	Enter
	Reliability	Responsiveness	
	Assurance		

a. Dependent Variable: TrCS
b. All requested variables entered

Table 2 Model summary

Model	R	R Square	Adjusted R Square	Std. error of the estimate
1	0.845	0.714	0.710	0.13599

a. Predictors (constant): Empathy, Reliability, Assurance
b. Dependent variable: Customer Satisfaction

Table 3 ANOVA

Model	Sum of squares	df	Mean square	F	Std. error of the estimate
Regression	8.654	3	2.885	155.985	0.000
Residual	3.458	187	0.018		
Total	12.113	109			

a. Predictors (constant): Empathy, Reliability, Assurance
b. Dependent variable: Customer Satisfaction

of perceived value (Giovanis et al. 2015; Brito et al. 2007; Kleimann et al. 2013). Secondly, the percentage of the R square (71%), standard error of the estimate (13%) and the level of P-values (0.000) not only revealed the impact on service quality on customer satisfaction in Nigerian car repair services but also validate statistical significance of the regression model applied. This outcome does clearly validate previous studies that have observed the strong impact of service quality as an important determinant of customer satisfaction (Sivadas and Baker-Prewitt 2000; Grigoroudis and Siskos 2010; Ladhari 2009; Jian-Ling et al. 2008; Sureshchandar et al. 2002; Dedeke 2003). Lastly, the outcomes of service quality dimension, empathy as the primary indicator of customer satisfactory further readdresses the importance of customer interaction (Izogo and Ogba 2015) even in technical oriented services (Brito et al. 2007; Grigoroudis and Siskos 2010; Jian-Ling et al. 2008; Wang 2012). This resolves regression model equation as shown below with Assurance, Reliability and Empathy denoted as (X_2, X_3 and X_5, respectively)

$$Y_{CS} = 2.656 - 0.210X_2 - 0.2.65X_3 - 0.471X_5$$

4 Conclusions

This paper presented an analysis of how quality service practices can promote profitability in the Nigerian automotive industry by focusing on customers perception rather than the business operational structure. The data employed 200 valid questionnaires returned by car owners and regular users in the Lagos metropolis in to understand their service experience and quality perceptions. The analysed data revealed considerable relationship exists between service quality and customer satisfaction in the characteristics of the quality attributes of service that is primarily a function of the effort of service providers. The study shares agreements with previous studies that argued on the strong impact of service quality on customer satisfaction in the automotive service industry. The managerial implication of the study does highlight the importance of improving customer interaction, particularly empathy qualities of car repair services in Nigeria automotive industry. A considerable insight from the study does suggest that the operational structures of authorized service centres are not customer friendly and perceived too costly to motivate more customer patronage. On the other hand, the impact of reliable service and the ability of service providers to display competence should not be overlooked amongst independent service operators. Future studies should be dispensed in benchmarking service quality practices among automobile maintenance services in Nigeria. Also, studies should be focused on developing operational strategies of regulating automobile services especially among the non-authorized service operators in developing countries.

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Evaluating the Influence of Training on Attitudes to Building Information Modelling (BIM) Adoption in Malaysian Construction Industry by Using Extended Technology Acceptance Model (TAM)

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Abstract

The adoption of Building Information Modelling (BIM) as technological advancement in the construction industry has become the main concern among its stakeholders. Research and expert advice have claimed that the BIM adoption rate can be increased by giving an in-depth understanding of the importance and benefits of BIM implementation. Training is one of the potential factors that could expedite the adoption of BIM. BIM training is a significant aspect in BIM implementation due to its role not only to expand the knowledge, but also as a means of facilitating BIM adoption. Therefore, the aim of this dissertation is to investigate the influence of BIM training on attitudes to BIM implementation among Malaysian construction players by using an extended technology acceptance model (TAM). The beliefs of ease of use, usefulness and employee resources were utilised as TAM variables for explaining the relationships between training variables and behavioural intention to use. In order to achieve this aim, an online survey was conducted among professional employees of government agencies. The findings demonstrated that extent of training was not related to TAM variables suggesting that a high amount of training would not positively affect the BIM adoption. In addition, TAM variables had significant positive relationships with behavioural intention to use. Finally, this study suggested the perspectives of ease of use, usefulness and employee resources should be taken into consideration by training organisers in organising BIM training in order to create an effective training that can facilitate BIM adoption.

Keywords

Building information Modelling (BIM) • BIM training • BIM adoption • Extended technology acceptance model

1 Introduction

Despite BIM popularity in the Malaysian construction industry, the utilisation of BIM among construction players is still at the lower level as they perceive BIM as a new technology (Zakaria et al. 2013). BIM adoption in the Malaysian construction industry is very low (Memon et al. 2014), stagnant (Zakaria et al. 2013), and limited in terms of implementation (Gardezi et al. 2014). Embracing and adopting BIM has encountered a number of barriers which include the reluctance of changing current work practice (Johnson and Laepple 2003), lack of clarity on responsibilities and roles (Holzer 2007) and lack of training (Bernstein and Pitmann 2004). In the Malaysian context, training is becoming a significant factor that affects BIM adoption. Lack of BIM knowledge (Zakaria et al. 2013), lack of trained people (Baba 2010; Rogers et al. 2015) and lack of training (Rogers 2013) are several major barriers that are related to BIM training in Malaysian construction.

The awareness of BIM in the Malaysian construction industry has grown rapidly (Hussain et al. 2015) and the Malaysian construction players have started utilising BIM in their project management especially the high-profile construction projects. However, the utilisation of BIM technology by construction players is not widely used and is still at the early phase (Hussain et al. 2015). The initiative of BIM implementation in Malaysia was a consequence of the government's awareness of the BIM benefits to handle the construction project issues in the design and construction phase and to control the project cost. The government took a step forward by forming a committee which will responsibly select the best BIM platform to be used and identify suitable

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projects as BIM's pilot projects. Also, preparing a BIM standard manual for the use of construction players as a guideline.

2 Literature Review

There are many organisations actively involved and provide BIM training to Malaysian construction players. These organisations consist of government agencies, professional bodies (architect, engineer and quantity surveyor) and private organisations. Nonetheless, the focus is more on BIM training provided by government agencies, namely the Construction Industry Development Board Malaysia (CIDB) and the Malaysian Public Work Department (PWD). This is because both agencies have significant roles in designing and organising BIM training and these organisations also are the most active organisations in providing BIM training in Malaysia.

CIDB and PWD also organised an intensive training for practitioners, who want to deepen their knowledge and skill of BIM in greater depth, particularly for the use of BIM software called technical training. The key purpose of technical training is to convey the right techniques and tools in the use of BIM and train participants to practice BIM software during the training or workshop to ensure the participant can effectually adapt the use of BIM software and apply the BIM in their work efficiently, thus, eventually improve their work performance. This training has been carefully designed to ensure that every training programme provided suits the participant's professions such as architects, engineers and quantity surveyors accordingly. The example of technical training provided by CIDB and PWD are Autodesk Navisworks, Revit Architecture Essential, ArchiCAD, Revit MEP and Revit. BIM, as one of the emerging IT applications in construction, has grown exponentially and being used widely in many countries in designing, construction and operating the facilities (Wong et al. 2009).

Construction Industry Transformation Plan (CITP) 2016–2020 is a Malaysian agenda to transform the construction industry and has highlighted several challenges of BIM implementation in Malaysia. The challenges include; a) lack of skilled personnel who is competent and has capability in using BIM effectively and, b) lack of proper training by the local authorities and have a little knowledge of BIM. Additionally, lack of training is a major barrier in attaining a satisfactory level of BIM adoption (Memon et al. 2014; Zakaria et al. 2013). Thus, a proper training has to be designed and properly provided to ensure participants could gain adequate BIM knowledge and skill which eventually lessen the resistance from people in the BIM adoption (Pfitzner et al. 2010).

Apart from the mentioned issues, another major issue that can be related to BIM training is the lack of awareness of BIM potential benefits in BIM implementation (Gu and London 2010; Talebi 2014). Latiffi et al. (2013) stated that the awareness of BIM benefits among construction players is important to improve the construction processes. There is a lack of understanding of the integration between BIM technology and current work practice. According to Gu and London (2010), there is a frequent misunderstanding among participants in the BIM concept that the work practice has to be totally changed in order to adopt BIM approach. Fundamentally, this is due to BIM users fail to notice that the use of the BIM approach is utilised for only parts of the project implementation to meet the project requirement.

Training is an organisational environment which is related to success of technology implementations. Marler and Dulebohn (2005) advocated at least two significant objectives could be attained from successful IT system training. Firstly, it facilitates potential users to be familiar with the use of the system and aid to diminish their anxiety and uncertainty. Secondly, which is the most important, the training programme can be used by organisations to convey the benefits of the new system to acquire users' acceptance and commitment.

For researches in BIM adoption, Son et al. (2015) and Yang (2015) have used extended TAM to examine factors that influence BIM acceptance in the perspective of architecture and facility management, respectively. Both studies showed similar results which perceived ease of use and perceived of usefulness have a significant positive relationship with behavioural intention.

3 Methodology

This research applied the quantitative approaches to examine the influence of BIM training on BIM adoption among construction professional in Malaysian Construction Industry. The experience and opinions of the construction professionals are needed from the perspectives of those directly involved in the industry. In order to support the theoretical study and hyphotheses, a large number of primary data is collected and analysed. For the purposed of this study, questionnaire is used as a survey tool to collect adequate primary data. This method involves the design and management of an online questionnaire-based survey to professionals in the construction industry. A total of 204 online questionnaires was received and have been completely answered by the respondents. Personal information in the answered questionnaire showed that the respondents consist of various professional backgrounds in the following proportions: architecture (12%), civil and structural engineering (34%), mechanical engineering (18%), electrical engineering

(10%), quantity surveyor (23%), building surveying (2%) and project management (1%). While, in term of respondent roles, there is slight difference compared to their professional background as the following: architect (12%), civil and structural engineer (30%), mechanical engineer (17%), electrical engineer (10%), quantity surveyor (22%), building surveyor (2%) and project manager (7%). The majority of respondents were from a range of low-medium level of working experience (1–15 years), making up 80% of the respondent.

3.1 Extended Technology Acceptance Model (Extended TAM)

Extended TAM for technology implementation training invented by Marler et al. (2006) was utilised as a means for measuring the influence of training on behavioural intentions to use BIM. Marler et al. used this extended TAM for their research on technology implementation training to investigate the influence of training in helping acceptance of the technology by employees in mandated organisation-wide information technology implementations. This extended TAM asserts that perceived resource is an additional key belief together with ease of use and usefulness as internal variables that could mediate relationships between external variables and intentions to use a new technology (Mathieson et al. 2001). Marler et al. (2006) and Mathieson et al. (2001) added that the perceived resources would contribute a positive impact on intention to use a technology because it has a direct relationship with the potential barrier to use and organisational support. Thus, the extended TAM related to technology training is particularly focusing on the specified external variables of the extent of training and training reaction that affect the intention of using the technology with the influence of internal belief of ease of use, usefulness, employee resources (Marler et al. 2006) as shown in Fig. 1.

TAM has been acknowledged to be the most accepted research model of information system among researchers, possibly due to its profusion of an empirical study on IS/IT acceptance (Agarwal and Prasad 1999). Extended TAM has been chosen as the research model because it provides sufficient information compared to the basic model regarding the relationship between training and intention to use BIM.

4 Results and Discussions

Table 1 highlighted the level of BIM awareness and its use. Although many researchers have analysed these matters, ongoing research is necessary to support the earlier results or find new findings. From the survey, the results indicated that the level of BIM awareness is very high where 95% of the respondents are aware of BIM. On the contrary, the usage of BIM is very low where only 8% of the samples are currently using BIM and 10% of the samples have used BIM. These results are illustrated in Table 1.

The samples for this study consists of respondents who have attended BIM training and also who have not participated in any BIM training. The result showed that 58.3% (n = 115) have not participated in any BIM training and 41.7% (n = 89) have participated in BIM training organised by PWD or CIDB. In the questionnaire, the respondent had been given the opportunity to choose more than one training that they have attended either introductory training or technical training. From 89 respondents who have participated in BIM training, 79% has participated in introductory training and 50% has participated in technical training.

Pearson's correlation coefficient approach was employed to measure the linear relationship (correlation) between the variables in the research model. A pair of the variables in the hypotheses were tested in order to examine if there is a significant relationship between two variables in each hypothesis. In determining the level of significant correlation, the guide proposed by Evans (1996) was used to determine the significant level of value of r which consisting 'very weak' (0.00–0.19), 'weak' (0.20–0.39), 'moderate' (0.40–0.59), 'strong' (0.60–0.79), 'very strong' (0.80–1.00).

SPSS (version 22) was used to analyse the data from the survey to provide information for the significant correlation

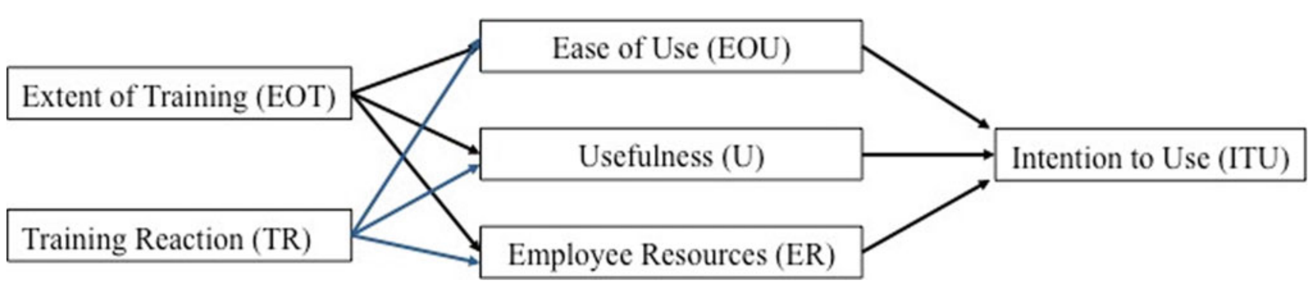

Fig. 1 Extended technology acceptance model (Marler et al. 2006)

Table 1 Level of BIM awareness and use

Item	Frequency	Percent
Aware and currently using BIM	17	8
Aware and have used BIM	21	10
Aware of BIM but have not used it	157	77
Not aware of BIM	9	5

for all variables in order to test the hypotheses. Table 2 and Fig. 2 demonstrated the results and it is clear that all the variables has either positive or no significant correlation.

4.1 Relationships Between EOT and TAM Variables (U, EOU and ER)

In voluntary context, the unsupported hypotheses (***H1a****—there will be a significant relationship between extent of training and perceived ease of use* and ***H3a****—There will be a significant relationship between extent of training and perceived usefulness*) have revealed that EOT does not predict perceptions of either EOU or U. In other words, the number of days training has no influence on EOU and U which might be explained with relation to characteristics of BIM adoption.

For perceived EOU, there is a similarity between a non-significant relationship with EOT in this study and those described by Marler et al. (2006). Furthermore, this finding also further support the idea of Agarwal and Prasad (1999) in their TAM research who have suggested training of new information technologies is a lack of significance on EOU. To explain the reasons, they have specified that two possible explanations about their research results on graphical user interface (GUI) training. First, the training lacks effect due to the use of GUI is so easy and second, the reason was derived from a previous study on GUI (Olfman and Mandviwalla 1994) that found effectual GUI training is intrinsically hard to deliver. From the analysis, specifically, the lack of a relationship between perceived EOT and EOU is more puzzling as one might expect that more training would increase the trainees' confidence in using BIM.

For perceived U, this finding is in agreement with those of Marler et al. (2006) who found that EOT has no significant correlation with U in the context of mandated organisation-wide information technology execution. However, in contrast, Agarwal and Prasad (1999) found that there is a significant effect of training on perceived U as training might be used as a mechanism to spread new information technologies by its influence on beliefs. They also suggested training might have been influential in displaying users to the extra functions offered by the system. From the result of Agarwal and Prasad's study, it might be speculated that EOT had little opportunity to influence this perception due to the general benefits of BIM that were already considered to be high. Alternatively, another possible explanation is that the usefulness of BIM could not be covered at the early stage in any combination of trainings and consequently subsequent additional days of training do not contribute further. As the BIM implementation is still in its infancy in Malaysia, it is likely that the individuals in the construction sector might not be able to see more positive results that can be achieved when using BIM. However, as only 18% of the respondents are currently using and have used BIM, the BIM benefits might not be fully gained because most of the respondents are not directly involved in the use of BIM. As a result, they might lack interest in learning BIM and only participating in training just to obtain a certificate of attendance.

As two previous hypotheses were not supported, the result of this study indicates EOT has a weak significant positive relationship with the ER (***H5a****—There will be a significant relationship between extent of training and perceived employee resources*). The finding supports previous research (Marler et al. 2006) into this relationship which links EOT and ER. It might means that EOT has positively

Table 2 Correlation coefficients

Variable	EOT	TR	EOU	U	ERITU
EOT					
TR	0.19				
EOU	0.17	0.68**			
U	0.15	0.58**	0.68**		
ER	0.30**	0.49**	0.50**	0.57**	
ITU	0.23*	0.43**	0.47**	0.58**	0.53**

*Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)

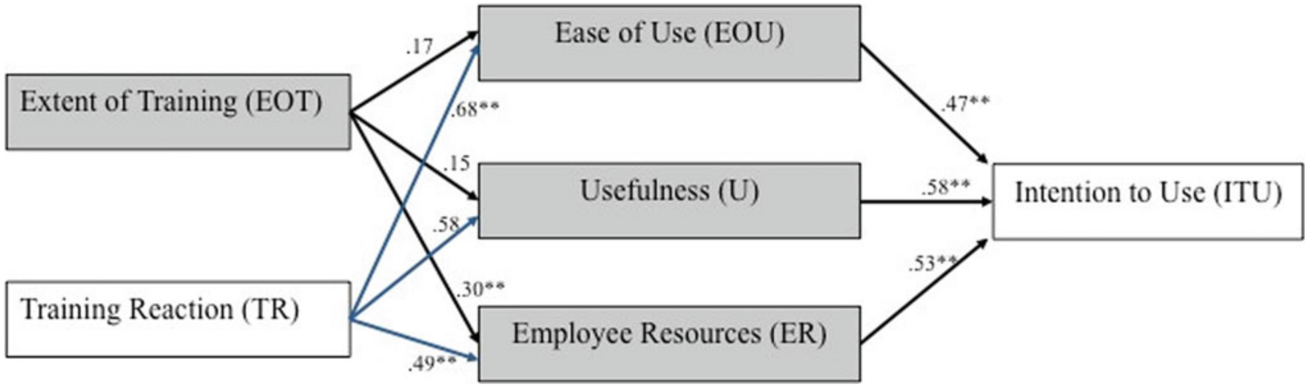

Fig. 2 Relationship between Training and TAM

influence participants by providing information regarding the availability of support resources, timing of project execution and opportunities to be proficient in BIM implementation. Thus, in general, it seems that more training participation might lead trainees to allocate time for implementing BIM in their work and would try to access BIM documents such as manuals, circulars and online library. Meanwhile, the reason for weak significant relationship might be due to extra effort that should be put to be able to access these documents, hence, could lessen behavioural ITU among the trainees.

5 Conclusions

Given that TAM variables demonstrate positive influence to behavioural ITU, the BIM training organisers should be sensitive to the current needs of the potential participants and not just provide the training to fulfil their training schedule. Although there was a weak significant positive correlation between EOT and ITU, as compared to the relationship between EOT and TAM variables, the number of days training may not be able to contribute a strong positive impact on the participants because the knowledge and skills they have learned in training were still unable to help them understand and explore the uses and benefits of BIM. Therefore, it could be concluded that possibly there is a lack of training quality in terms of content and trainer. With the view of BIM adoption in Malaysian construction industry, it seems that providing effective training programmes is essential to support the professional in using BIM efficiently. It is clear in the findings that professionals still lack intention in using BIM despite that they have participated in BIM training. In stepping ahead to utilise BIM, government agencies and BIM specialist would be the most appropriate organisations to organise BIM training sessions for Malaysian professionals. As a result, an effective BIM training could be provided to the potential participants and conducted by an experienced trainer.

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Multi-objective Resource-Constrained Scheduling in Construction Projects

Vasiliki M. Lazari and Athanasios P. Chassiakos

Abstract

The resource-constrained scheduling problem (RCSP) is one of the most challenging problems in project management. It is a combinatorial optimization problem with multiple and contradictory objectives (resource allocation within resource availability levels, project completion prior to a given deadline, resource leveling throughout the project length) and constraints (precedence constraints between activities) while its complexity grows as the number of activities increases. In this study, the objective function includes a number of sub-objectives that result from practical considerations of actual construction projects. These are the cost of daily resources exceeding the resource availability, the cost from the day-by-day resource movement in and out of the project work, and the cost of prolonging the project duration or exceeding the project completion deadline. Due to the large solution space size (even for a small-sized project), genetic algorithms are employed in this study to develop the optimal or a near-optimal solution. The model is applied to a case study project and tested for different constraints and goal scenarios, in order to provide insight regarding the effectiveness of the method in different optimization criteria and project management priorities. Evaluation results indicate that the proposed approach can effectively approximate the optimal solution in all cases.

Keywords

Resource-constrained scheduling • Resource allocation • Resource leveling • Multi-objective optimization • Genetic algorithms

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1 Introduction

The resource-constrained scheduling problem (RCSP) has been extensively studied in the past and it is still a case of great interest for researchers because of its importance in project management. The aim of project scheduling analysis is to develop optimal schedules with regard to time and resource allocation and leveling within resource availability margins and project completion deadlines.

Existing research efforts have led to a variety of methods and algorithms for addressing the resource-constrained scheduling problem. They can be categorized into exact methods, heuristic and metaheuristic or evolutionary algorithms. Exact methods, such as linear/integer programming, attempt to tackle the problem by forming mathematical relationships describing the problem objective and constraints in linear form and solving with a pertinent method (e.g., Simplex method) (Shtub et al. 1994; Damay et al. 2007). Although these methods can provide exact solutions, they become unproductive in setting up the computerized problem structure as the project size and parameters increase.

Heuristic approaches, such as branch and bound algorithms, initially develop lists of potential solutions but, because the solution space is often too vast to fully traverse, they handle the problem by bounding and pruning. Main limitations of such methods are that there is no universal bounding algorithm working for all problems and that the optimal solution is not guaranteed. In this class of methods, the works of Brucker and Knust (2003) and Moukrim et al. (2015) can be mentioned.

When the employment of previous methods is ineffective to develop or the exact solution is computationally expensive to obtain, metaheuristic methods or evolutionary algorithms are used in order to approximate the global optimum. Evolutionary algorithms operate through the selection process in which the least fit members of the population set are eliminated whereas the fit members are allowed to survive

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and continue until better solutions are determined. Researchers have used Genetic Algorithms for the exploration of near-optimum solutions in resource-constrained scheduling problems (Leu and Yang 1999; Alcaraz et al. 2003; Besikci et al. 2014; Kaiafa and Chassiakos 2015; Mathew et al. 2016). Genetic Algorithms have also been used for leveling the daily usage of resources and minimizing project duration (Roca et al. 2008; Ponz-Tienda et al. 2013). Other studies have combined Genetic Algorithms with other evolutionary algorithms or methods to form hybrid ones so as to obtain better solutions (Lova et al. 2009; Bettemir and Sonmez 2015).

Previous studies regarding the resource-constrained scheduling problem are typically based on a single (and rather theoretical) decision parameter, such as some type of statistical moment of the obtained resource histogram, to evaluate the effectiveness of the produced resource allocation. In this study, alternative decision parameters, closer to the ones encountered in practice, are explored developing different optimization structures, which are comparatively evaluated to provide performance indications as well as practical implications regarding the employment of the alternative parameters.

2 Proposed Model

The objective function of the proposed model represents the total cost to be minimized and is formulated as the cost summation of all optimization sub-objectives. The sub-objectives are the project completion goal within a deadline (or as soon as possible), the confinement of the daily resource usage within the availability level, and the development of a flat daily resource usage pattern throughout project execution. Unit cost values are used in order to indicate the weight of each sub-objective in this multi-objective formulation. More specifically, the total cost (objective function) consists of the following elements:

- The project direct cost, which represents the cost of the required resources for project execution. This cost is proportional to the resource-days needed to complete the project under normal execution and is invariant to different solutions.
- The indirect cost, which represents the general project expenses. It is practically considered to be proportional to the project duration.
- The cost of exceeding a given project completion deadline, which represents the financial impact of delaying the project beyond a specified time frame.
- The cost of exceeding the daily resource availability, which represents the (increased) expenditures needed for recruiting additional resources than initially planned.
- The cost associated with the deviations in daily resource usage, which represents the cost for moving resources in and out of the construction site day by day.
- The cost associated with the deviations in daily resource usage, which (alternatively to the previous case) is considered on the basis of the standard deviation of the daily resource usage histogram.

The above sub-objectives are considered with different unit cost values in order to compare different optimization structures and criteria. For instance, if the unit cost value of exceeding the daily resource availability is set at 1 while all other unit cost values at 0, the optimization aims at minimizing the cumulative (along the project length) number of daily resources above the resource availability level.

A single resource type for all activities and a single execution mode for every activity (in terms of duration and daily resource usage) are considered in this study and the optimization is performed by rescheduling activities according to their precedence relationships and time slacks.

The optimization model has been implemented in an MS Excel spreadsheet and the resource graph is automatically produced with all quantitative characteristics that describe the effectiveness of the solution in accomplishing the optimization objectives. The optimization is performed through genetic algorithms (GAs) via a commercial optimization software (Palisade Evolver 7.5) which works as an Excel add-in.

3 Results

A case study with a simple project consisting of 10 activities is considered to illustrate the algorithm application. The project activities and durations, the precedence relations, and the resource requirement per activity are shown in Table 1. Figure 1 presents the network diagram of the project and Fig. 2 presents the resource histogram for the early project schedule (initial solution). The normal project duration is 17 days. This is also considered as the desired project deadline and set as a constraint in the optimization model. The resource availability level is set at 6 units per day.

A number of scenarios considering different optimization criteria are evaluated as indicated in Table 2. Case 1 represents the initial project schedule with the earliest start of the activities that is shown in Fig. 2. Case 2 provides the result of minimizing the cost of exceeding the daily resource availability that is shown in Fig. 3. It can be seen that a considerable amount of leveling has been achieved compared to the initial solution. Case 3 provides the result of minimizing the standard deviation of daily resource usage. In this particular case study, the resource allocation histogram is identical to the previous one that is shown in

Table 1 Project data for the application example

Activity	Predecessors	Duration	Resources
A	Start	5	2
B	Start	10	2
C	Start	4	2
D	A	7	2
E	C	5	2
F	A	4	2
G	E, D, B	3	2
H	C	6	2
I	Start	4	2
J	F, G, H, I	2	2

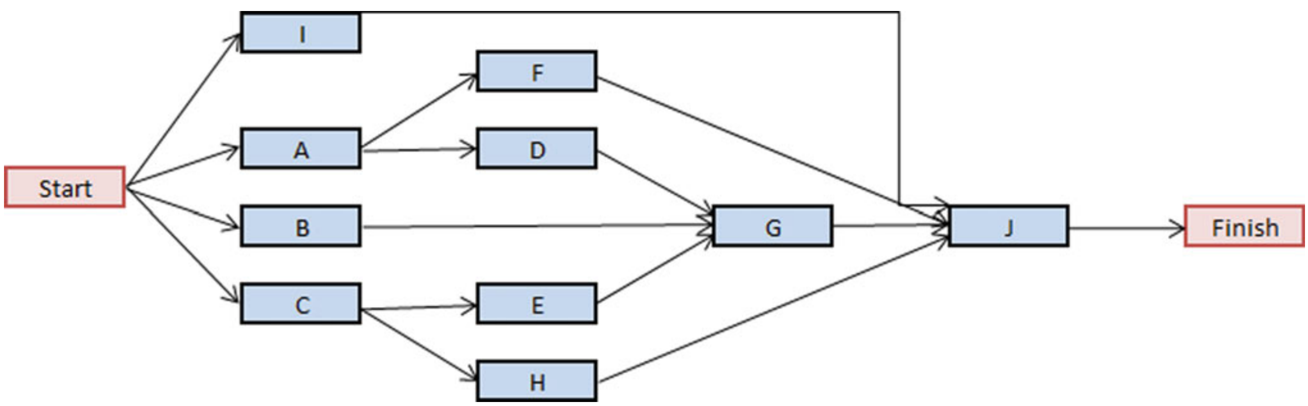

Fig. 1 Network diagram of the example project

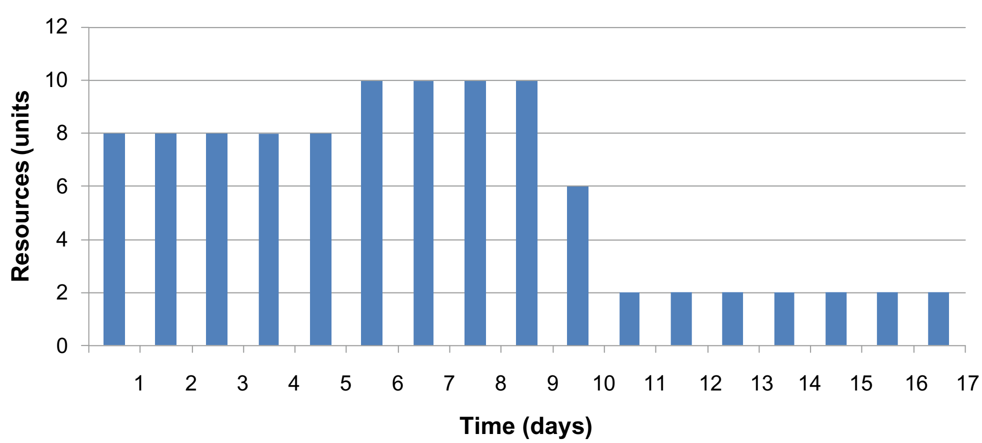

Fig. 2 Resource histogram for the early start project schedule

Fig. 3 and this is due to the relatively small project size that does not develop a large number of alternative resource allocation patterns. However, the experimentation with other examples shows some deviation in the final resource allocation between the two sub-objectives but this deviation is typically not enormous. In fact, the results of these two cases indicate their quite similar performance since both focus on a smooth resource histogram within the resource availability constraint.

On the other hand, the optimization in Case 4 shows (rather surprisingly) that, if the criterion is the minimization of the cumulative number of resources in and out of the project along its duration, the "best" histogram that is shown in Fig. 4 is not globally leveled but rather on a phace to

Table 2 Optimal results for example project

Case no	Case description	Resource constraint	Project duration	Resource standard deviation	Resource exceedance	Resource fluctuations
1	Initial early time schedule	–	17	4.00	26	10
2	Resource allocation under resource constraint—minimizing resource availability exceedance	$R \leq 6$	17	3.11	6	12
3	Resource allocation under resource constraint—minimizing resource standard deviation	$R \leq 6$	17	3.11	6	12
4	Resource allocation under resource constraint—minimizing resource fluctuations	$R \leq 6$	17	3.56	20	6
5	Resource allocation under resource constraint—minimizing resource standard deviation and fluctuations	$R \leq 6$	17	3.16	8	6

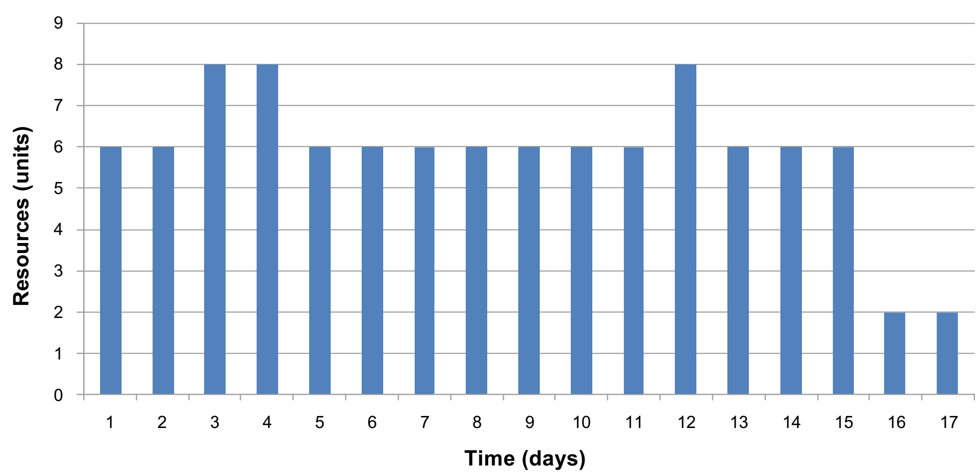

Fig. 3 Resource histogram for Cases 2 and 3

phase basis. Case 5 provides an optimization result following the combination of the sub-objectives represented by Cases 3 and 4. The resulting resource allocation histogram is shown in Fig. 5 and lies somewhere in between those produced by the sub-objectives (Figs. 3 and 4).

4 Discussion

On the basis of the results presented in Sect. 3 and from further elaboration with other case studies, the following observations can be made:

- The resource-constrained scheduling problem is a very complex one taking into account that activities should not only be optimally shaped (resource requirement, duration, placement at the right time frame) but also that there are other types of constraints that need to be satisfied (activities precedence relations, resource availability, completion deadline). As a result, metaheuristic algorithms seem to be more appropriate for solving the problem than exact optimization methods.
- The application of genetic algorithms (or any other type of metaheuristics) to solve the resource-constrained

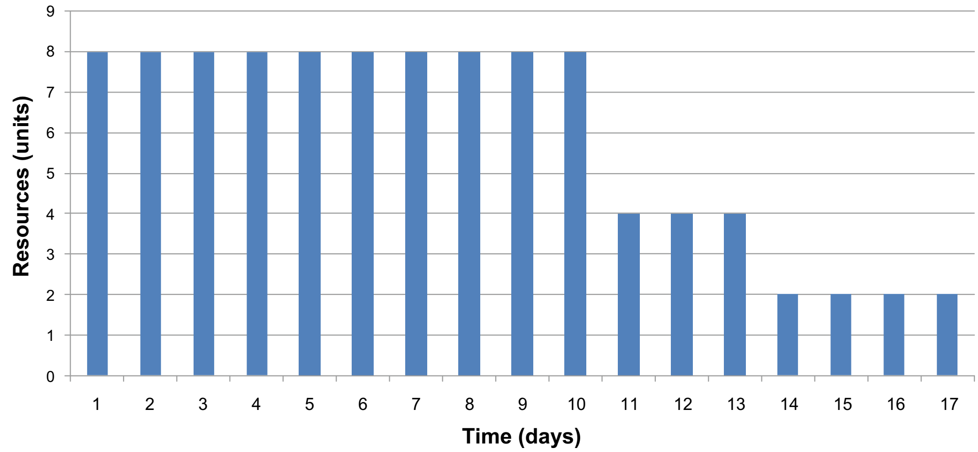

Fig. 4 Resource histogram for Case 4

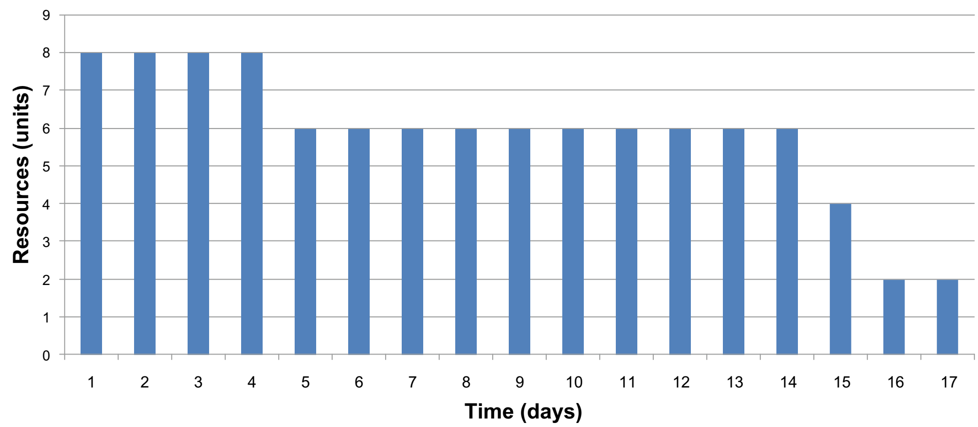

Fig. 5 Resource histogram for Case 5

problem does not guarantee to find the optimal solution in a single run of the algorithm (or ever). To improve the success rate (i.e., to minimize the deviation from the optimal solution), it is suggested to run the algorithm repetitively to make use of the fact that, due to the stochastic nature of the algorithm, the results do not generally coincide from run to run.

- Different optimization criteria should be developed in order to find the one that better fits the individual problem objectives and characteristics. Focusing solely on a single sub-objective may exclude alternatives with a higher generalized resource allocation impact.

5 Conclusions

The resource–constrained scheduling problem is one of the most challenging in the area of project management. It is a combinatorial optimization problem, which incorporates conflicting objectives (resource allocation within resource availability thresholds, project completion within certain deadlines, resource leveling) and constraints (e.g., precedence relation constraints between activities) while its complexity grows as the number of activities increases. The size of the solution space in such cases leads to the need for employing metaheuristics to obtain an approximation of the optimal solution.

In this work, an optimization model is developed for multi-objective resource-constrained scheduling. The aim of this optimization is to minimize a cost function, which is composed of the sum of individual cost parameters associated with (a) resource availability exceedance, (b) day-by-day resource fluctuations, and (c) project completion beyond a given deadline. The present study examines different objectives and criteria, either separately or in combination, to evaluate the degree that each optimization structure facilitates certain or prevailing objectives in actual projects. The optimization is performed with the employment of genetic algorithms as an effective tool to handle large combinatorial problems. The evaluation indicates that the proposed method can provide reliable solutions for the multi-objective resource-constrained scheduling considering the priorities and individual objectives in every project case.

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Contingency Use and Project Delivery Influence on Infrastructure Project Risk Assessment

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Abstract

Risk assessment and management in infrastructure projects is considered one of the main factors that can enhance project success. Project team perceptions on risk identification are important to develop a risk mitigation strategy. Cost overruns are one of the critical risks in this industry, which have been mitigated by allocating a contingency amount to the initial cost estimate. The aim of this study was to understand the use of project contingency by the owner and contractor. Additionally, it analyzed the project delivery methods that entice the use of intensive project risk assessment procedures, especially in infrastructure construction projects. It was found as one of the factors that drive the use of risk assessment.

1 Introduction and Background

Project risk is an uncertain event or condition that, it occurs, has a positive or negative effect on any project's objectives. Owing to the unique and complex nature of infrastructure projects, uncertainty in cost and schedule overruns are vital. It is important and special for budget and schedule preparation, it helps to accommodate changes without affecting the project's cost and duration (Touran 2003).

Cost overruns and late completion times in large infrastructure projects have been widely recognized as project performance risks impacts (Love et al. 2014; Touran and Lopez 2006). Cost escalation can be affected by the length of the project implementation phase, project size, and project ownership type (Flyvbjerg et al. 2004). Therefore, accurately estimating project costs and contingencies is an important factor for successful project cost management from the start of the planning phase to the completion of construction (Akintoye and MacLeod 1997). Consequently, an institution like the Washington Department of Transportation (DOT), adopted a cost estimate validation process (CEVM). This method uses Monte Carlo simulation to assess the likelihood of completing a project within budget and schedule (Touran and Lopez 2006; Reilly et al. 2004).

Traditionally, project cost contingency was added by adding a base percentage to the overall project cost (Idrus et al. 2011), but this method is arbitrary and difficult to implement, given various complexities and large scale of construction projects (Baccarini 2006). Also, past studies showed that, specifically in the construction industry, the need to use expert opinions, past experience, intuitive, and thumb rules. And it cannot be avoided completely due to a lack of statistical data (Dikmen et al. 2007; Kangari and Riggs 1989).

Managing different project risks, especially in the construction phase, is the most effective strategy that helps control cost and time escalations (Touran 2003). Akintoye and MacLeod (Akintoye and MacLeod 1997; Akintoye and MacLeod 1997) found that the construction industry in the UK has approached risk management in terms of individual intuition, judgment, and experience gained from previous contracts. Contractors have the tendency to contract out all the work packages in a project to sub-contractors and undertake contract management as part of a strategy to reduce or eliminate their risk. The more powerful and sophisticated risk assessment (RA) techniques, the more time and data are required. The construction industry is lagging behind in terms of big data management and analytics. Furthermore, most contractors are reluctant to use sophisticated risk assessment, analysis, and many management techniques.

Using risk assessment in highway projects improved construction performance. In this study, the statistical dependency correlation analysis showed that the use of risk

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assessment in the reported projects has improved project and construction management practices (Diab et al. 2012).

Project delivery selection is one of the critical factors for projects' success (Chan et al. 2001). Traditional project delivery methods include, but are not limited to, the Design-Bid-build (DBB), Design-Build (DB), and Construction Manager as Agent and at Risk (CM/A or CM@R) (Liu et al. 2013). State DOTs in the United States often use three fundamental project delivery methods: Design-Bid-Build (DBB, Design-Build, and Construction Manager-General Contractor (CMGC) (Tran et al. 2013).

As observed in the literature above, the use of risk assessment has been inconsistent among the different infrastructure construction projects. This can be attributed to several factors that have been identified through the different studies yet, there were no different answers about the association between the risk assessment use and these factors. Moreover, there have been many studies on the different methods of assigning contingencies. There is a lack of understanding of how the different stakeholders use their contingencies during the project. which in turn can later enhance the methods for developing these contingencies. Therefore, this paper, which is part of a larger study, will address the following objectives:

1. Understand the use of project contingency by the different stakeholders, mainly the owner and the contractor.
2. Analyze the project delivery method that entices the use of intensive project risk assessment procedures in infrastructure construction projects.

2 Methodology

The data collection was administered through a survey instrument to collect infrastructure projects' data from several infrastructure projects across the US. (North, East, Midwest, West, and South Regions) for a variety of infrastructure projects with different parameters. Some of these parameters are project type (Road, Bridge, Tunnel), project delivery method (DBB, DB, Other), Procurement methods (low bid, Best Value, other), Contract type (lump sum, unit price, etc.), Total Planned Costs (TPC), Total Planned Duration (TPD). All of these parameters along with specific risk management questions such as risk assessment use and tools, contingencies percentages, contingencies use were included in the data collection process.

The collected data were analyzed through descriptive statistics. The goal is to obtain general data tendencies such as mean, median and standard deviation, and other inferential statistics such as correlation analysis, Chi-Square tests, and Fisher's exact tests. These tests used to analyze specific hypothetical questions. The total number of responses received was 246, some of which contained responses for more than one project. Out of these responses, 48 responses had completed the survey questions used in this paper analysis.

3 Discussion and Results

This section will focus only on the results that pertain to the paper's objective, which addresses the contingency use by the owners and contractors. Additionally, the factors that might entice the use of risk assessment tools like project delivery methods.

3.1 Contingency Use Results

After analyzing the survey responses, the results showed that most of the owner's contingency was directed towards the cost changes as related to the following; additional work and unknowns, bid item overruns, contract changes for environmental cleanup, claims and change orders, unforeseen environmental mitigation, right-of-way cost increases, asphalt cement and fuel adjustments, owner-directed changes, utility relocation, undefined damages discovered during reconstruction (because of issuing/incomplete data of road/bridges and state of the art condition, etc.), changes in site conditions, additional deterioration of highways/bridges during final design, inspection, and engineering costs.

On the other hand, after analyzing the survey responses, most of the contractor contingency in these infrastructure projects reported in survey responses were directed towards the cost changes as related to the following: escalation, weather-hurricanes, minor owner-directed changes, quantity variations, permit delay, and design delay, proprietary information, materials cost increases, fuel increases, unforeseen environmental mitigation, and acts of nature, all potential risks that are not mitigated by the owner, design growth, quantity growth, labor availability and cost, equipment availability, schedule risk, liquidated damages, differing site conditions, force majeure issues, funding availability, difficult owner and owner's representative, predicted damages, unforeseen circumstances, the added value for the extended pavement design life, material/fuel cost increase, change orders, workers compensations, utilities, material escalation, environmental, scheduling complexities; and minor overruns.

3.2 Project Delivery Methods and the Use of Risk Assessment in Project

As mentioned earlier, the responses were obtained for three types of project delivery methods: design-bid-build (DBB), design-build (DB), and others. The data analysis was carried out only for DBB and DB project delivery methods. The goal was to investigate if there is a significant correlation between the project delivery methods and the use of RA in the chosen projects. The hypothesis behind the analysis can be explained as in the following:

H_o: There is no dependency correlation between the project delivery method and the use of risk assessment in the chosen construction project.

H_a: There is a dependency correlation between the project delivery method and the use of risk assessment in the chosen construction project.

After running a Chi-square analysis as shown in Table 1, there is not enough evidence to reject the alternative hypothesis. About 85% of the projects using a DB project delivery method used RA, whereas only 53% of the projects using the DBB project delivery method used RA. This indicates that the use of RA is more prevalent, significant and important in projects using the DB project delivery method. This could impact the cost and schedule of these projects more significantly than the projects using the DBB project delivery method. Following the Chi-square test, Fisher's exact test was used here because of low cell counts in certain cells. Fisher exact test also indicated low probability value, and provided the basis for rejection of the null hypothesis at alpha (α) value of 0.05, which further supports the conclusions from Chi-square test.

4 Conclusion

This paper, as part of a bigger study, was focused on understanding how the different stakeholders (Owners and contractors) use their contingencies in infrastructure projects. Moreover, the study also aimed to identify some of the major factors that can entice the use of risk assessment tools during project planning and management like the project delivery method. The results showed that unforeseen site conditions (e.g., changing site conditions, unforeseen environmental mitigation, unforeseen circumstances) are a common ground for contingency spending among both parties. However, most of the contractor's contingency spending is more directed towards unpredictable cost escalation items (material costs, fuel costs, design growth). This research also showed that DB project delivery is one of the major factors behind using RA in project planning and management. This

Table 1 Project delivery methods and the use of risk assessment in project

Using risk assessment	Project delivery method			
Frequency row Pct Col Pct	DBB	DB	other	Total
Yes	31	17	5	53
	58.49	32.08	9.43	
	53.45	85.00	83.33	
	27	3	1	31
No	87.10	9.68	3.23	
	46.55	15.00	16.67	
Total	58	20	6	84
Statistic		DF	Value	Probability
Chi-Square		2	7.4947	0.0236
Likelihood Ratio Chi-Square		2	8.1750	0.0168
Fisher's Exact Test				
Table Probability (P)			0.0019	
Pr < = P			0.0177	

can be attributed due to the additional risks that a Design-Builder might take when being responsible for both design and construction. For future study, the authors are interested to explore other delivery methods analysis utilizing more quantitative risk assessment tools.

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Investigation of Electronic Document Management Applications in the Construction Projects: Case Study in Jordan

Hesham Ahmad, Turki Al-Suleiman (Obaidat), and Abeer Elhour

Abstract

Document Management System (DMS) is always known to be vital for management of the complexity of construction projects. This study aims at investigating the opinions of DMS practitioners regarding the use of an Electronic Document Management System (EDMS) in construction projects. A questionnaire survey was conducted with 91 respondents involved in the construction projects. The respondents were asked to evaluate the extent, motivations and challenges of applying EDMS in the construction projects in Jordan. According to the survey results, only 8.8% of the respondents described the document system in their construction projects as mostly electronic, while 38.5% described their document system as using an almost similar percentage of electronic and paper-based documents. The results also showed that the top motivation to the application of EDMS in the construction projects is the improvement of search and retrieval of information, while the top challenge is the high expected financial cost of EDMS. This study helps to evaluate the existing DMS, and investigate the motivations, challenges and opportunities to improve EDMS implementation and application in the construction projects.

Keywords

Document management • Construction management • Construction projects • Electronic document management system

1 Introduction

In construction projects, the traditional manual methods of filing are still common especially in small- and medium-size construction companies (Ahmad et al. 2015). These methods were proven not effective for information management, because they require previous knowledge and understanding of document content, high capabilities, and time consumption from the seeker (Al Qady and Kandil 2014b). Many organizations have claimed saving time and efforts, increasing productivity and profitability, and improving coordination and collaboration among end-users by implementing effective EDMS (Laserfiche 2007).

Some factors in the construction projects may prevent the successful application of EDMS such as the complexity, the diversity of work performers, the non-repetitive nature of processes, the time and cost pressure, difficulty of systems' integration, and the need to make changes to the routine procedures of work (Björk 2003; Carrillo et al. 2004; Ahmad and An 2008; Egbu 2004). A research by Björk has investigated the use of internet-based DMS in the project-based construction industry (Björk 2006). The results showed that among the most important challenges for applying EDMS successfully are the complexity of contents' structure, the use of paper documents in parallel with electronic ones and the difficulty of measuring the benefits of applying the system.

This research seeks to investigate existing DMS in construction companies in Jordan. The research will highlight the use of the system, and the motivations and challenges to its successful application in the construction projects.

2 Literature Review

A paper by Van Wormer and Larkin was designed to provide a guide in the selection, development, and deployment of an Electronic Data Management system used for

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Engineering, Construction, and Owner operators (Wormer and Larkin 2017). The authors stated that the use for electronic document and content management has been motivated and become more advanced with the availability of free or low-cost cloud collaboration solutions along with the wider use of 3D design and BIM models. They argued that the traditional document control methods no longer work efficiently or with flexibility as the new advanced technological solutions.

Alshibly et al. have investigated the critical success factors that affect EDMS applications in government agencies (Alshibly et al. 2016). Through a questionnaire survey, a list of 37 factors grouped into six categories was evaluated. The study supported that a comprehensive list of critical success factors should not only include the factors focused on the system, but should also include top management support, resource availability, training and involvement, technological readiness and work environment and culture. The results showed that the factor related to the system is the most important for successful implementation of EDMS, followed by top management support and resource availability.

Research by Al Qady and Kandil has presented a technique to improve managing knowledge contained in construction documents (Al Qady and Kandil 2014a, b). Their research attempts to improve document categorization and retrieval by analyzing the contents of documents using natural language processing. Techniques were used to extract semantic knowledge from construction contract documents that can be used to improve EDMS functions. The research has presented a method to overcome the restrictions imposed by the traditional supervised learning text classifiers, which require a comprehensive training set to classify new instance. An unsupervised learning method was used in this research to automatically cluster documents together based on textual similarities.

Research conducted by Rujirayanyong and Shi presented a design of a project-oriented database that consists of 26 tables that are connected to each other through primary and secondary keys (Rujirayanyong and Shi 2006). Using data processing tools such as data mining, analysis and reporting will help to add meaning to data and transform them into knowledge that is more useful in problem-solving and decision-making. This will increase its value to other users. The presented data warehouse can maintain data from different existing software systems. It associates data of each project so that a user can retrieve information combined with required background information of the related project.

3 Results and Discussions of the Questionnaire Survey

The questionnaire survey was designed to target engineers recently involved in construction projects in Jordan. The questionnaire was split into three main sections. The first section seeks general information about the respondents and the projects they are involved in. The second section investigates the respondents' evaluation of the DMS used in the projects they are involved in whether the system is mainly paper or electronic based. Finally, the third part asks the respondents to provide their assessment and expectations of the motivations and challenges for implementing EDMS in the construction projects.

The questionnaire uses five-point Likert-scale to collect the respondents' evaluation of the organization of existing DMS, and the motivations and challenges of the application of EDMS in the construction projects.

3.1 Profile of Respondents and Projects

The questionnaires were distributed and filled electronically using Google Forms. Most of the sample individuals were contacted either by calling or by direct visits to encourage them to fill the questionnaire. The final number of effective responses equals 91. Figure 1 shows the categorization of respondents by the role of their organizations in the construction projects, while Fig. 2 shows the role of respondents in their organizations.

More than half of the respondents have over 10 years of professional experience as shown in Fig. 3. Figures 2 and 3 indicate in general that the respondents have professional experience and placed in positions that makes their response a useful source of data for this study.

Majority of the projects (57.2%) that the respondents involved in are with a financial size of less than five million US dollars. Figure 4 illustrates the percentages of the construction projects that the respondents involved in by the financial size of these projects.

3.2 DMS Evaluation

The questionnaire participants were asked to give their opinion if there is EDMS applied in the construction project they are involved in. The results showed that 63.8% agree

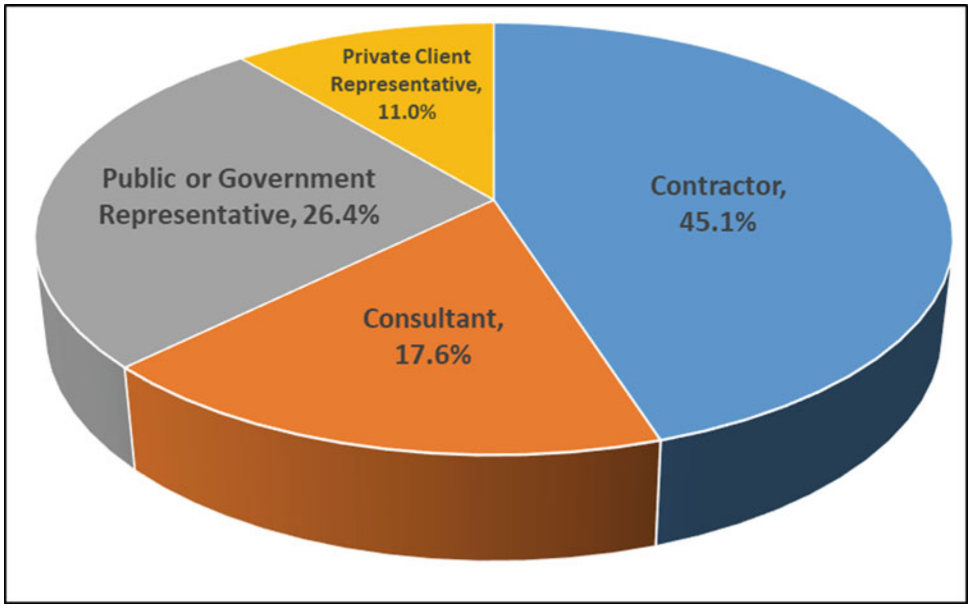

Fig. 1 Percentage of respondents by type of their organizations

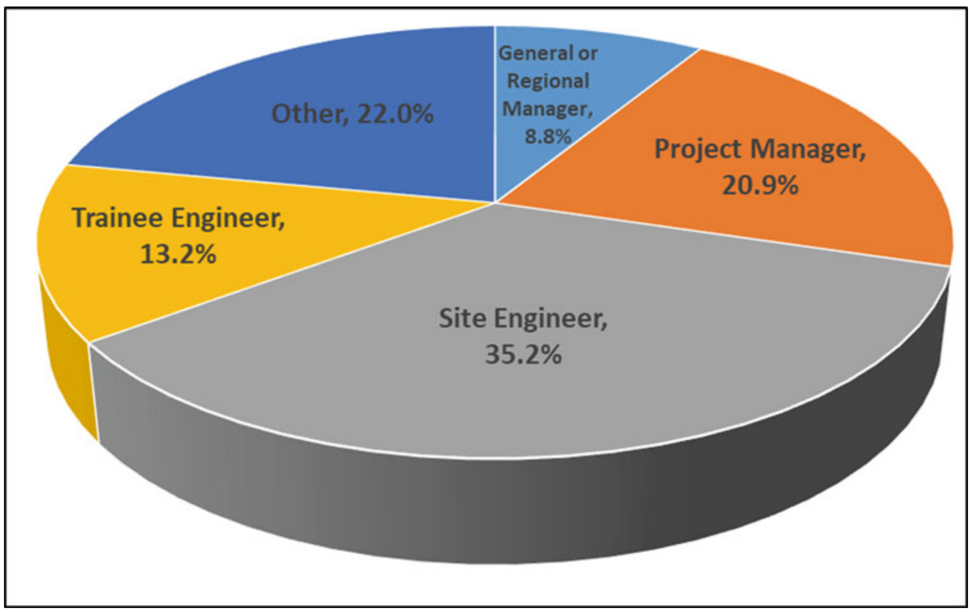

Fig. 2 Percentages of respondents by their jobs in the construction projects

that there is EDMS applied in the construction projects they are involved in as presented in Fig. 5.

Also, the respondents were asked to evaluate the extent of using electronic-based contents compared to paper-based contents in their projects. Figure 6 shows the response to the evaluation of these questions.

The results from Fig. 6 show that paper-based contents are more commonly used in the construction projects than electronic contents. A major percentage of the respondents (38.5%) indicated that electronic- and manual-based contents are used almost equally in their construction projects.

Furthermore, Fig. 7 shows that electronic-based documents have a higher level of organization than paper-based documents according to the respondents' opinions. This result reflects the abilities of practitioners to manage electronic documents effectively and successfully.

3.3 Motivations and Challenges

The questionnaire respondents were asked to rank seven motivations and seven challenges for applying electronic DMS in the construction projects. Mean score method was used to rank the factors from the most important to the least important. The results are shown in Tables 1 and 2.

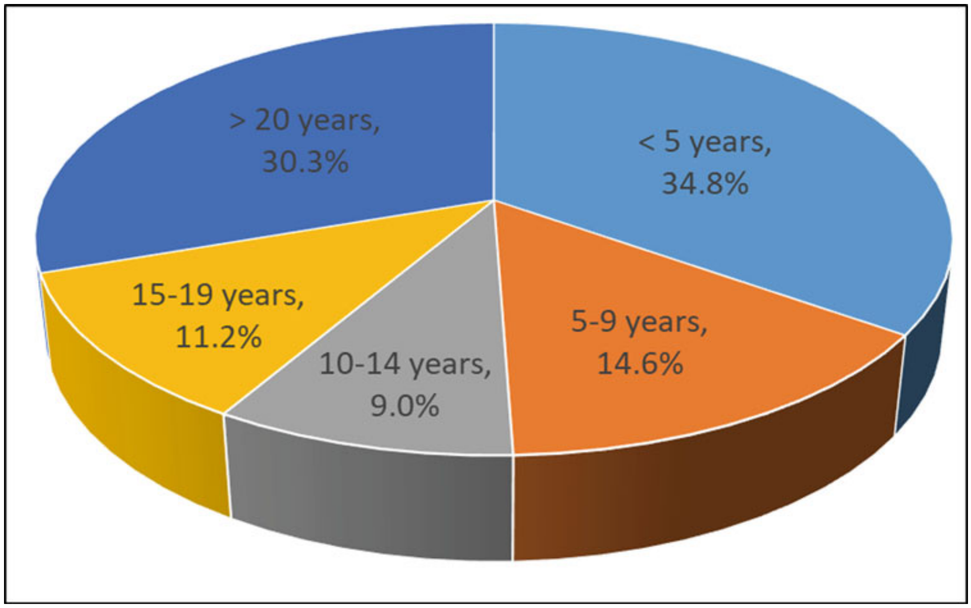

Fig. 3 Percentages of respondents by their years of experience

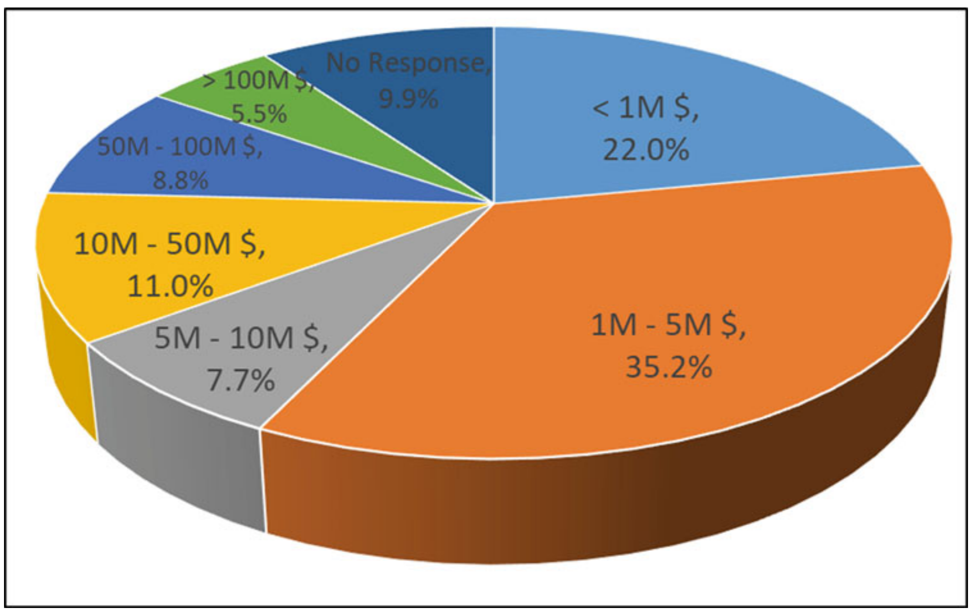

Fig. 4 Percentages of respondents by their project financial size

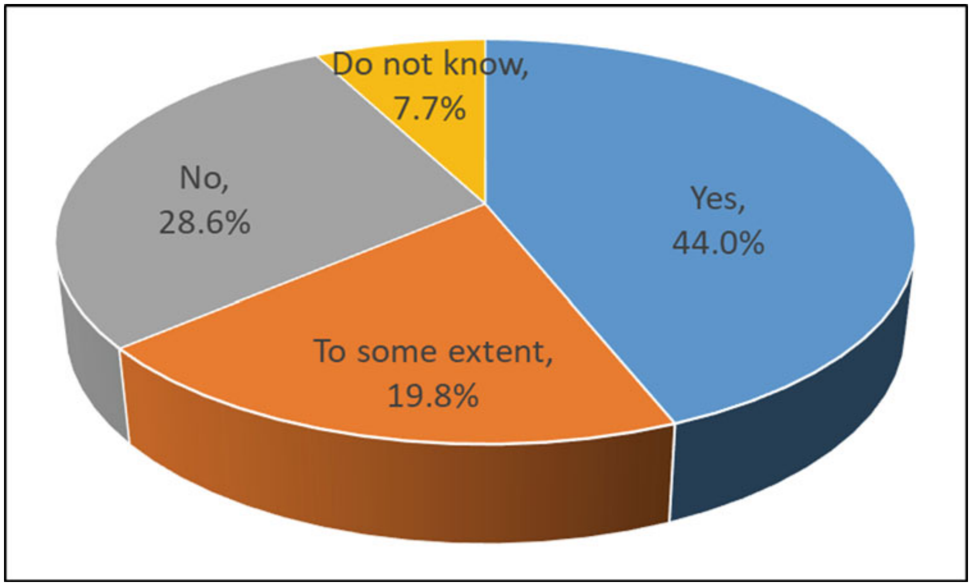

Fig. 5 Percentages of respondents by the application of EDMS in their projects

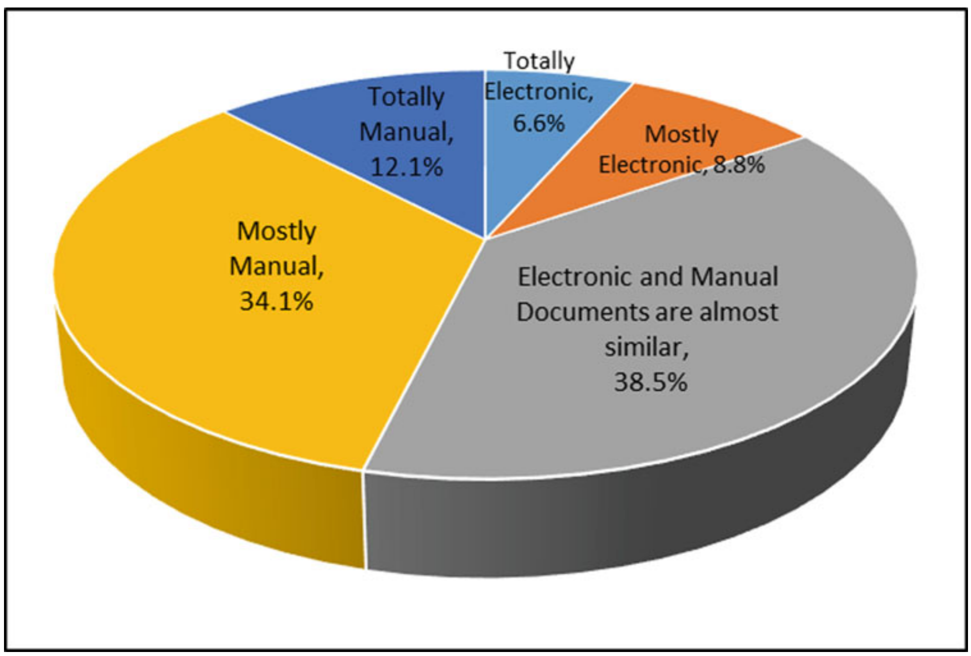

Fig. 6 Respondents' evaluation of the extent of electronic and paper-based documents in the construction projects

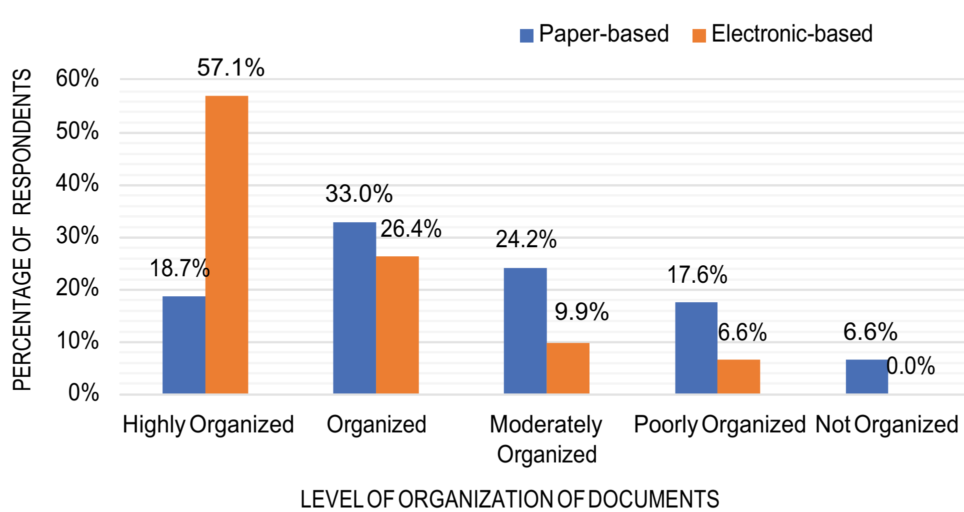

Fig. 7 Comparison of the level of organization between paper-based and electronic-based documents in the construction projects

Table 1 Ranking of motivations for EDMS according to participants' opinions

Motivations	Number of respondents	Average score	Rank
Reduce storage size	90	4.57	5
Enhance search and retrieval of information	90	4.78	1
Improve Ability to store documents for a longer time	90	4.68	2
Enhance transfer and share of information	87	4.68	3
Improve problem-solving and decision-making	90	4.32	6
Improve ability to analyze data and discover	89	4.28	7
Conclusions and lessons learnt Enhance learning process and training of junior	89	4.58	4
engineers			

Table 2 Ranking of challenges for EDMS according to participants' opinions

Challenges	Number of respondents	Average score	Rank
Time pressure in construction projects	88	3.24	7
The high expected financial cost of electronic	88	4.06	1
systems Staff lack of skills for the use of electronic systems	87	3.92	2
Difficulty persuading the usefulness of its	88	3.48	6
application Lack of interest or awareness about EDMS	87	3.77	4
Unclear financial return for applying EDMS	87	3.77	5
Difficulty and unwillingness to change routine processes of work	87	3.83	3

The results in Table 1 show that according to the respondents' opinions the most motivating factor for applying electronic DMS in the construction projects is enhancing the process of searching and retrieving required information. This is followed by the motivations of saving important documents and files for a longer time than in the existing paper-based systems, and enhancing transfer and share of important information.

The results in Table 2 show that the high expected financial cost is the most important challenge for implementing and applying EDMS in the construction projects. Also, the respondents think that the lack of staff skills for the use of EDMS and the difficulty and unwillingness to change routine processes of work are very important challenges for the successful implementation and application of EDMS.

4 Conclusions

Although the results showed that the use of documents in paper-based formats is more common than electronic based, it was noticed that the document management practitioners have the awareness of EDMS importance and usefulness and have the required skills and motives to apply it successfully. Their interest to enhance information search and retrieval is the most important motivation for applying EDMS in the construction projects. However, the need for a major investment of time, effort, and money, while benefits may need time to be noticed may stop construction companies from adopting electronic systems. Another important barrier for EDMS applications is that the organizations and personnel may be unwilling or unable to learn the new methods and procedures accompanying the application of new systems. This can be mitigated by applying user-friendly systems, and effective training and support.

Future research will aim at conducting more analysis of the questionnaire considering the different types and sizes of construction projects. The results can help to understand the different conditions, motivations, and challenges of DMS in the different construction projects. Future stages of the research will aim at developing and applying a computerized DMS that integrates the different electronic systems in the construction projects. The developed system will be evaluated and tested for the applicability and usefulness in the construction projects of different sizes and types.

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Exploring Individual Adaptability as a Prerequisite for Adjusting to Technological Changes in Construction

Derek Asante Abankwa, Rita Yi Man Li, Steve Rowlinson, and Yadi Li

Abstract

The advances in globalisation and technology have had significant impacts on the work environment, as they make various jobs more dynamic and fast-paced. Changing technologies such as digital transformation and automation require employees to adapt to new ways of working. To prevent the resistance to change, adaptive employees have become essential ingreidents for organisation's success. This study considers the reactive approach of individual adaptability, which is seen as modifying one's behaviour to meet the demands of a new situation, event or a changing environment. The study employed an exploratory research approach to understand the concept of individual adaptability to technological changes in construction organisations. It involved semi-structured in-depth interviews with three top management professionals and four construction workers from four different firms. These organisations were selected based on their number of employees, main construction business as contractors and investments towards technological changes. The findings indicated that individual adaptability is a performance construct instead of a personal characteristic. Workers are not involved in the decision-making processes regarding technological changes. Furthermore, the difficulties in implementing technological changes mainly consist of changing the mindset of workers, who have used the same method for a long time, and a lack of investment in innovation methods. The study identifies leadership, experience and open-mindedness as the predictors of adaptation to new technology. Workers consider learning through training as adaptive behaviour in technologically advanced environments. We propose future empirical studies on adaptability and trainability.

Keywords

Adaptive behaviours • Technological change • Exploratory study

1 Introduction

The construction industry is currently driving towards technological advancements with automation and digital technology which, when adopted during projects, reduce errors, save cost and time and increase client satisfaction. These change the traditional methods of construction amongst construction workers. However, regulations and existing attitudes about how the industry has always done things present powerful inertial forces for stakeholders such as the resistance to change. Adaptability is considered as a necessary skill when we face changes. There is a lack of studies regarding the construction personnel's adaptability and the understanding of employees' adaptation (Parent et al. 2010), which drives the motive of this research. To understand the individuals' ability to adapt to change, the study considers predictors of adaptability (predictor space), dimensions of adaptability (criterion space) and the relationship linking both spaces. This exploratory study was undertaken to understand the characteristics and behaviours of individuals, especially during technological changes in the construction context. Such knowledge is crucial for organisations which intend to implement change to know of possible pitfalls.

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1.1 Propositions of Individual Adaptability (I-ADAPT) Theory

Individual adaptability is the process by which an individual achieves some degree of fit between his/her behaviours and the new demands created by the novel and often ill-defined problems resulting from changing situations (Chan 2000). It has been considered in task performance that adaptability involves changes to cognitive processing, coping and adapting to organisational change. The study of individual adaptability leads to the development of the I-ADAPT theory, which integrates all the various dimensions of adaptability by providing a discussion of individual differences with a network of Knowledge, Skill, Ability, Other characteristics (KSAO)-performance relationships. Individual adaptability involves both the ‘will do’ (personality) and ‘can do’ (ability) characteristics. Chan (2006) indicated that the ‘can do’ and ‘will do’ characteristics are essential for excellent performance in jobs which require high levels of adaptation. However, when ‘can do’ is lacking, more ‘will do’ leads to a poorer performance outcome than less ‘will do’. Having a ‘will do’ attitude may be adaptive/maladaptive, depending on whether one is high/low on ‘can do’. The theory makes no specific claims about the nature of performance. When individuals perceive the need for change in a no-change environment, adaptability is often proactive, but when change is dynamic and frequent, adaptability is reactive.

This study focuses on technological advancements as the changing situations in the environment. The reactive nature of adaptability is due to the frequent changes in technology. The I-ADAPT theory posits that the environment drives the performance requirements of adaptability. If the situation requires adaptation, any dimension of performance is determined by individual differences in adaptability.

1.2 Technological Changes

Technology is often considered as either hardware or software that support the transformation of inputs into outputs in an organisation’s processes. The introduction of new technological processes has been identified as an enabler of efficient improvements, cost reductions in production and R&D (Zelbst et al. 2012). Technology needs to be acquired or developed internally and must fit the context in which it is implemented (Lager and Frishammar 2010). Such changes invoke equivocality, as well as technological, financial and social uncertainty, since the technology, in its initial stage, is not well understood (Stock and Tatikonda 2004). Technological change is a loose concept that has many meanings depending on the discipline. Changes in technology refer to (a) new technological inventions-tools, facilities, services and their variations in society; (b) new production techniques and the introduction of new methods of production. The difference between (a) and (b) is the distinction between process and product technology. However, process and product technology are often used interchangeably. There are some similarities between changes in process and changes in a product, because the new process might require some product change, and product change might also involve some elements of a new process. New technologies comprise materials and components which can be combined to produce an overall working system which includes elements such as skills and abilities (patterns of behaviour) necessary to operate the said technologies.

The study does not focus on product technology per se since there are many products which require several KSAO determinants. For instance, the KSAOs needed for operating drones might not be the same as those required for BIM. The study, therefore, focuses on technological processes.

2 Methods

The purpose of this study is to gain an understanding of how individuals adjust to technological changes in organisations. There is little research available regarding the industry's perception of adaptive behaviours towards technological changes in construction research. Cooper and Schindler (2006) cemented the use of the exploratory approach in research which has limited information available, but the researcher wishes to have the flexibility to conduct future exploration.

The I-ADAPT theory provides the theoretical framework for this study since it aggregates predictors and behaviours in an adaptive environment. It was also used to guide the data collection, analysis and discussion of findings. The constructs employed were initially discussed with academic peers and construction practitioners to increase the validity of the work. An exploratory study may not have a rigorous methodology, as used in conclusive studies, and sample sizes may be smaller (Nargundkar 2003). Therefore, the study rests on seven semi-structured, face-to-face in-depth expert interviews. Three interviews were conducted with employees at the management level of their organisations who were responsible for implementing changes in their organisation. The other four were construction operatives, who were required to navigate the processes of technological changes successfully (see Table 1). The purpose of this was to capture respective experiences with implementing and adapting to technological changes. The interviewees were purposively selected from four contractor organisations in Hong Kong with strong technological competencies and which make substantial investments in technology. These organisations have hierarchical structures and departments that impede flexibility, making the environment challenging for process development and implementation. Purposive selection increases the chances of capturing valid insights. We collected ten hours of recorded interview data. Interviews focused on the respondents' experiences with implementing technological changes at the management level and adapting to these changes at the operations level. Interview transcripts were coded based on the categories of the I-ADAPT theoretical framework. The purpose of this measure was to identify adaptive behaviours employed by operatives during changes in technological processes and to establish the antecedents of their adaptability.

3 Results

3.1 Management Level

The most important thing was that all interviewees agreed that there is a need for change in the construction industry by employing new ways of undertaking work activities. However, interviewees saw change as a challenging event. Changes are likely to be caused by different sources at any stage in the organisation. In construction, the source of technological changes comes from either inside or outside the organisation, as highlighted by TM1 and TM3, which makes managing change very difficult.

TM1: '*It comes from people; it comes from materials, supplies, and site conditions. All sorts of things. I would say the reason why we struggle with change or why change happens most of the time, though, is poor preparation and poor planning. People think that they have a plan or routine, but it is not until they start to deliver or do it that they realise this might not work; I need to change the product or process.*'

TM3: '*The minimum is defined from the client's side in the contract, but they don't care about your day-to-day change, they care about changes in formal submissions. If clients ask for the change in technology, then you must do it. If they don't ask for it, then it's harder to get the adoption. The clients' requirements are a driver towards the new technology.*'

Construction organisations should change without external influences such as waiting on clients to suggest technological changes. Being able to assess the environment and identify relevant cues that require change falls under the proactive dimension of adaptability. Surprisingly, technological changes in construction demand a reactive approach of adaptability rather than one which is proactive in nature.

None of the top management interviewees had specific procedures regarding technological changes adaptation. They depended on the understanding and skills of their subordinates. According to TM2, their organisation gives everyone an understanding of the technology by implementing it in a project. The workers are then asked to provide both onsite and offsite digital delivery strategies for the technology. However, the top management faces several challenges in implementing the technologies and trying to get everyone to adapt to them. Most of the problems or barriers to technological changes were attributed to human resources, particularly changing the mindset of individuals who have routine ways of delivering projects.

TM2: '*These workers are more traditional therefore they are happy with previous technologies, and now they are asked to use digital. For some people, the change becomes a change too far. They are not ready to adapt to it because they don't quite understand the benefits.*'

TM3: '*Technology provides a lot of benefits, but the 'culture' that goes around, that is where you start getting the challenges. You can track people, but people do not want to be tracked or monitored, so how do you create an environment where the tracking is possible? Where we do not track the individual but track his/her trade. You cannot force technology on people. You cannot force people to change.*'

TM1: '*The client has a decision to make on whether to continue with the human, which is far cheaper, or invest in technology. The role of clients in promoting innovation and change is the difficult one.*'

The top management mentioned that the first step one takes, which is significant is getting people to see the value in changing their behaviours to take up new technologies. If operatives get to know the value, they will adapt more easily. TM1 indicated that the incentive operatives get by adapting to a technological change is the offer of training programmes, after which an Information Engineer is appointed to police the use of implemented technology because if this is not conducted appropriately, everyone will learn it improperly. Through innovation seminars, workshop meetings and development programmes, the organisation enhances the awareness of technological processes and gives operatives the confidence, knowledge and skills needed. Scenarios and simulations are built to put processes and products into the context, which helps with training programmes. TM2's organisation has set up a structure whereby each division builds up a divisional innovation lead, and they have their innovation network champions or scouts, encourage active and enthusiastic workers.

Operatives are not involved in the decision to implement technological changes if the change is an industry standard, but TM2 admitted that middle-aged operatives with new thinking suggest most changes in the organisation. These individuals are involved in the implementation and testing of those technologies. The outcome of individual adaptation to new technological changes is seen in the impact on the project delivery.

TM3: '*Through digital platforms, we can see the impact on the delivery of the project. We benchmark where we are now in the project, institute the change through software or approach and see individual behaviours through the digital platforms.*'

3.2 Operatives Level (Individuals)

According to the I-ADAPT theory, if the environment requires adaptation, any dimensions of performance are determined by individual differences in adaptability. The interviewees described technological changes and how they adapt to them. Researchers were able to extract the antecedents of their adaptive behaviours. An individual's adaptive behaviour could be predicted with the right leadership support.

OP5: '*Our HR talk about Yammer and encourage it, so that was one method to kind of show what the executive directors expected of us. I had not heard about it, but when I saw that the executive directors talk about it now, I wanted to know.*'

OP7: *'Innovation is so well supported and driven by the CEO. He does not only talk about it but commits numbers and budget towards it.*'

A transformational leader is the source of inspiration and motivation for the followers in inducing a desirable change (Robbins and Coulter 2007); indeed, as a result, an environment of creativity, trust and accomplishment is developed (Mumford et al. 2002). Other interviewees referenced either their personality as being open-minded or previous experiences with similar technologies as determinants of their adaptive behaviours. Open-minded individuals enjoy searching for and trying new things because they are imaginative and curious.

OP4: '*I was brought in because I already had a lot of experience with using it, so I was tasked with leading it. It saves me time and information is more precise and more traceable.*'

OP5: '*As part of my morning routine, I spend time on websites not looking for anything but just trying to stay on top of new things as they come out because things are moving quickly.*'

OP7: '*I am a very straightforward, direct kind of person, so I am not very interested in these technological changes unless you convince me of the benefit or the value return for myself.*'

The next step is to capture the operatives' understanding of adaptability and their behaviours when there is a change in technology.

OP6: '*It was introduced to me by one of my senior colleagues in my first project. I learnt it, and since then I have gotten used to it.*'

OP5: '*I understand the meaning of adaptability, and I consider it more as learning, specifically on-the-job learning. My company coordinates with a technology company to give some workshops to help us learn about the technology. These companies invent apps that assist us in our processes.*'

OP6: '*My company wanted everybody to know how to use it, and so they organised training for the workers. I attended a workshop and became familiar with the software. I also go to my friends to help me.*'

Table 1 The details of the participants

Participant/Years of experience	Role and academic background	Technological changes
Interviewee 1 (TM1) (12 years)	Engineering Manager (BSc, MSc, Chattered Professional Exam)	ProjectWise, Microsoft Share Point, BIM, Engineering Management Systems
Interviewee 2 (TM2) (22 years)	Engineering Director for Digital transformation, innovation and virtual construction (BSc, MSc)	Sensors and Trackers, Digital environment
Interviewee 3 (TM3) (4 years)	Innovation Catalyst (BSc, MSc)	Yammer
Interviewee 4 (OP4) (4 years)	Site Engineer/Technical works designer (BSc, MSc)	RFID real-time monitoring, Photogrammetric Technology, Modular Integrative Construction
Interviewee 5 (OP5) (7 years)	Project Engineer - Operations team member (BSc)	Temporary reclamation, Google Sketcher
Interviewee 6 (OP6) (4 years)	Planning Engineer (BSc, MSc)	SynchroPro
Interviewee 7 (OP7) (5 years)	Operations Engineer	Automatic Detection System

TM Top management, *OP* Operatives

OP4: '*When there is a change, I learn how to change myself first. I change my habit. This is a good change, so it just takes some time, and gradually all the staff will follow the system.*'

From the exploratory study conducted, individual adaptability is operationalised as work behaviours relating to '*Learning new work tasks, technologies, and procedures*', which is identified by Pulakos (Pulakos et al. 2012) as one of the sub-dimensions of adaptability. Adaptability can be learned and changed; hence, it is more malleable than individual traits (Ployhart et al. 2006). A high-learning orientation contributes to individual adaptive behaviours which are established mostly through training programmes organised by their firms.

4 Conclusion

This study utilised an exploratory approach to understanding the challenges regarding technological changes in construction organisations and the associated adaptive behaviours. It reveals that top management does not involve operatives in decision-making processes towards changing technological processes, which could be a contributing factor to the resistance shown by workers towards change. The study identified leadership skills, experience and open-mindedness as significant predictors of adaptive behaviours in the context of technological change. In the said context, operatives adapt by learning new tasks, technologies and procedures. Such learning experiences mostly occur during effective training programmes. The results show that individuals are willing to accept and adapt to changes in technology if they understand the benefit or value it will bring to them. This confirms one of Homan's five basic propositions about human behaviour, which states that individuals are more likely to perform actions if there are valuable rewards. Technological changes or advancements vary from one organisation to another; hence, it is suggested that information about technologies which are successfully used on projects should be shared across the industry so that people become exposed to the change. By considering adaptability as a performance construct, (Pulakos et al. 2012) focused on learning new tasks, as well as the technology and the procedural dimension of adaptability, which was equated to trainability. Trainability is an inherent part of successful adaptation in response to technological change to acquire and apply expertise to solve problems creatively. While the exploratory approach is used to explore the research question, more data is required to confirm the findings and make them more generalisable. This study is followed by an intensive case study which will allow us to explore trainability and adaptability with greater precision.

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Undesired Contractual Behaviour of Key Participants in Civil Engineering Projects

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Abstract

The most important key participants in a construction project are the integration between different entities comprising client, the multidisciplinary consultants (architect, engineers, surveyors) and the contractors. Thus, the contract is needed to protect the contracting parties against opportunistic behaviour and other risks in business relations besides to govern the project implementation in achieving the project goals. Unfortunately, literature has replete with the problems rendered in construction projects caused by the behaviour of key participants who do not duly adhere to the contract in the project implementation. Therefore, this paper aims to identify the common undesired contractual behaviours of key participants in civil engineering projects which largely reported as one of the major factors affecting the project performance. 288 feedbacks received out of 700 questionnaires distributed to the G7 CIDB registered contractors and professional engineers registered under the Board of Engineers Malaysia. Descriptive analysis and Mann-Whitney U test were used in data analysis. The findings revealed that among the seven (7) undesired contractual behaviours investigated in this study, the delay in making payment was ranked as the highest occurrence followed by the delay in work progress, delay in issuing drawings and information and delay in site possession. Poor communication and unauthorised instruction were considered as moderate while client direct instruction was a very low occurrence in civil engineering projects. In the attempt to observe the performance of civil engineering projects in Malaysia, the four high occurrence contractual behaviours are critical to be put more concern.

Keywords

Civil engineering • Contractual behavior • Contract • Project performance

1 Introduction

Civil engineering projects are unique. Their natures are very different to that of general building construction where mostly they have to be designed for some specific purposes and specific location before they can be constructed and put into use. This makes, civil engineering projects are the projects that mainly full of uncertainty and most of the time quite complex, difficult to manage and replete with undesired behaviour of project key participants. Although, the standard form of contract used for a civil engineering project provides a consensus as to allocating risks and responsibilities of every key participants of the project, unfortunately, literature are still replete with the behaviour of them who fail to duly obey it (Alaghbari et al. 2007) where eventually reduce the project success. This shows that the problems rendered in construction projects caused by the behaviour of key participants who do not duly adhere to the contract in the project implementation. Thus, in this study, the term 'contractual behaviours of key participants' is referring to an action or a conduct of a key participant towards other key participants of the project based on what are stipulated in the agreed contract. In other words, the contractual behaviours of project key participants is referred to what extent the contract is implemented by the people who make decision by the contract.

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One of the common undesired contractual behaviour of key participants that rendered in construction industry is that the delay in interim payment made by the client. The delay in making interim payment to the contractor will cause big impact to the project implementation and eventually lead to the project failure. In fact in Malaysian context, the delay in making interim payment was ranked as first in client related cause of project delay (Sambasivan and Soon 2007). On the other hand, the weaknesses of payment by the client in terms of the payment amount which is less that the actual workdone also become a factor that lead to disputes between the project participants.

Besides, Chini and Valdez (2003) stated that the undesired contractual behaviour of the architect also will reduce the project success. The failure of the architect to accordingly follow the standard form contract could lead to problems in project implementation such as delays, cost overruns and dispute among the project participants. On top of that, the failure of the contractor to comply with the standard construction method and failure to comply with the approved work program (Jaffar et al. 2011) are among the factors caused by contractor that contribute to the project failure. In general building project study, other undesired contractual behaviour of participants of project such as direct instruction by the client to the contractor (Hassanein and Nemr 2008); late in certifying certifications (Jatarona et al. 2016); and communication skill of contractors (Mitkus and Mitkus 2014) also among important undesired contractual behaviour that contribute to the project failure. Regrettably, the study on the contractual behaviour of key participants of civil engineering projects are very limited. This provides impetus to study and explore the occurrence of the aforementioned undesired contractual behaviour in civil engineering projects. In this study, the undesired contractual behaviour of key participants' variables used were "delay in payment", "delay in work progress", "delay in issuing drawing and information", "delay in site possession", "poor communication", "unauthorised instruction" and "client direct instruction".

2 Research Methodology

This study adopted a quantitative approach using questionnaire survey where the process started with an intensive literature review to identify the project performance criteria to be used in this study, the common undesired contractual behaviours of key participants which have the possibility in affecting the project performance. It is found that seven contractual behaviours of key participants i.e. "delay in payment", "delay in work progress", "delay in issuing drawing and information", "delay in site possession", "poor communication", "unauthorised instruction" and "client direct instruction".

Next, to ensure the validity of variables gained from literature reviews, preliminary questionnaire survey was piloted to G7 contractors and consultant engineers. This phase has formed the foundation for subsequent phase and assisted in the design of the main survey. 12 responses gained by the cut-off date given and then the Reliability Test using Cronbach's alpha coefficient test was performed and the value of the test was 0.739, which was more than 0.7. This indicates that the 5-point Likert scale measurement was reliable, and the main questionnaire survey could be carried out to all respondents. The 5-point Likert scale used to determine the common undesired contractual behaviour of key participants in civil engineering projects with values on the scale was as follows: 1 as "very low", 2 as "low", 3 as "moderate", 4 as "high" and 5 as "very high". Hence, factors with mean values between 4 and 5 were considered as having very high occurrence on contractual behaviour of key participants in civil engineering projects.

Out of 700 numbers of questionnaire sent out, only 288 numbers returned before cut-off date (deadline) given representing 41% response rate. The data gathered was analysed using statistical software SPSS version 21. Descriptive analysis and Mann-Whitney U test were used to analysed the data.

3 Results

In terms of respondent profile, the respondents of this study consist of 52% contractors and 48% engineers (see Table 1) with 100% of their position at their respective organisations are at executive level (see Table 2). Furthermore, the respondents' working experience in road projects were 40% more than 10 years' experience, 52% have experience between 5 and 10 years and only 8% have experience between 1 and 5 years (see Table 3). These indicate that the respondents of this study were capable and competent enough to participate in this study.

The objective of this study was to identify the common contractual behavior of key participants in civil engineering projects particularly from the perspective of contractor and engineer (representing the client and as the consultant team leader). This was achieved by determining the frequency of occurrence of contractual behavior of key participants in the respondents' most civil engineering projects. The common undesired contractual behavior of key participants in civil engineering project rated by all respondents were tabulated in Table 4. Meanwhile in Table 5, the comparison of undesired contractual behavior of key participants rank rated by both contractor and engineer respondents.

Table 1 Respondents' organization

Respondent's organisation	Percentage (%)
Contractor	52
Engineer	48

Table 2 Respondents' position in their organisation

Respondents position in their organisation	Engineer		Contractor	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Manager	17	12	19	12.60
Civil engineer	120	88	20	13
Quantity surveyor	0	0	112	74.20
Total	137	100	151	100

Table 3 Respondents' working experience

Respondent's experience in road projects	Percentage (%)
2–5 years	8
5–10 years	46
More than 10 years	46

Table 4 Undesired contractual behavior of key participants in civil engineering projects rated by all respondents

Undesired contractual behaviour of key participants	N	Mean	Standard deviation	
Rank				
Delay in payment	288	4.04	0.247	1
Delay in work progress	288	3.78	0.441	2
Delay in issuing drawing and information	288	3.42	0.495	3
Delay in site possession	288	3.42	0.494	4
Poor communication	288	3.37	0.483	5
Unauthorised instruction	288	3.27	0.443	6
Client direct instruction	288	1.84	0.903	7

Table 5 Undesired contractual behavior of key participants in civil engineering projects based on contractor and engineer perception

Contractual behaviour of key participants	Overall			Engineer			Contractor			Mann-Whitney U
	N	Mean	Rank	N	Mean	Rank	N	Mean	Rank	
Delay in payment	288	4.04	1	137	4.01	1	151	4.07	1	0.025
Delay in work progress	288	3.78	2	137	3.89	2	151	3.68	2	0.000*
Delay in issuing drawing and information	288	3.42	3	137	3.34	3	151	3.50	4	0.006*
Delay in site possession Poor	288	3.42	3	137	3.34	3	151	3.66	3	0.000*
Poor communication	288	3.27	5	137	3.34	4	151	3.40	5	0.280
Unauthorised instruction	288	3.27	6	137	3.17	6	151	3.36	6	0.000*
Client direct instruction	288	1.84	7	137	1.68	7	151	1.99	7	0.004*

4 Discussion

Following the interpretation of the 5-point Likert scale, the analysis of the survey data indicated that out of the mean scores for the seven contractual behaviour of key participants rated by overall respondents, only “delay in payment” seen to have very high occurrence in civil engineering projects with mean value of 4.04. For moderate occurrence of contractual behaviour of key participants, “delay in work progress” by contractor (M = 3.78) was ranked as the second-high occurrence, followed by “delay in issuing drawing and information” (M = 3.42), “delay in site possession” (M = 3.42), “poor communication” between engineer and contractor (M = 3.37) and “unauthorised instruction” (M = 3.27). Meanwhile, with the mean value of 1.84, the “client direct instruction” seen to have low occurrence in civil engineering projects. However, by referring to Table 5, there was slightly difference opinion between engineer and contractor on the rank order of contractual behaviour of key participants with sig. p-values less than 0.05 (marked with asterisk). The significance of difference of the rank was tested using Mann-Whitney U test.

Both contractor and engineer opinion showed that “delay in payment” was the most frequent undesired contractual behavior of key participants occur in civil engineering projects with Mean value 4.07 and 4.01 respectively. This finding supports the literature that “delay in making payment” has given severe impacts on the project performance (Sambasivan and Soon 2007; Shehu et al. 2014). With the cut off mean value of 3.50, both contractor and engineer admitted that “delay in work progress” was moderate-to high occurence in civil engineering projects.

This finding also in line with Alaghbari et al. (2007), Sambasivan and Soon (2007), Jaffar et al. (2011), Cheung et al. (2008) and Lo et al. (2006) who claimed that delay in work progress by contractor mainly lead to construction time overruns. On top of that, the “delay in issuing drawing and information” as well as “delay in site possession” also perceived by contractor as the moderate-to high occurrence of undesired contractual behavior of key participants in their most civil engineering projects. “poor communication” and “unauthorised instruction” were considered as moderate occurrence in this study with Mean value ranged between 3.17 to 3.40. Meanwhile, the result showed that the “client direct instruction” was very low occurrence in civil engineering projects with Mean value of 1.68 and 1.99 rated by engineer and contactor respectively.

5 Conclusions

Civil engineering projects in Malaysia mostly associated with severe cost and time overruns with unsatisfactory quality. Due to its important to national development and economic activities a mitigating action must be put into civil engineering projects to ensure the future projects can be delivered satisfactorily as required. The outcome of this study contribute by identifying the undesired contractual behaviours of key participants affecting the previous civil engineering projects’ performance. The “delay in making payment” towards contractor was perceived to have highly occurrence in civil engineering projects and might all this while highly cause their poor project performance. Thus this undesired contractual behavior must be put more concern. Other than that, “delay in work progress”, “delay in issuing drawings and information” and “delay in site possession” also have potential to affect project performance. Therefore, these four undesired contractual behaviours of key participants in civil engineering projects need to be given more attention by the government and project participants to ensure we can deliver project satisfactorily.

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Modular Versus Conventional Construction: An Analysis of Cost and Benefits via a Case Study

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Abstract

This paper presents a broad analysis of the cost and benefits of the two main construction methods currently in use in North America—the conventional construction and the modular construction. The main goal is to provide a cost estimate of the implications of both construction methods for low-rise apartment buildings as well as to determine which one is more cost-effective. The methodology consists of a qualitative analysis that outlines the benefits of each construction method over the other, and a quantitative analysis that compares the cost of the finished building per square foot. Both analyses are conducted by evaluating a case study of a five-story low-rise senior residential building with similar characteristics, one built using conventional method and the other built hypothetically with modules. The benefits identified for the conventional low-rise building include later design changes, easy to understand for investors, less logistics, and easy to manage. On the other hand, the benefits for modular low-rise are higher quality control, less on-site work, and less on-site trades. The quantitative results show that the modular construction method is only marginally more cost-effective than the conventional construction method under the same circumstances. Through the proposed method, the contractors and developers can assess the cost-effectiveness of the two construction methods for low-rise residential apartment projects to make informed decisions.

Keywords

Conventional construction • Modular construction • Construction costs • Prefabrication • Decision making

1 Introduction

Traditional stick-built construction is the most common type of construction method in North America and many other parts of the world. The entire building is constructed on the site and offers the most flexibility for in-house designing [1]. A modular building on the other hand is defined as "a building that is partially built in a plant, shipped to a development site, and placed on a foundation, where the roof structure and exterior finishes are completed" [1]. The important difference between the two construction methods is the amount of work on-site. For the conventional construction, the majority of work is completed on-site whereas for the modular construction the majority of work is done off-site. Both systems have implications that make them valuable alternatives to each other, but the question of how to know which one to select or which one is a better fit for a specific project still exist.

This paper seeks to answer the following question, "Which construction method is more cost-effective, conventional or modular?" Therefore, the main goal of this paper is to provide a comprehensive analysis of the cost and benefits of each construction method using a low-rise five-story residential building as a case study. The results will establish which method is more cost-effective and what are the tradeoffs when choosing between the two.

2 Methodology

This paper implements both a quantitative and qualitative analysis in relating to the two construction methods: modular and conventional. The qualitative analysis involves a

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summary of the advantages of each construction method over the other in order to suggest a framework of the implications of each method and the potential tradeoffs that would have to be made by choosing one method over the other. The quantitative analysis compares the cost of the finished building per square foot built using each method. The scope of the research is limited to a five-story residential building that is used as a case study. The details of the case study building are provided in the next section.

3 The Case Study Project

The case study project is a five-story senior residential building named "Cochrane Senior Residential Building" is located in Alberta, Canada as shown in Fig. 1. Its cost estimates were prepared in 2016. Construction phase started in Summer 2016 and the building completed in October 2017. The total duration of the project was 20 months.

Cochrane Senior Residential Building project is a five-story building with one floor for underground parking. The building is originally designed based on concrete structural system using concrete columns and concrete suspended slabs. The building consisted of 59 single bedrooms and 16 double bedrooms. Approximate size of each unit is 7.5 m by 11 m. The original design consisted of two central staircase and one passenger elevator with six stops. The external cladding is metal and aluminum composite panels are used for doors and windows. The roof system is designed based on SBS modified bituminous membrane roofing. In the first step, estimates of this building were prepared using conventional construction methods.

As the second step, the same building with similar characteristics of interior finishes was estimated if it was built with modules. In order to estimate the cost of modular construction for the building, the following assumptions were made: (1) Each apartment to be built of two modules, the modules are approximately 3.3–3.7 m wide and 9 m to 11 m long; (2) Two modules will form one apartment with either one or two bedrooms, depending on the length of the module; (3) The estimated cost for the modules are carried based on the modules to be designed with partially open sides with K-Bracing; (4) All 150 modules are expected to be installed in 5 months, and finishing work to be completed

Fig. 1 Modules selected for the case study project construction

in the following 4 months; and (5) The 2.5 m wide prefabricated stairs and elevator shaft are also considered as modules. The project schedules and floor plans for both alternatives are included in Appendices A and B.

4 Qualitative Analysis

4.1 Benefits of Conventional Construction Method

The first benefit that the conventional construction method has over the modular construction method is its flexibility to take almost any shape and does not limit creativity [2]. Moreover, in the conventional method, alteration can be made at the last minute, as long as the formwork and rebar are not ready. It is also easy to monitor and coordinate because the whole production activities are conducted on-site [2]. In addition, there are many players in the industry that make the market competitive which will guaranty the best price. On the other hand, there are some disadvantages in conventional construction such as not easy to control the quality of the finished work, labor intensive, unfavorable site condition due to weather, lower work safety compared to off-site construction, and relatively slower speed of construction [3, 5].

4.2 Benefits of Modular Construction

The main advantage that the modular construction method offers is quality control [1]. Modules are almost entirely built in manufacturing facilities, which allow for better quality control and higher quality outcomes. Next, the fieldwork required in modular construction is considerably lower given that the majority of the building components arrive at the construction site over 90% complete [3]. In addition, modular fabrication manufacturing can be done simultaneously with foundation works at the job site. This overlap can reduce project time and save money [4, 6].

5 Quantitative Analysis

To implement the quantitative analysis, the conventional project and the modular project were compared in terms of the actual construction and manufacturing costs to build and fully finish the building. However, some costs were taken off from the analysis such as land, site earthwork, site services, foundation works, bonds and insurance cost, fees and permits, which were not taken into account because they indicate common costs related to the site and not subjective by the construction method.

Table 1 shows the cost per division for each project in USD per square foot.

In Table 1, the duration for the conventional method is 20 months whereas the completion time for the modular construction is estimated to be 16 months. Division 1.1—project indirect cost—includes project staff and temporary services such as site office, site mobilization and demobilization. Indirect cost will be lower for modular construction due to shorter project time. Division 1.2—Construction equipment—includes the cost of small construction equipment such as skid steer, site vehicle, and material handler for the conventional project, and one 120 tones crane plus transportation cost for modular units. Earthwork cost in division 2 would be the same for two projects. In division 3, the concrete cost for conventional construction is almost 4 times more than the concrete cost in modular construction. This cost, however, is offset in division 5 where the steel framing for modular units increases drastically to $35.63 compared to $1.30 in conventional construction. For divisions 6–16, the cost of material is almost the same, however there is an average of 9–11% of cost saving on labor cost. This is most likely due to work on shop in a weather-protected area which would result in higher labor productivity and lower construction time.

The results of the analysis demonstrate that the modular construction method is more cost-effective, with a cost difference of approximately 11%. Between the two methods, most of the cost items have similar costs such as cost for interior finishes materials, however, the major difference can be seen on the cost of the on-site interior work, due mostly to the increase in amount of labor and time required for the electrical, mechanical and drywall trades for installing and connecting their respective systems or elements.

6 Discussion on Results

As detailed in the previous section, the quantitative results show that the modular construction method has an approximately 11% lower cost than the conventional construction method, but that difference is not large enough to outweigh any other considerations. Hence, qualitative aspects should also be considered. When choosing the construction method for any construction project, there are always tradeoffs to be made, considering the advantages of one method in contrast to its disadvantages. Therefore, a qualitative analysis should definitely be combined with quantitative cost evaluation.

For this specific case, performing modular method would contain the following main tradeoffs:

Table 1 Results of quantitative analysis for conventional and modular construction

Work Item	Description	Conventional construction (UD$/S.F)	Modular construction (US$/S.F)
Project duration	–	20 months	16 months
Division 1.1	Indirect cost	$19.57	$13.21
Division 1.2	Construction equipment (crane and trucks)	$1.17	$5.38
Division 2	Earth working and	$7.55	$7.55
Division 4	Masonry	$5.4	$3.06
Division 5	Steel structure framing	$0.96	$26.44
Division 6	Millwork and carpentry	$9.97	$7.97
Division 7	Roofing and siding	$12.19	$14.62
Division 8	Doors and windows	$7.90	$6.79
Division 9	Interior finishes	$24.44	$21.77
Division 10	Specialties	$1.31	$1.12
Division 11	Equipment	$2.69	$2.23
Division 12	Furnishings	–	–
Division 13	General building items	–	–
Division 15	Mechanical systems	$26.31	$23.67
Division 16	Electrical systems	$13.69	$12.32
Division 17	Design fee	$11.79	$12.00
Total Cost/S.F		**$195.39/S.F**	**$173.31/S.F**

(1) Restricted flexibility; Module sizes and shapes can be limiting; (2) Poorer overall design/aesthetic quality; and (3) Design that is not fully context or user specific [3].

There are a number of factors that could affect the quantitative analysis results, including (1) Difficulty transporting and handling modules, because transportation of the larger and heavier manufactured elements and installation equipment would be more expensive and more difficult; (2) The significant investment required to develop designs and manufacturing processes for modular buildings; [4] (3) a location's extreme climate, which could change the building's needs in terms of insulation and more efficient heating/cooling systems [1].

7 Conclusions

An analysis method has been proposed to evaluate conventional construction versus modular construction methods using a mixed-methods approach based on cost per square foot of construction, and by listing benefits of each construction method and thinking about the compromises between them. Through this approach, it is possible to evaluate the cost-effectiveness of the two construction methods for low-rise modular apartment projects in a way that could serve as a valuable tool for decision making.

This paper concludes that modular construction method is marginally more cost-effective than conventional construction method for the specific case study and under the specified conditions. It also delivers a discussion of the tradeoffs when choosing the modular method over the conventional method. Both the qualitative and the quantitative analysis developed in this paper are specific for the case study, and although results are meant to apply for other low-rise modular apartment projects in North America, each project has its own features and some of them could considerably change the results.

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Appendix 1—Project Schedules

Schedule for Conventional Construction.
Schedule for Modular Construction.

Appendix 2—Comparison of the Floor Plans

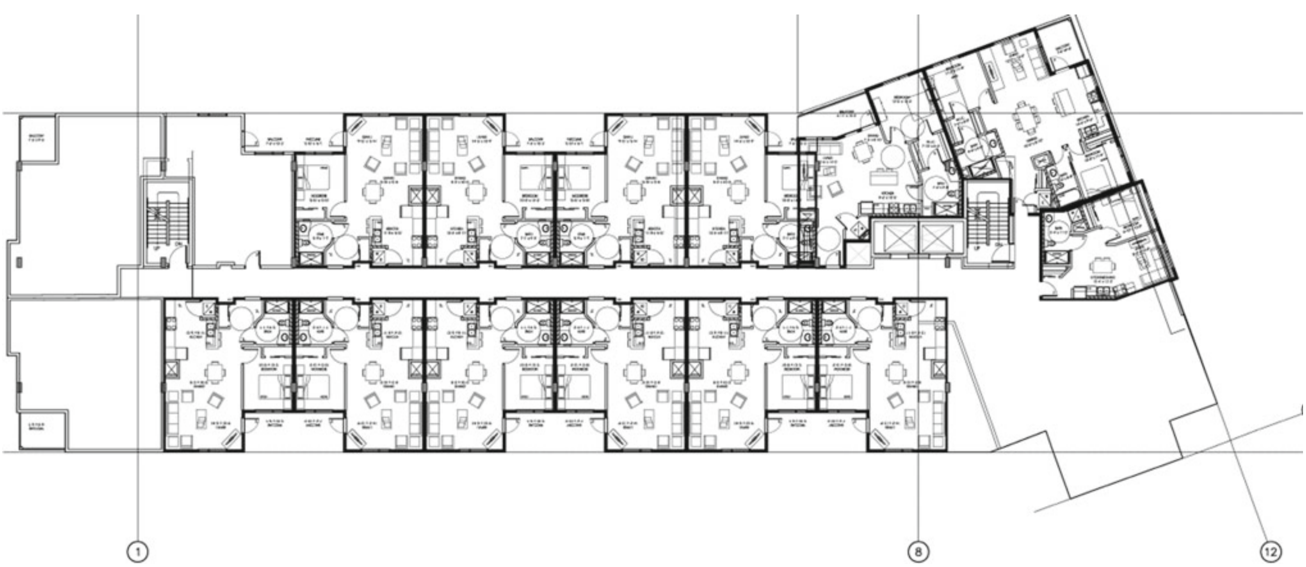
Cochrane Residential Building—The Original Floor Plan.
Cochrane Residential Building—The Modular Floor Plan.

Conventional (On-Site) Construction Schedule

Description	Month																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Sub-Structure	■	■																		
Construction			■	■	■	■	■	■	■	■	■	■	■							
Cladding & Roofing												■	■	■	■	■				
On-Site Services												■	■	■	■	■				
Partitioning and Boarding													■	■	■	■	■	■	■	
Finishing fitments														■	■	■	■	■	■	■

Modular Construction Schedule

Description	Month																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Sub-Structure	■	■																		
Manufacture	■	■	■	■	■	■														
Installation						■	■	■	■	■										
Cladding & Roofing								■	■	■	■	■								
On-Site Services									■	■	■	■	■							
Finishing													■	■	■	■				



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Academic Satisfaction and Career Preparedness: An Exploratory Study on the Perceptions of Construction Management Graduates

Lewis Waller, Delasio Foust, and Kamalesh Panthi

Abstract

When students graduate from higher education, their objective is to gain employment in a field of study where they can utilize the skills they have obtained. Many Construction Management programs are designed to encompass within four years, as much academic knowledge and training pertaining to the construction industry the program is designed around. However, there is often a disconnect between what is taught in the curriculum and the skills that is valued in the workplace. Many higher education programs want to know whether their program provides the necessary skills for their students' success. Students' satisfaction is one major indicator of their success and by conducting a survey of the students' satisfaction level in relation to their education and job, programs often define areas that need improvement so they can create the best possible learning environment for the students. The objective of this research is to discover whether the Construction Management program is meeting the needs of its students. With this knowledge, the Construction Management program can address the areas that may require further development, making the program more satisfying for current and future students.

Keywords

Construction management • Job satisfaction • Academic satisfaction

1 Introduction

When students graduate, they want to be satisfied with their major, and they want that satisfaction to transition over from their major to their perspective career. "The closer the fit between an individual's major and subsequent job field, the more satisfied they should feel with their work experience" (Wolniak and Pascarella 2005). However, "the evidence on the effects of education on job satisfaction is rather limited," as stated by Vila and Garcia-Mora (2005).

Academia satisfaction is researched using such factors as GPA, time to finish a major, or academic performance. Graunke and Woosley wrote, "For research and practice with college students, major satisfaction represents an important construct in its own right, as it is associated with academic performance" (Nauta 2007). Job satisfaction, like academic satisfaction, has a set of recurring factors seen throughout research, such as hours worked, pay, and benefits—but rarely is academia satisfaction included. "It is not clearly understood how specific college experiences affect the acquisition of better, more intrinsically rewarding work experiences" (Leslie and Brinkman 1988).

Satisfaction is important in both academics and career, and it is something most individuals seek on a personal level. Students want satisfaction of their major and from their universities; likewise institutions make goals to provide satisfaction; thus, one can find abundant research and information on satisfaction. "The subject of job satisfaction and dissatisfaction has attracted a considerable amount of research. It is by far one of the most studied work attitudes by organizational behavior researchers" (Ghazzawi 2008). Research on satisfaction is conducted not only to know whether the employees are satisfied but also to correct the causes of dissatisfaction. "The purpose of employee satisfaction surveys are not only to discover employee satisfaction levels, but also to determine necessary improvements via the results of employee satisfaction surveys" (Chen et al. 2006). With these determinations, employers can seek to

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improve their employees' satisfaction, which will hopefully translate to benefits on the job, such as employee productivity.

This is highlighted in Vila and Garcia's (2005) first of two main approaches, using job satisfaction as an economic variable. "Analyses here focus on the impact of job satisfaction on diverse aspects of workers' labour market behaviour, such as productivity, absenteeism, turnover, quits and punctuality" (Vila and Garcia-Mora 2005, p. 411). Like businesses, universities and program facilitators seek knowledge from satisfaction surveys. The objective of these surveys is to improve the program, benefitting school, major, or program of study.

2 Research Purpose

Four-year degree programs are designed and implemented to prepare students for their future careers in the workplace; therefore job satisfaction is crucial for graduates upon obtaining a position in their area of study. This research seeks to assess academic and career satisfaction, with a focus on construction management students who have graduated from a university located in the Southeastern part of the United States. The objective is to determine whether the students were satisfied with their academic studies; and how well the knowledge they obtained transferred over to their first job in the construction industry. Did they gain job satisfaction because they were well-prepared through their higher education or were they dissatisfied because what they learned was insufficient or unrelated, perhaps leading to frustration within their working career? Regardless of the reason for satisfaction or dissatisfaction, the aim of this research is to discover whether the Construction Management program is effectively preparing its students for their career. With the findings from this study, the Construction Management program can address the areas that may require further development in an effort to improve the capacity of the program to satisfy current and future students.

3 Literature Review

With the advancement of construction management technology and practices, it is in the best interest of the Construction Management (CM) program to align student's knowledge with industry learning outcomes. As McDermott notes, "Change is a force constantly shaping the economy, society, and construction. In order to be successful, it is important for organizations involved with the construction industry to stay abreast of the current state of affairs, both locally and globally" (McDermott 2009).

According to McDermott (2009) it is significant that the construction industry foresees and prepare for the future while operating in the market conditions of the present. Likewise, the Construction Management (CM) programs must be mindful of the current and future conditions because as the industry changes and adapts, so must their CM program. This follow-up study allows the Construction Management program to address issues that former students perceive would improve the program through their experiences in the workplace.

In McDermott's study (2009), the research focused on the future of the construction industry and the implications of project management and education. The researchers addressed four key drivers that would affects the construction industry, such as workforce issues, "increasing environmental considerations, global growth and interconnectedness, and productivity and efficiency improvements" (McDermott 2009, p. 101). These changing trends and key drivers increased the level of difficulty to obtain knowledge within the construction industry. Therefore, it can be a challenge to ensure that the CM program generates satisfaction among their students and meet the employee expectations. Again, CM programs must prepare students for successful careers.

The Construction Management industry is driven by several factors; therefore, graduates must implement both soft skills and hard skills. Also, graduates must have a desire to advance and improve the industry, by utilizing practical knowledge gained in their program of study. It can be a challenge for many graduates to be successful from the academic to the workforce without practical on the job experiences through intern and co-ops build in the program. Rojas and Dossick (2008) specified that "one of the major challenges in Construction Engineering and Management education is incorporating practical knowledge from the field and practice of construction into classroom environments" (Rojas and Dossick 2008, p. 67).

The review of literature cited and discussed above provides background on the relevance of follow-up studies and on how program facilitators and others can take advantage of them. Such knowledge provides a foundation for this current study, the objective is to determine whether the students of the Construction Management program at a particular University in the South East USA (name concealed) were satisfied with the program and with the effects, if any, that it had on their career within the construction industry.

4 Methodology

This research on academic and job satisfaction was conducted using a questionnaire developed by the research team. The survey questionnaire focused on three areas:

demographics, academic satisfaction, and job satisfaction. The survey was developed using Survey Monkey and sent via Facebook and emails to students who graduated between 2002 and 2011 from a Construction Management program at a higher institution in the Southeast region of the United States. The data indicated that the recent students provided the most valuable information because they shared current insight about the latest program of study and practices based on their job evaluations and success on the job site.

The survey results were collected and analyzed regarding the graduates perceptions of the Construction Management program. By gaining insight from former students, the program facilitators and professors can implement strategies which can improve their program. The findings can provide CM programs and other disciplines with the information necessary to meet the needs of CM students and the demands of the CM industry.

The survey consisted of two parts: Part 1—Biographic information and Part 2—Education and Job satisfaction. The research provides feedback about the following areas:

1. The students' satisfaction about the CM program.
2. The students' satisfaction about their preparation for entry into the field of construction.

The responses from former students regarding their satisfaction within these areas provided data to assist the Construction Management department in evaluating the department.

Data was collected using a 5-point Likert scale, ranging from 5 (strongly agree) to 0 (no opinion). Partial agreement with the question received a value of 3 from that respondent. After all the responses were collected and averaged, a mean score was given to each question. The mean score represented the feelings of the group as a whole to the particular question; thus, for example, a mean value of 4 meant that the majority of the respondents agreed with the statement.

5 Results

5.1 Demographic Characteristics

This survey was intended for all graduates from the Construction Management program. The survey instrument was sent to 65 participants; however, only 36 responded to the survey, and 3 of those who responded did not complete the survey.

Where N appears in the responses, it represents the number of respondents who responded to the statement. A total of 91.7% of the respondents were employed, and 78.8% were employed within the construction industry. Six of the respondents had obtained advanced degrees, also six of the respondents were currently seeking an advanced degree, most obtaining or had obtained a degree in Construction Management.

5.2 Education Satisfaction

The education satisfaction section of the survey consisted of 18 questions relating to various aspects of the Construction Management curriculum. These questions were presented using the Likert scale and were placed in the order of their average in Table 1, focusing primarily on what the students agreed with most through least. The averages ranged from 5 to 0; with 5 = strongly agree, 4 = agree, 3 = partially agree, 2 = disagree, 1 = strongly disagree, and 0 = no opinion.

5.3 Employment Satisfaction

The employment satisfaction section of the survey contained 11 questions. In their jobs or career, respondents were for the most part satisfied with their work. The responses in Table 2 show that the averages ranged from 4.15 (agree) to 1.61 (completely disagree).

6 Discussion and Conclusion

The education section of the survey addressed multiple concepts that provide a holistic view of the respondents' opinion about their education. To obtain this holistic view, the questions were grouped into three categories for analysis: preparedness, services/help, and effectiveness/satisfaction. The three categories address what students and the department consider in determining the quality of their program. Preparedness relates to how well the respondents felt that the program developed their skills for the construction industry. Services and help relates to how well the school and department provided needed assistance and resources for students to ensure that they succeeded within the program. Finally, effectiveness entails how well the respondents felt that they were taught. The program might have taught the students the expectations of construction companies, but if the teaching or learning was not effective, it can hinder students progress in their careers.

Preparedness: The overall average of the responses to each question was "partially agree"; thus, one may conclude that the respondents thought some omitted details would have been significant to their preparedness to work in the construction industry.

Interaction and communication are factors of preparedness to work within the construction industry or any

Table 1 Graduates' satisfaction with education

Question	N	Avg.	Rank
Most of my classes included sufficient group interaction	33	3.88	1st
Overall I am extremely satisfied with the experience I had at the University	34	3.71	2nd
I feel the teaching within my major was effective	34	3.65	3rd
Resources and information for my major were easily obtainable	34	3.68	4th
My degree in Construction Management contributed to my fulfillment in my job	34	3.62	5th
The group interaction within my major was productive and effective	34	3.59	6th
The class lectures within the major were effective in meeting my learning needs	34	3.56	7th
My major provided resources to help me find employment after graduation	34	3.53	8th
The professors in my major taught current practices	34	3.56	9th
My construction management degree prepared/positioned me for future advancement	34	3.44	10th
Career advice I received from my advisor and professors was satisfactory	34	3.35	11th
My education in construction management contributed greatly to my overall satisfaction within the construction industry	33	3.33	12th
My professors were current in practices applicable to technology and techniques within the construction industry	34	3.32	13th
Help I received from my academic advisor was satisfactory	34	3.32	14th
I was effectively prepared to interact and communicate within the field of construction management	34	3.32	15th
The teaching I received within my major prepared me to work within the construction industry	34	3.32	16th
My major prepared me for the challenges of the work environment of the construction industry	34	3.09	17th
Services provided by the on-campus career center were very effective and helpful	34	3.09	18th

Table 2 Graduates' satisfaction in employment

Question	N	Avg.	Rank
I find my job pretty interesting	33	4.15	1st
Most days I am enthusiastic about my work	33	3.97	2nd
I find real enjoyment in my work	33	3.88	3rd
I am satisfied with my job for the time being	33	3.76	4th
I look forward to going to work most days	33	3.76	5th
I feel satisfied with my present job	33	3.55	6th
My job is like a hobby to me	33	3.12	7th
I would rather have another job	33	1.94	8th
I consider my job rather unpleasant	31	1.77	9th
I definitely dislike my work	33	1.61	10th
Most of the time, I have to force myself to go to work	33	1.58	11th

industry; individuals must be able to communicate well in aspects such as terminology, correspondence, and so forth.

Education Services/Help: Higher education is a time not just for learning but also for asking questions and making connections. As students progress through their academic career, they will require help, guidance, and access to resources outside the class. Without such resources and help from professors and advisors, an academic curriculum can become frustrating; with that frustration, students may develop a dislike for the program.

The participants responded to five questions that related to the area of services and help. The responses indicated that the respondents felt they did not completely receive the help they should have had and did not have access to the resources needed, required, or wanted. The questions relating to services and help ranked from 4 to 18th as shown in

Table 1. The average response to each question was "partially agree," with the exception of the statement that "Services provided by the on-campus career center were very effective and helpful"; this one was ranked last, with an average response from the respondents of "disagree," at 2.91. The statement that "Resources and information for my major were easily obtainable" received an average score of 3.68, ranking 4th. "My major provided resources to help me find employment after graduation" averaged 3.53, ranking 8th. "Career advice I received from my advisor and professors was satisfactory" averaged 3.35, ranking 11th. Finally, "Help I received from my academic advisor was satisfactory" averaged 3.32, ranking 14th.

Respondents deemed the inclusion of group interaction the best item in the construction management program. "Most of my classes included sufficient group interaction" was the highest-ranked question, with an average of 3.88, but respondents did not rank the efficiency and productivity of these group interactions as well. "The group interaction within my major was productive and effective" received an average score of 3.59, ranking in 6th position in Table 1. Because group interaction is a valuable skill to students in Construction Management, the respondents' positive ranking of it is a positive sign; however, overall, the respondents only partially agreed with that statement. They also partially agreed that the group interaction was efficient and productive, revealing that although there is group activity, professors should make sure that students are using the time in an appropriate and beneficial way. They also need to ensure that the group activities they assign or incorporate meet the needs of the curriculum.

Employment Satisfaction: For most people, working is a lifelong process, and a career is a major part of most individuals' life; hence, people have feelings of some kind about their career. As individuals progress throughout their career, those who have been in their particular career for a good amount of time probably have strong, positive feelings about it. Some individuals know from the beginning what they want in a career, while others stumble into their career by chance. Regardless, those who are satisfied with their career will stay with it and do well within their career.

According to the survey responses, respondents were (on average) satisfied with their career within the construction industry. The two highest-rated responses within the employment satisfaction were "I find my job pretty interesting" and "Most days I am enthusiastic about my work." Many areas of one's job may yield satisfaction, but those two statements probably have the most influence. As individuals, we have a natural interest in whatever we do, and with that interest, enthusiasm is created. The respondents agreed that they find their jobs interesting and that most days they are enthusiastic about their work; the average response was 3.97, only 0.03 away from "agree." When they are interested, individuals tend to want to go back to learn, participate, or support whatever the interest is. With the respondents having such a strong interest, it is likely that they will continue to want to learn and participate within their career; clearly, the majority of the respondents want to be involved in their work and participate because they want to, not because they have to.

Job satisfaction has many aspects and levels; only some aspects relate to the program, but knowledge of these aspects can help the program prepare students for work environments. Allen states: "for students, major satisfaction is analogous to job satisfaction because, like work environments, academic environments vary with respect to reinforcer patterns, opportunities to use various skills and interest, and opportunities to implement one's self-concept" (Nauta 2007, p. 447).

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Land Use Optimization Based on Transit-Oriented Development with Linear Programming

Mohammed Ali Berawi, Van Basten, Fuad Adrian Iskandar, and Gunawan Gunawan

Abstract

The large-scale and continuous increase in the number of urbanization make the daily needs in urban areas more diverse and significantly following to increase. The basic needs become the main thing to make the stability and survival of the city area that must get support from the surrounding environment. The concept of transit-oriented development (TOD) is present to help the direction of the urban development program. The main problem is how to determine the priority function or designation of an urban area effectively. This research tends to attempt the function optimization in the urban area so that the infrastructure development can support urban progress effectively. Research began with qualitative methods which validation is the analysis rule in the city development variables as a result of literature studies. The results of the validation are input to the Linear Programming analysis process which is a quantitative method. There are five types of property that become the main property development priority to support the ridership effectiveness of infrastructure development with the TOD concept. The study took a case study in a developing country region that recommended office, residential, and retail functions which are the three functions having the greatest influence on the development of the TOD region that is in line with the region's potential. The number of ridership improvements in the case study reached 55% which the model recommended in this study.

Keywords

Transit-oriented development (TOD) • Land use • Transit • Ridership • Optimization Process

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1 Introduction

Traveling using private vehicles is commonly found in developing countries such as Indonesia to reach their targeted destination. The increasing trips using automobiles will increase the use of fuel, pollutant emission, and traffic congestion. In longer term, it may affect the people's quality of life (Hasibuan et al. 2014). Provision of rail rapid transit system has been identified as a solution to overcome those consequences by partially shifting auto trips to transit usage and reducing their dependency on private vehicles (Gariepy et al. 2017; Mudigonda et al. 2014), as well.

as reducing carbon emission, raising economic growth through accessibility improvement, and decreasing road-related accidental risks (El-Sharkawy et al. 2011). Therefore, many cities worldwide have started to establish rail-based transit system including Indonesia. LRT system is one of the transit projects recently executed by Government of Indonesia to alleviate the traffic problem in greater Jakarta.

On the other hand, rail transit development consumes as one of the biggest investments among the other transit modes and requires high return to attract private sectors (Evans et al. 2007). The main typical problem is about the ridership. Although incapable to cover the overall investment, the revenue merely from fare box is significant. Railway and its related operations contribute 34% to the total net income of Hong Kong's MTR Corporation (Suzuki et al. 2015). Therefore, fare box revenue is one of the determinant factors of transit system income. Increasing the fare box revenue of rail transit related to many factors and one of them is the integration between transit corridor and land use pattern. When the land use offers seamless movement of users, it may attract them to use the public service more frequently. In longer term, it generates more revenue for the business entities. Hence, appropriate land use strategy is required to attract users by arranging urban spatial structure through transit-oriented development or TOD (Zheng et al. 2010).

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This paper is intended to fill the gap by offering linear programming-based optimization model of land use allocation in parcel level of rail-based TOD to maximize rail transit ridership. As mixed-use development is the main characteristic of TOD, the planning involves several different developments to be built in a limited land around station to achieve maximum rate of transit ridership. This is a typical choice task of linear programming problem. The goal of the study is to obtain optimum gross floor area (GFA) of each development as an alternative approach for transit operator or property developer to conduct proper transit-oriented development planning.

2 Literature Review

TOD is a form of spatial development of high-to-moderate density, mixed-use, and pedestrian-friendly within walkable distance around transit station (Cervero and Kockelman 1997). Bertolini (1999) defined TOD as mixed-use development within comfortable distance for pedestrians, which was about 2,000 feet or 10 min walking from transit station, while this distance magnitude may differ among areas depending on their physical features. TOD is a way to engineer the built environment around station area to modify the resident's travel behavior and encourages them to use active and transit modes and thus decreases their car dependencies (Papa and Bertolini 2015). It will increase transit ridership and revenue of transit operator to maintain the transit service (Wu et al. 2004; Singh et al. 2015). Therefore, transit ridership could be one for the main performance indicator on how a TOD is stated successfully. TOD can also generate significant revenue for rail transit service by land value capture mechanism. That is potential to be an additional function to increase the feasibility of railway projects, such as Jakarta-Surabaya High Speed Train (HST) Project (Husin et al. 2015), which is estimated to yield 51–57% of the total revenue.

TOD concept has been applied in many countries but such development concept relatively new in Indonesia. TOD started gaining its popularity in Indonesia since the construction of mass rapid transit (MRT) in greater Jakarta and its adoption as a strategy to improve MRT project feasibility through real estate development (Berawi 2018). Several studies have focused on TOD planning in relation to increase transit ridership. Li and Bai (2013) established decision tree approach to forecast the number of boarding and alighting passengers based on land use acreage inputs in Chongqing, China. Kim and Taylor (2017) investigated the correlation between percentage of land use in areas of 500 m radius around rail station and diurnal rail ridership pattern in Seoul Capital Area using ridership-based station clustering approach. Suzuki et al. (2015) provided several successful TOD cases in relation to rail ridership in Japan and Hong Kong, China. While analyzing Hong Kong's Rail and Property Development model, (Cervero and Kockelman 1997) investigated the model's performance in increasing rail transit ridership. To arrange the allocation of several land uses to increase ridership, (Yang et al. 2007) and (Litman and Steele 2017) used genetic algorithm to generate non-dominated alternatives of land uses allocations in a station area in China while (Lin and Li 2008) utilized grey linear programming technique. Lin and Gau (2006) performed model development to obtain alternatives of optimum floor area ratio (FAR) as input in policy-making process regarding allowed FAR in TOD areas in Taiwan. However, these studies focused on station-area-level planning, not on parcel level, which deals with gross floor area of land use development as its decision variable. Liou et al. (2016) performed linear and nonlinear programming optimization to determine the best mix of uses in a mixed-use area. However, neither of both were in TOD context.

3 Methodology

The Indonesian TOD designs are collected from reports and discussion meetings with the TOD developer of LRT Jabodebek. The existing designs collected in this study took place in five on-going LRT station areas. Using the model resulted from this study, the ridership generated by existing designs will be evaluated and compared to the proposed design from this research.

The mixed-use optimization problem is solved by using Linear Programming (LP) approach. LP is a form of mathematical programming in which all its functions, i.e., objective function and constraints, are linear (Giuliano 1985). Mathematical programming addresses optimization problems concerned with the allocation of competing needs (i.e., floor area of uses) in a valuable resource (a land parcel or a site) to achieve an objective (Latief et al. 2017). Transit ridership in a station can be modeled as a linear equation involving gross floor area and transit trip generation rate per unit area of each use (Lin and Gau 2006). Therefore, LP becomes the suitable technique to solve this problem.

Establishing the model with three components of LP framework, i.e., objective function, decision variables, and constraints, must be determined. As mentioned above, the quantification of objective, i.e., maximizing ridership, as a function of decision variables, i.e., floor area of uses, is adopted from the model developed by. The issue is to define the type of uses to be accompanied in the model. The type of uses is determined by benchmarking from the successful TOD practice based on relevant literatures.

Considering the limited availability of references regarding the transit trip generation rate of specific type of uses in TOD area, the decision variables are defined as four categories of uses as defined in (Li and Lai 2009) and (Lund 2006): (1) residential, (2) office, (3) retail and commercial, and (4) hotel. Thus, the objective function of the problem is modeled as

$$\text{Maximize } Z = T_1X_1 + T_2X_2 + T_3X_3 + T_4X_4 \quad (1)$$

where is the amount of transit ridership as the objective variable T_1; T_2; T_3; and T_4 are transit trip generation rates, respectively, residential, office, retail and commercial, and hotel uses as parameters, while X_1; X_2; X_3; and X_4 are the decision variables of floor areas of the above-mentioned type of uses. The value of required input parameters, i.e., transit trip generation rates, is estimated by multiplying rail transit modal split and required space area per person in a building planning for abovementioned purposes (Table 1). Modal split value for commuting trip is obtained by a benchmark study from Tokyo, which rail transit act as the backbone modes of travel activity. On the other hand, non-commuting trip is retrieved from previous study conducted by Lund (2006).

The mandatory constraint related to the maximum gross floor area (GFA) permitted to be built on the site. It is the result of multiplication between floor area ratio (FAR) and area of the land site. In other words, the mixed-use development gross floor area shall not exceed those figures. The conditional constraints are related to restriction on developing particular uses, such as the maximum GFA of commercial areas, minimum GFA of residential area, and other factors. It would be expressed in values or percentages. The last constraint is about non-negativity which inhibits model to generate negative value of decision variables. These are defined based on the benchmark study on three examples of successful TOD in Japan, Hong Kong, and South Korea.

Based on the above explanation, the TOD optimization model to maximize ridership is presented as follows:

$$\text{Maximize } Z = 0.08X_1 + 0.16X_2 + 0.09X_3 + 0.12X_4 \quad (2)$$

where A is the area of the site; and f is the maximum FAR in the site.

4 Results

The above model will be used to resolve optimization problem in TOD planning on a land parcel around five LRT station areas. Bekasi 1 LRT station area will be an example of the model application. The TOD of Bekasi 1 is planned to be built on a 50,000-m^2 land. The planned floor area ratio (FAR) is 3.56, thus maximum GFA will be 178,100 m^2. The existing TOD plan is residential development, supported by retail commercial and other development.

The first step is evaluating ridership using the typical TOD design from the benchmark study looked like in Table 2 (Zulkifli et al. 2015). Equation (2) will be utilized to evaluate rail transit ridership of Bekasi 1 LRT station. The value of decision variables, i.e., GFA of each land use, is the results of multiplication involving the maximum GFA of Bekasi 1 TOD (178,100 m^2) and each land use proportion (%). The result of this step is shown in Table 3.

The next step is to optimize TOD design using program linear optimization approach.

Based on the case study above, the constraints will be as mentioned below:

$$X_1 + X_2 + X_3 + X_4 \leq 178.100 \quad (3)$$

$$X_1 \geq 42.744 \quad (4)$$

$$X_1 \leq 99.736 \quad (5)$$

$$X_2 \geq 10.686 \quad (6)$$

$$X_2 \leq 42.744 \quad (7)$$

$$X_3 \geq 7.124 \quad (8)$$

$$X_3 \leq 26.715 \quad (9)$$

$$X_4 \geq 14.248 \quad (10)$$

$$X_4 \leq 60.554 \quad (11)$$

$$X_5 \geq 21.372 \quad (12)$$

$$X_5 \leq 69.459 \quad (13)$$

Table 1 Required space per person in building planning

Purposes	Minimum required space per person (m^2)	References
Apartment	9,29	Engineering Toolbox (2003)
Hotel	5	Engineering Toolbox (2003)
Mall and shopping center	4,2	Engineering Toolbox (2003); Adler (1999)
Office and bank	4,645	Engineering Toolbox (2003)

Table 2 Typical TOD design based on benchmark study

Property types	Proportion (%)	Range (%)
Residential	44	24–56
Office	18	6–24
Hotel	10	4–15
Retail	16	8–34
Others	12	12–39

Table 3 The typical TOD design applied in Bekasi 1 station area and its ridership

Development	Quantity	Unit	Proportion
Residential	78,364	m^2	44%
Retail	28,496	m^2	16%
Hotel	17,810	m^2	10%
Office	32,058	m^2	18%
Others	21,372	m^2	12%
Ridership	15,921	trip	

Table 4 shows the optimum design of TOD from linear programming-based optimization model using the typical TOD design. Based on Table 3, ridership estimation of LRT Jabodebek generated by the typical TOD design is 15,921 trips per day, while the optimized design generates 1,407 additional trips. This increase is resulted from space optimization taken from residential proportion. Residential space is reduced by 20% to be allocated in retail, hotel, and office development based on their trip generation rates and the defined constraints.

The objective function has shown that the highest rate of transit trip boarding comes from the office user. This is in accordance with several studies revealing that workplace development near the station is the main determinant of transit ridership. The result of study conducted by Kwoka et al. (2015) in Denver, Colorado, suggested that locating workplaces nearer to transit is more effective to encourage non-car worker commute trips than that of residential places. Evans et al. (2007) revealed that, every 1,000 feet further from the station in Washington Metro lines, the reduction of transit mode share regarding office location was 58% higher than of housing. More recent research on ridership determinant factors of Shanghai rail transit system uncovered that employment within 500 m from the station is the dominant factor of increasing rail passenger volume, thus suggested to be key component of TOD planning (Pan et al. 2017).

After obtaining the potential ridership of benchmark and optimized TOD design, the research compared it to the existing LRT station TOD design. The existing design contains residential development as its major use, and non-residential development is allocated less than 40%. Table 5 contains additional rate of ridership in each case study resulted from ridership evaluation of benchmark design and optimization process.

The optimized design can boost LRT ridership up to 55% in East Jakarta 1, while the minimum increase took place at East Jakarta 2. The optimized design of TOD to gain maximum value of ridership is 24% residential, 25% retail, 15% hotel, 24% office, and 12% others.

Table 4 Optimum TOD design of Bekasi 1 station area

Development	Quantity	Unit	Proportion
Residential	42,744	m^2	24%
Retail	44,525	m^2	25%
Hotel	26,715	m^2	15%
Office	42,744	m^2	24%
Others	21,372	m^2	12%
Ridership	17,328	trip	

Table 5 Additional ridership of benchmark and optimized design compared to existing TOD design

Development	Percentage of additional ridership compared to existing TOD design	
	Benchmark design (%)	Optimized design (%)
East Jakarta 1	43	55
East Jakarta 2	13	22
Bekasi 1	25	36
Bekasi 2	39	51
Bogor 1	15	25

5 Conclusions

This paper demonstrates the effectiveness of using mathematical programming approach to resolve optimization problem of mixed-use TOD planning. As TOD planning consists of a typical task in allocating limited land resources among several competing uses and different mixes to achieve certain objective, linear programming would be a suitable analytical tool to analyze to that matter. This paper presents a linear programming framework by defining decision variables and formulating objective and constraint functions based on similar TOD in different cities. The objective function is to maximize transit ridership, by taking into account performance indicators of successful TOD. GFA of each development type is defined as decision variables, for instance, residential, office, hotel, and commercial. The constraints are formulated based on the range of total and each type of development's GFA derived from benchmark study of successful TOD.

Objective is quantified as a linear function consisting of ridership as objective variable and different types of uses' GFA as decision variables. The value of required input parameters, i.e., transit trip generation rates, are obtained by multiplying transit modal split and required space area per person in a building planning. The highest rate of trip is generated by office development, while residential development generates the lowest rate of trip. The more mixed-use development design is potential to produce higher transit ridership as well as offers more livable communities than existing TOD development scenario, which dominated by residential use.

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An Overview of Onsite Residential Sewage Disposal and the Implications on Underground Water Supply and Health in Nigeria

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Abstract

A residential housing is normally designed to serve the immediate need for human activities. Usually, provision for collection and disposal of sewage is a priority to enhance a healthy living environment. The millennium development goal on human health remains unrealistic in many developing countries due to poor disposal of sewage. Using a combination of primary and secondary data this study presents an overview of onsite sewage disposal and its impact on underground water and health issues in Nigeria. Findings show that onsite septic tank is the main method of sewage disposal. An average of 5 m was observed between the shallow dug well and septic tank. Hence, the underground water is highly susceptible to contamination but remains the primary source of domestic water supply. Reported cases of cholera traceable to fecal contamination of underground water remain very high. This paper argues for the involvement of professional in the building industry to present a proposal or a central sewage system particularly where the risk of infiltration of sewage into the water body is high.

Keywords

Housing • Sewage • Septic tank • Disposal • Health • Policy

1 Introduction

Man's interaction on land constantly produces waste which impinges negatively on the ecological balance of the environment. It constitutes issues which are often neglected until a lapse in the care for environment (Liu et al. 2015). Hence, conscious efforts are made to evolve safe and sustainable method for collection and disposal of Municipal Solid Waste (MSW) from houses. Without this, the millennium development goal which finds expression reduction in mortality rate, infectious diseases, and sustainable environment may not be realized in many developing countries due to unsafe disposal of MSW. According to Barkha et al. (2016), the rate of generation MSW is expected to increase to 2.2 billion tons per year by 2025 worldwide. However, the collection and disposing are still challenging in the third world countries. The narrative in the developed world is quite different. Emerging technologies have produced different by-products such as heat, electricity, compost, and bio-fuels from MSW (see Jeswani and Azapagic 2016; Scarlat et al. 2015; Tarek et al. 2014). Generally, MSW is a pool of various solid wastes by towns and cities from different types of household activities (Niazi et al. 2016). However, this study is concern with sewage, it is often generated from several sources where variable human activities occur. Several studies indicate that (55–80%) of the municipal solid waste from developing countries are generated from households (Miezah et al. 2015). Hence, this study draws context from the sewage from the residential home to examine the impact of onsite septic tank on underground water and health. In the developing world, the disposal of sewage is popularly done via an onsite septic tank. This practice had been largely de-emphasized in the developed due to the danger it portends to the human environment. According to Mackenzie (1954), the importance of individual household sewage disposal systems in American sewerage practice is rarely recognized since the mid-twentieth century. It was estimated that, as of 1945, only 17,000,000 persons were served by individual home sewage disposal systems, compared to 75,000,000 persons served by public sewer systems. According to Petitjean et al. (2016), about 20% of the population use onsite wastewater treatment in France. In the United States Katz et al. (2010) reported that about one in

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four households in the United States uses a septic tank for wastewater disposal. Approximately, 500,000 rural households depend on onsite wastewater treatment systems for their effluent disposal in Ireland Keegan et al. (2014). In Nigeria, the popular means is the onsite septic tank and open defecation in the rural areas. The source of concern is the proximity of the septic tanks to shallow dug well.

2 Disposal of Municipal Solid Waste and Sewage

Generally, there are two main ways of disposing sewage in the residential environment, namely, onsite septic tank and central sewage system. While the onsite septic tank is not popular, it is not entirely bad, but its application is quite limited in the developed world cities. According to Garry and Cathy (2018), many homeowners rely on onsite sewage systems (septic tanks and absorption fields). Every year, many of these systems fail with a costly consequence. This is simply because onsite disposal systems cannot be installed in all situations. For example, they cannot be installed: in areas that flood regularly, areas that have a high water table (that is, where the underground water is close to the surface), where the amount of wastewater to be disposed of is large near to drinking water supplies. Subsurface pathways of sewage are increasingly recognized as a problem for underground water (SeeBarnes et al. 2008; Focazio et al. 2008). According to Scandura and Sobsey (1997), onsite septic tank soil absorption system treating sewage has led to contamination of groundwaters with enteric viruses and other pathogens and outbreak of water-borne diseases. This is substantiated by some empirical studies on the impact of onsite septic tank in homes.

For instance, Keegan et al. (2014) noted that one of the key threats to groundwater and surface water quality in Ireland is the impact of poorly designed, constructed, or maintained onsite wastewater treatment systems. The study quantifies the impact of existing sites on water quality. Six existing sites consisting of a traditional septic tank and soakaway system, located in various ranges of subsoil permeabilities were identified and monitored to determine how well they function under varying subsoil and weather conditions. The preliminary results of the chemical and microbiological pollutant examination show fecal contamination in the nearby groundwater. Levett et al. (2010) noted that there are currently several onsite wastewater treatment systems (onsite systems) in peri-urban and rural areas in the south-east of South Australia. The study found that onsite systems and the subsequent localized discharge of treated effluent can lead to public health and environmental concerns through direct contact with effluent and contamination of groundwater resources. While the management of sewage and MSW is still a concern, turning it to wealth and useful product for power generation is gaining ground in the advanced nations. For instance, Malinauskaitea et al. (2017) found that turning waste into energy could be key to a circular economy, enabling the value of products, materials, and resources to be maintained on the market for as long as possible, minimizing waste and resource use. As the circular economy is at the top of the EU agenda, member States of the EU are moving away from the old-fashioned disposal of waste to a more intelligent waste treatment encompassing the circular economy approach in their waste policies. Scarlat et al. (2015) assess at the African level, the role of waste in providing energy to citizens. The study found that energy recovery from waste can play a role in minimizing the impact of MSW on the environment with the additional benefit of providing a local source of energy. There is a growing understanding, at global level, about the negative impacts that waste can have on the local environment (air, water, land) and human health, etc.

3 Domestic Water Supply in Residential Housing in Nigeria

Water supply and sanitation provision have been at the core of international attention reflected in various international directives and declarations over the decades. Akpabio (2017) assesses the Nigerian policy trend and practices in relation to water supply and sanitation coverage over the past ten decades. The review observed that the Nigerian water and sanitation policy environment is characterized by too many short-lived policies without corresponding action. According to Federal Ministry of Water (2017), Nigeria is targeting 100% access to basic water supply and sanitation services by 2030. To achieve this, the government requires US$2.74 billion yearly however the financing gap stands at $106 million per annum. WHO and UNICEF (2010) joint monitoring program reveals that accessibility to safe water delivery in Nigeria by public mains on premises is low and yearly declining.

Statistics reveal that 32%, 20%, and 11% were recorded between 1990, 2000, and 2008 respectively. The implication of this is that most urban dwellers will have to depend on accessibility to improved water via underground source in their premises. This led credence to the fact that many Nigerians depend on private arrangement via shallow well which is normally located in a proximate location to septic tank. Recently, cholera epidemic engulfed 14 states and over 700 lives were lost. It is pertinent to state that most of the cholera cases were recorded in informal residential districts or slum there were no development control measure to restore sanity in onsite disposal of sewage. Smout (2010) discovered that basic water, hygienic improvement could eliminate 3% to 4% of global region diseases. He stressed that the commonest water and sanitation-related diseases (Cholera, arsenicosis, fluorosis, guinea worm, intestinal worms, schistosomiasis, typhoid, and trachoma can be potentially avoided with the provision of improved water supply and sanitation. Furthermore, people living with HIV/AIDS can more readily avoid opportunistic infections associated with the disease if they have no access to improved water supply and sanitation.

4 Research Method

This study employs a combination of desk research and observation. Dominantly, it involves the collection of data from existing resources. Also, personal observation was employed to collect primary data concerning the proximity of the septic tank to underground water sources.

5 Findings and Discussion

Onsite septic tank is the primary method of disposing sewage in Nigeria at large. It is usually located within an average of 5 m to shallow well which is the major source of domestic water supply. This portends grave danger to peoples' health as corroborated by a study carried by Olabisi et al. (2008) on assessment of bacteria pollution of shallow well water in Abeokuta. Interview conducted reveal high turbidity and offensive odor particularly during rainy seasons which indicate seepage and leaching of fecal coliform into underground water source. Unfortunately, the commonest source of water for domestic uses is a shallow dug well. For example, in Ondo state Table 1 shows that 44.37% collect their water from a shallow well. The implication is that 44.37% in the state are exposed to water-borne diseases from underground water pollution due to nearby onsite septic tank in homes. Also, 9.98% access water via borehole while only 1.82% used water from pipe-borne water in dwelling houses. In addition, 2.24% depend on sachet water which has led to alarming increase in the plastic waste threatening aquatic life in Nigeria.

Assessing the risk of onsite disposal of sewage, Table 2 shows that the risk of cholera infection of water has not changed significantly, although the death recorded has reduced for the 37 years in which the data collected. The table shows that 22,931 cases of cholera infection were reported in 1971 while 18,205 were reported 47 years after in 2018. This statistic exhibits a link with onsite location of septic tank in homes. This assertion is strengthened by Lagos State Ministry of Health 2017 confirmation on the death of two students of the Queens College who died of cholera infection. This was traced to the pollution of the underground water source by nearby onsite septic tank.

This shows and confirms (Adagbada et al. 2012) findings. The study found that cholera, which was once common throughout the world, is now largely confined to developing countries where onsite septic tank is rife. This is also buttressed by (WHO 2016) findings which reveal that cholera cases and 2420 deaths were reported to WHO globally in 2016. It noted that 54% of the cases occurred in Africa, 13% from Asia, and 32% from Hispaniola.

Notably, Cholera remains a major health issue primarily in developing countries with poor sanitation, sewage disposal, and water supply.

Access to improved water and sanitation services in Nigeria are less than those seen in many other Sub-Saharan African countries. Fifty-seven million people in Nigeria continue to live without access to improved water (Luis et al. 2018). As many as 130 million people do not meet the Millennium Development Goal (MDG) standards for sanitation. Even if the access to improve sanitation is higher, it does not reduce the negative health implications of disposing

Table 1 Sources of water supply in Ondo state

Sources of water supply	Frequency	Percentage (%)
Pipe-borne inside dwelling	13,908	1.82
Pipe-borne outside dwelling	24,210	3.17
Tanker Supply/water vendor	12,675	1.66
Shallow dug Well	338,579	44.37
Borne hole	76,116	9.98
Rain Water	42,220	5.54
River/Stream/ Spring	230,095	30.16
Dug out/Pound/lake	8,095	1.06
Sachet water	17,122	2.24
Total	763,020	100.00

Source Calculated from National Population Census 2006

Table 2 Nigeria cholera cases and resulting deaths between 1971 and 2018

Year	Reported cases	Recorded deaths
1971	22,931	2,945
1991	59,478	7,654
2001	2,050	80
2005	37,289	1,434
2008	5,140	247
2009	13,691	431
2010	41,787	1,716
2011	22,454	715
2018	18,205	235

Source Nigerian Centre for Disease Control, World Health Organization.

the sewage into onsite septic tank in homes. Although the mortality report from cholera cases has reduced, the reported cases of infectionare still high due to vulnerability of underground to fecal contamination from nearby onsite septic tank and open defecation (See Table 2). The implication of this is whooping sum of 455 billion naira ($2 billion) spent on poor sanitation per annum.

6 Conclusion

Previous studies show that onsite septic tank is a method of sewage disposal, however, its application is quite limited in the developed world where cases of cholera and other water-borne disease are low. What is clear from the existing studies is a link between, onsite sewage disposal, underground water supply contamination, and water-borne infection like cholera. With a primary reliance on onsite sewage disposal in homes health issue resulting from cholera put most people at risk of the disease in Nigeria.

This risk may continue to increase until something is done to limit the use of onsite septic tank and direct sewage to a treatment plant where it could be converted to other useful by products. This study provides an overview of the possible impact of the onsite septic for sewage disposal in homes. Finding from this study reveal that the use of onsite septic tank has serious policy implications. Achieving a sustainable sewage disposal and improved underground water supply call for guidance in the wider application of onsite septic tank. Environmentally sound sewage disposal must go beyond the mere onsite disposal and access to improved sanitation. Also, government should embark on the construction central sewage system throughout the urban area to eliminate unhealthy use of onsite septic tank near shallow well in Nigeria. This paper argues for a position paper written by professionals in the building industry to the public authority for the construction of central sewage system and restriction of onsite septic tank to all building site.

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Green Building Retrofitting in the UAE

Mariam Ibrahim, Eilin Rachid, Yousef Awera, and Salwa Beheiry

Abstract

The UAE went through a huge building boom in the last twenty years, resulting in extensive useful infrastructure, yet not necessarily all were built with green design parameters in mind. As these buildings reach their retrofitting milestones, it is an opportunity for owners/developers to retrofit the necessary components for improved energy efficiency and reduced carbon footprints. Thus, this paper summarizes the rationale behind the basic elements identified in a study to develop a green retrofitting toolkit for commercial buildings in the United Arab Emirates. The study focused on refurbishing the passive systems, such as the building envelope (wall enclosures and roofs), and the active systems (lighting and HVAC systems). The methodology that was followed involved looking at the purpose of retrofitting a building for each criterion and examining the necessary issues to be considered, as well as providing the optimum solutions along with a performance matrix for the UAE climate in terms of energy and cost savings. Moreover, a Revit based model was used on a prototypical commercial building design to assess the energy efficiency and resultant cost savings. The study emphasized an all-inclusive retrofitting approach.

Keywords

Green buildings • Retrofitting • UAE • Toolkit • Passive and active systems design

1 Introduction

Several innovative building technologies have been put into practice to reinforce the concept of sustainability in modern construction. These practices may include passive or active designs. Passive designs consist of dealing with the building envelope to help reduce energy consumption for the building as a whole. On the other hand, active designs deal with high-efficiency ventilation systems that also contribute to energy savings. Countries such as the UAE can greatly benefit from implementing certain efficient design techniques since the cooling load is extremely high in the summer given the harsh summer weather. Buildings that use both techniques will have the most efficient energy performance.

This study focuses on retrofitting an existing building by looking at the passive and active design techniques together to create a holistic approach to building retrofitting.

The focus of this paper is to tackle 3 main components of a building that are the building envelope components, lighting systems, and HVAC (heating, ventilating, and air conditioning) to save energy. This can be done by implementing the best techniques to retrofit existing buildings in the UAE. It is essential to optimize the practical performance of each technique to obtain promising results, in which cost plays a role.

Therefore, any client that uses this toolkit will vary his/her decisions based on the amount of money he/she is willing to pay, as well as examining the status of the energy performance of the building.

2 Background

The preliminary idea behind this project is to discover the possibility of revamping existing buildings, making them sustainable using passive and active design techniques.

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More focus will be placed on implementing this strategy in the UAE, where the climate is viewed as hot and humid. During the summer season, cooling systems are extensively used in buildings. Therefore, using efficient retrofitting techniques is a promising strategy to increase energy savings. The more general perspective of the project is to enforce energy efficient strategies by enhancing air-tightness measures, as well as the lighting and HVAC systems. This is because energy efficiency is the main component of green buildings. In practice, energy efficiency can be implemented using either active or passive systems. Active systems include improvements on HVAC and lighting, while passive systems tackle the building envelope components. It is the focus of this project to explore the considerations of the main design techniques, and which types will be the most efficient in the UAE climate to allow for more energy-saving building systems. At the end of the project, our deliverables are to produce a toolkit that measures the performance of a retrofitted building. Furthermore, a physical model and a Revit model will be done to represent a retrofitted building.

3 Literature Review

3.1 Passive Buildings

With the rising level of energy consumption due to rapid industrialization and population growth, more fossil fuels are burned which essentially causes global warming. In a hot and humid climate such as the UAE, cooling is the major contributor in energy consumption specifically during summer peaks. It is mentioned that 75% of the electricity consumption in summer months in Abu-Dhabi is due to air conditioning (Al-Sallal 2012). For such high levels of energy consumption during harsh climate conditions, it is important to incorporate passive techniques that ensure the use of an appropriate building envelope and insulation measures. Since the weather plays a significant role in the performance of the building, accommodating the humidity factor in the UAE is necessary for building design. Regarding the adverse effect of humidity on the building envelope, it is argued that the higher the humidity, the more is the decline of insulation benefits from the wall systems due to air infiltration (Pukhkal et al. 2015). In turn, this might affect the durability, which means that the building will not have a longer service life that will lead to costly maintenance results.

Green buildings, also called passive or low energy buildings, have less negative impact on the environment than traditional buildings due to natural lighting and aesthetic views when combined with green roofs. It is mentioned that green roofs with drought tolerant grasses, especially useful in the UAE, can a decrease in temperature by 15 degrees (Burns 2006). A green roof also helps in keeping the air clean and improving storm water management. In addition, using windows with low emission glazing helps in reducing the interior heat gain, lowering the need for high cooling loads.

The building envelope consists of the building components that surround the indoor spaces, while interacting with the outside environment (Pratt 2006). This includes windows, doors, roofs, walls, cladding, and façade systems. The main issue with building envelopes is their tendency to infiltrate air, increasing the heat gain, which may result in unfavorable indoor environments. The solution to this would be to focus on enhancing the air-tightness of the building by retrofitting its envelope using cost-effective measures. Another solution that is widely discussed regarding building energy efficiency in hot climates is the double facade (Boake 2014).

The use of a double facade is justified to elevate the heating and cooling loads, as well as climate conditions found in the UAE such as humidity. In the UAE, solar avoidance would be the primary reason behind adding a double facade to escape the harsh summer sun. The best way to retrofit windows tailored for hot climates is to apply double glazed windows with low-e coatings (Mccluney and Jindra 2002). In fact, a special coating will actually reduce the size of the air conditioners needed and thereby reducing the cooling load of the building. In addition, a few added benefits come with better-insulated windows such as the reduced sound transfer and increased comfort of the occupants (Mccluney and Jindra 2002).

3.2 Active Buildings

Retrofitting active systems in a building involves elements such as lighting and HVAC. All building systems interact in a way that any improvements to a single system indirectly enhance the performance of the other. For example, the performance of the lighting system in a building is affected by the HVAC choices made (Franconi and Rubinstein 1992). Specifically, it was shown that lighting systems retrofits that save one watt in the lighting power would save about a third of a watt in the cooling load. Typically, lighting retrofits have a payback period of about 2 years (Dubois et al. 2015). LED lamps are shown to be more energy efficient when compared to fluorescent lamps. Therefore, considering a lighting retrofit that incorporates LED lamps would be important on a whole building scale. Besides changing the type of lamps to more efficient ones, the usage of a lighting control system is also an efficient method to upgrade a lighting system (Dubois et al. 2015). The main drawback of using control systems is the difficulty of estimating an exact payback period since it would mainly depend on the usage of the system by the occupants. Adding an automated occupancy-based control system which can increase energy savings by 20–93% (Dubois et al. 2015). Daylighting systems can also be used in a way that automatically switches off whenever daylight is sensed. According to the UAE Energy Efficiency Standard, 20% of the electricity is consumed by households globally for lighting purposes (UAE 2018).

Also, there is a potential for using high-energy efficient lamps such as Compact Fluorescent Lamps (CFLs), Light Emitting Diodes (LEDs), and Halogen bulbs (UAE 2018). The UAE can save up to 668 million/year from overall saved electricity bills from households. For atypical medium-sized villa in Dubai, lighting retrofits that are more efficient can save up to AED 2,315/year.

In office buildings, lighting consumes about 2045% of the total electrical demand. It is assured that using lighting control systems can reduce energy consumption up to 15% (Al Awadi 2014). Similar to the positive effects of well-insulated windows, buildings with lighting systems that are appropriately designed to integrate enough daylight are shown to lead to increased occupants comfort and reduced headaches resulting from overly installed artificial lighting. When dealing with a harsh UAE summer, it is of great significance to focus on the most energy-intensive systems that are more relevant than others. Primarily, HVAC systems require the most energy in commercial buildings. As an example, researchers have explained that the use of Variable Air Volume (VAV) systems can lead to energy savings when compared to unitary systems (Fasiuddin and Budaiwi 2011). Different studies were dedicated to explaining energy savings methods of an HVAC system. For example, air conditioners, central air conditioners, chillers, and ducts can be more energy efficient when certain methodologies are followed. These will be elaborated on in more detail later in this report.

4 Statement of the Problem

Energy consumption should be considered when talking about the economy and the environment since it is an important feature. The energy consumption in the UAE has increased by huge amounts because of several factors, such as the rapid growth in the population and industrialization. Energy in the UAE is obtained from burning fossil fuels and this is known to be a high source of emitting the greenhouse gas carbon dioxide (CO_2) (Olabemiwo et al. 2017). These emissions have negative impact on the environment, human beings, and animals; hence, they tend to speed up the climate change and global warming process, giving an unsuitable place for humans and animals to live in due to the health problems attributed with the emissions. The projected data for the UAE's CO_2 emissions from 2011 to 2050 has showed that it will increase to a high number from 188.77 to 390.05 Mtonnes (Olabemiwo et al. 2017).

However, this is a far-reaching problem that should be treated differently, and various solutions are available. In an attempt to decrease the carbon footprint, dealing with the building envelope by improving its insulation acts as a passive retrofitting technique. Furthermore, the problem can also be tackled by the concept of lighting and HVAC system retrofits as an active design technique. These elements can contribute in reducing the energy consumption of thermal heating and cooling loads during summer peak time, when the energy consumed on the usage of HVAC systems is the highest.

5 Significance of the Project

With regard to energy consumption, the UAE requires additional innovative design ideas for building systems that account for the general concept of sustainability. Currently, there exist ideas that have already been implemented in the UAE such as geothermal energy and solar energy used for building heating and cooling systems, e.g., Masdar City. More focus is placed on cooling systems since the country undergoes relatively violent summers. With the increasing amount of building construction, there is a growing need to increase energy savings as much as possible. The focus of this project is to bring the combination of active and passive design techniques idea forward to get a high-performance retrofitted building that is cost effective. It will benefit the engineering industry by providing an optimum solution that is tailored to the weather and existing building systems in the UAE. The aim is to offer an efficient solution that can be put into action in the hope of revamping existing buildings, making the building sustainable in nature. This project idea is unique since there is no combination of techniques that is specifically made to suit the climate of the UAE, which will have a strong impact in the building engineering industry. The objective of this study was to propose a green toolkit to retrofit existing buildings in the UAE for better energy efficiency.

6 Methodology and Approach

The methodology hinged on an extensive literature and product review for both passive and active buildings design criteria. In addition, certain building components were identified and analyzed to propose the standardized toolkit and assess the performance of the suggested retrofits based on cost and energy saving for these UAE-based buildings. The suitability of the proposed retrofits for the UAE climate is also assessed. The following section summarizes the key elements included in the proposed toolkit with solutions.

7 The Basic Elements for a Green Retrofitting Toolkit

7.1 Building Envelope Air-Tightness

The primary focus of improving the air-tightness of a building is to reduce heat gain through better insulation, namely, preventing the entrance of hot air, dust, and moisture. Since these are specific problems in the UAE, it is vital that building envelope components should be retrofitted to provide better insulation, and hence elevated air-tightness measures. The building envelope consists of the parts of the building that are directly subjected to the outdoor environment, including windows, doors, roofs, walls, foundations, etc. Windows and doors are very important components through which high-energy savings can be incurred if retrofitted appropriately.

At this point, it is essential to define the term “fenestration”. Fenestration means the arrangement, in terms of design and position, of structural openings in a building (Pratt 2006). Fenestration affects building energy use in several ways including conductive heat transfer, solar heat gain, air leakage, and daylighting. Since daylighting does not fall under the aspect of air-tightness, it will be dedicated a whole section later in this report due to its significant energy contributions. Solar heat gain is the radiant solar heat that penetrates the building, usually through windows, that contribute to increased heat loads. Solar heat gain is defined by the Solar Heat Gain Coefficient (SHGC) meaning “the fraction of solar energy that enters the window and becomes heat” (Pratt 2006). Air leakage is the uncontrolled airflow throughout the building envelope. Any building envelope retrofit option that would minimize any of the above-mentioned energy mechanisms is considered worthwhile and efficient. Namely, adopting glazing systems that would reduce conductive heat transfer and solar heat gain would entail reduced cooling loads.

Furthermore, components that prevent air infiltration through any possible openings are preferred.

7.2 Double-Skin Façades

A double-skin façade is one that includes constructing a second layer of façade over the existing one that is usually transparent (Kamel and Memari 2016). It has been supported by several researchers that adopting a double-skin façade in a hot humid climate like the UAE is very energy efficient since it significantly reduces the solar heat gain parameter, while also keeping dust and humidity outside the building (Burns 2006; Ashour 2014). This promotes the concept of enhanced air-tightness measures throughout the building envelope. However, the payback period is quite long due to its extensive planning and design making it an option that is more on the expensive side of the spectrum.

7.3 Green Roofs

Green roofs technology is on the rise all over the world for its great benefits to people and environment. Green roofs have been done widely in Europe for more than a decade, and now 20 percent of roofs on medium and large buildings in Tokyo are required to be green roofs (Fischetti 2017). Green roofs are vegetated roofs that have vegetation layer with waterproofing and sometimes drainage layer, which is considered to be optional. The five different layers of green roofs include a root barrier layer to prevent the root from penetrating the building; a protection mat layer to increase the safety from any penetrations; a drainage layer that allows heavy rain to runoff; a filter sheet to stop particles, and dust from clogging the drainage layer; the last layer is the growing medium which can be soil or an engineered material that provides the necessary food for plants to grow (Fischetti 2017). Green roofs can be implemented by retrofitting or in new construction. Mainly, there are two types of green roofs: extensive and intensive. They differ in the layers and the lengths of the layers in addition to the maintenance. Intensive roofs allow for deeper substrates, while extensive roofs allow for thinner substrates (Sadineni et al. 2011). Cutlip (2006) suggests that the use of extensive green roofs are more preferable because they do not require large-scale maintenance, unlike intensive green roofs, and they are thinner than intensive green roofs (Cutlip 2006). Extensive green roofs are known as “eco-roofs” and minimal weight load; whereas, the intensive green roofs have increased load/system weight (Cutlip 2006).

7.4 Lighting Systems

It is important to look at the lighting system in a building because it can be considered a good contributor in saving energy. The electric lighting represents 15–60% of electricity consumption in buildings (Dubois et al. 2015). Therefore, it is significant to retrofit the lighting system in the UAE since it can make a significant difference. Two aspects must be considered, efficiency and effectiveness. Efficiency looks at the performance of the equipment (lamps, control gears, etc.) and the improvement of the lighting design practice; while effectiveness looks at the lighting control systems and ways to improve it in order to avoid energy waste, and hence save energy (Martirano 2011). The lighting system consists of three categories: the luminaires, the control system, and the services. It is not necessary that retrofitting the lighting system would reduce energy only, it has several other advantages such as improvement in lighting quality, occupant satisfaction, and productivity, improved corporate image, energy security, etc. (Dubois et al. 2015). In order to retrofit a lighting system of a tall building, it is important to select the most suitable light bulbs, control systems, and services. The most common retrofitting strategy that has a high saving potential is the replacement of lamp, ballast, and luminaire as well as the usage of an electric lighting control system that is known to reduce the energy consumption (Dubois et al. 2015). For the replacement of lamps, three standard lamps (Compact Fluorescent Lamps (CFLs), Light Emitting Diodes (LEDs), and Halogens) that are used in the UAE will be discussed later and compared to incandescent lamps (UAE 2018). As for the control systems, four main systems will be discussed including the manual control, scheduling, occupancy control, and daylighting.

7.5 HVAC Systems

The occupants' comfort in the surrounding environment of any building is of major importance which makes designing the most appropriate Heating Ventilation and Air Conditioning (HVAC) system crucial in providing the optimum temperature required by the occupant. However, the HVAC system is known to be one of the largest end-users of energy especially in hot harsh climates. Only in case the system is properly selected and designed, it can save energy up to 30% (Fasiuddin and Budaiwi 2011). With proper operation of HVAC system, it is compelling to reach the highest energy consumption of the building (Fasiuddin and Budaiwi 2011). The system tends to add and remove heat to maintain a certain temperature, as well as adds and removes air by keeping same temperature and aims at the improvement of the indoor air quality and thermal comfort (Grondzik and Furst 2000). The main concern in dealing with HVAC is occupants comfort which, according to an air conditioning clinic (Trane), can be categorized into temperature, humidity, air movement, fresh air, clean air, noise levels, lighting, and furniture and work surface (Trane 2012). HVAC has three functional categories: the source component that is responsible for providing and removing heat/moisture, the distribution component that distributes the air to locations where conditioning is required, and the delivery component that combines distribution system and occupied space (Grondzik and Furst 2000).

8 Conclusions

This paper summarized the approach and the main elements that were identified in a study to develop a green retrofitting toolkit for commercial buildings in the UAE. In addition to a thorough review of the relevant literature and available products, the study, highlighted in this paper, also used a Revit model to analyze a typical commercial building design in terms of energy efficiency and cost savings. The project focused on commercial buildings since they typically registered the highest energy consumption spikes as mentioned in a report of the American Council for an Energy Efficient Economy (Ellis and Mathews 2002). Making buildings more energy efficient is particularly relevant in harsh hot climates. Ultimately, the study identified the most UAE relevant measures and guidelines, and performance metrics were developed. Moreover, energy throughputs were modeled and cost savings were analyzed. Future work can target more building types and explore different retrofitting elements and their feasibility.

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Digital Technology and Integration in Construction: The UAE Context

Irtishad Ahmad and Sameh El-Sayegh

Abstract

Traditionally construction is a fragmented industry too slow in adopting new technology. As a result, construction sector productivity continues to remain stagnant. Digital technology offers a great opportunity to improve productivity by integrating many entities and functions in construction. The paper argues that integration can be achieved to a large extent with proper adoption of digital technology. Technology's transformational role in construction needs to be recognized and harnessed by the stakeholders. The transformations and potentials are evidenced in the construction sector of UAE, where the government is taking a proactive role in facilitating adoption of digital technologies, such as Blockchain. A conceptual model that explains the push/pull relationship between technology and integration is presented in the paper. The main conclusion of the paper is that the construction industry at all levels—firm, industry, and government—must take proactive actions to foster and facilitate integration in its processes by adopting technology.

Keywords

Construction • Integration • Technology • United Arab Emirates

1 Introduction

Two major thrusts—demands for integration and a need for technology adoption in construction have defined the construction industry for decades. Construction is known to be a traditionally fragmented industry and a low-tech sector of businesses. It is not surprising that the sector productivity in construction has remained consistently stagnant or have been declining globally over the past four decades. We argue in this paper that these two needs—integration and technology adoption—are not only interrelated but complementary.

Objective of the paper—The major objective of the paper is to present an analysis of interrelation between integration and technology in construction. The paper puts forward the argument that a greater extent of integration can be achieved with appropriate technology adoption. The ultimate goal is to emphasize the transformational role of (digital) technology in construction.

Scope of this paper—Although the lack of integration is mostly an internal issue at the sector level; technology (digital, in particular) is an external factor. In the sense that the construction industry is the user of technology developed in "other" sectors. In addition, the scope of this paper is on the process technology (such as the information and communication technology or ICT) and not much on the product technology (robotics or 3D printing, for example). Although it may be argued that at times the two can be related. As an example: prefabrication, primarily a product improvement technology which is fostered or facilitated by Building Information Modeling (BIM) or Virtual Design and Construction (VDC), a process innovation.

A World Economic Forum report (2016) published in 2016 identifies the areas that fall under *Processes and Operations* as

- front-loaded and cost-conscious design and project planning;
- innovative contracting models with balanced risk-sharing;
- enhanced management of subcontractors and suppliers;
- lean and safe construction management and operations; and
- rigorous project monitoring (scope, time, and cost).

Further, we discuss the case of current state of the construction sector in UAE as an example. UAE is a part of the Middle East and North Africa, which is one of the most

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vibratant regions of construction globally and is poised to grow at the highest rate in the next five years. UAE is also the region that is proactively (evidenced by both private and government initiatives) looking into new technologies for implementation in its construction sector.

Organization of the paper—The rest of the paper is organized as follows: First, we present a brief overview of the global construction industry, followed by a discussion on the UAE construction market. Next, in Sect. 3, the issues related to construction productivity and its dependence on integration and technology are discussed. In the following section (Sect. 4), the current state of the UAE construction industry and the near-term outlook is presented along with a discussion on how digital technology is playing a role in the growth of the UAE construction. In Sect. 5, we present a conceptual model that relates integration and technology and explains how one can push or pull the other. This model is presented in order to help stakeholders understand the dynamic relationship between integration and technology. In the last section (Sect. 6), conclusions of this study are outlined.

2 Overview of the Construction Industry

The Construction Intelligence Center (CIC) forecasts the pace of expansion in the global construction industry to average 3.6% a year over the forecast period 2018–2022 (Timetric-Construction Intelligence Center 2018). In real value terms (measured at constant 2017 US$ exchange rates), global construction output is expected to rise to US $12.7 trillion in 2022, up from US$10.6 trillion in 2017. This represents an increase of almost 20%.

The same report forecasts, as shown in Table 1, that the Middle East and Africa region is expected to grow at a rate of 9% CAGR (Compound Average Growth Rate) between 2018 and 2022. These countries will likely spend significant amounts of their oil revenue on major infrastructure projects.

As can be seen in Table 1, the construction sector will continue to be one of the most vibrant sectors globally, in general, and in the Middle East and Africa, in particular. The underlying reason for this continued growth and expansion is, increasing urbanization driving the need to build more habitable facilities and infrastructure. At the same time, advances in digital technology are having an impact on the construction sector and its entities. The demand to build sustainable and resilient buildings and facilities is another added dimension to this need. Thus, these three factors—need for building infrastructure and facilities, advances in digital technology, and demand for sustainable and resilient construction—will define the construction industry in the coming decades.

Construction in UAE—The construction industry contributes more than 10% to the United Arab Emirates' (UAE) gross domestic production (GDP). The UAE construction industry is growing consistently and expected to grow more in the near future to accommodate the UAE's strategic goals that include significant spending in infrastructure construction. As for example, in 2015, the government announced its plans to invest over AED 32.0 billion (US$8.7 billion) to construct the Expo (Dubai Expo 2020) site on a 4.3 million m^2 area, as well as other related infrastructure facilities in the Dubai South district (Newswire 2017). Another example, the UAE has approved the construction of 7,200 housing units for Emiratis across different parts of the UAE at a total cost of US$1.9 billion, with projected completion time by 2021 (News 2018). The construction activity is projected to continue rising as a percentage of real GDP in the UAE; from 10.3% in 2011, to 11.3% in 2015, on to 11.5% in 2021 (Dubai 2012).

Against this backdrop, however, we see a bleak picture when it comes to construction productivity. For decades, construction productivity remained stagnant or even declining in many regions.

3 Construction Productivity

Despite all the advances in construction technology, digitization of the products and processes in a frantic pace, construction of many spectacular buildings and infrastructures and impressive megaprojects, construction productivity actually declined in the US over the forty-eight years from 1964 to 2012. According to the aforementioned World

Table 1 Average annual construction volume (billion US $)—2018–2022

Region	Annual volume (in billion US$)	CAGR—compound average growth rate (%)
North America	$1,779	4.4
Europe	$2,564	5
Asia-Pacific	$5,125	6.3
South and Central America	$486	6.3
Middle East and Africa	$635	9

Source Global Data (formerly: Timetric)

Economic Forum Report (2016) "Shaping the Future of Construction: Future Scenarios and Implications", construction labor productivity in the US has declined by 19% between 1964 and 2012 with a corresponding Compound Average Growth Rate or CAGR of −0.4%. During the same period, non-farm business labor productivity rose by 153% with a CAGR of +1.9%. (These figures are inflation adjusted and indexed to 1964). This is a matter of concern. Globally, according to a 2017 report by McKinsey Global Initiative (2017), during the twenty years from 1995 to 2014, construction productivity rose by CAGR of only 1%. The Report concludes, "The Engineering and Construction (E&C) sector has been slower to adopt and adapt to new technologies than other global sectors. While innovation has occurred to some extent on the enterprise or company level, overall productivity in the sector has remained nearly flat for the last 50 years."

McKinsey report (2017) asserts that construction sector productivity can be improved by 50–60% with actions in the following seven areas:

- Reshape regulation (External Forces—Government)
- Rewire contracts (Industry Dynamics)
  - Collaboration
  - Contracting
- Rethink design and engineering (Industry Dynamics)
- Improve onsite execution (Firm-level operational factors)
- Infuse technology and innovation (Firm-level operational factors)
- Reskill workers or capability building (Firm-level operational factors)

Also estimated in the report, "technology" has the highest contribution to improving productivity—14–15%. It is revealing to note that other six recommended actions fall under the premise of process improvement, as opposed to products. It should be noted that in the above list of actions, the major responsible parties indicated in the parenthesis are External Forces (Government), Industry Dynamics, and Firm-level operational factors. This is an important issue as productivity must be understood at different hierarchical levels or layers—first, firm-level or intra-organizational; second, industry-level or inter-organizational; and third, regulatory-level or governmental.

Thus, the issue of integration, or lack thereof, must also be considered along with productivity measures at these levels for possible and potential actions. We need to consider integration in construction at these three distinct but interrelated levels—informational, organizational, and contractual.

3.1 Integration in Construction

Informational integration refers to integration of functions within an organization (intra-organization). Informational integration supports communication functions, promotes collaboration, and facilitates formation of virtual teams and is usually achieved by developing effective information systems (Ahmad et al. 2019).

Organizational integration is inter-organizational (between organizations) in nature and is a response to the needs of coordination and collaboration. Integration of this type usually implies design and production (construction) functions physically in one organizational boundary under a common leadership. Design-build project delivery system, combining engineering design and construction under the same entity is an example of organizational integration in construction.

Contractual integration evolved in response to the need for making organizational integration more effective. For, without backing of appropriate contractual languages, organizational integration cannot be effective. Integrated Project Delivery (IPD), for example, is a project delivery system that promotes integration of contracting parties.

3.2 Digital Technology

Full-scale digitization of the construction industry—including 3D printing, AR (augmented reality) and even autonomous construction—could save up to $1.7 trillion globally within 10 years, as the aforementioned World Economic Forum report (2016) asserts. As John M. Beck, Executive Chairman Aecon Group states in the Foreword of the Report, "Any improvement in productivity and successful adoption of modern innovative processes facilitated by the digital technology will have a major impact. For example, a 1% rise in productivity worldwide could save $100 billion a year."

In this paper, however, we will keep the discussion on digital technology limited to Information and Communication Technology (ICT) as the scope of this paper is focused on mainly process improvement in construction. ICT can contribute tremendously to increase in construction productivity. The seven action items recommended in the McKinsey report can be effectively pursued using ICT. ICT provides the impetus to foster integration at all three layers—informational, organizational, and contractual—in the construction sector.

The construction industry already embraced many ICT techniques and tools in the area of visualization, data analysis, communications and collaboration, information sharing and management, and information modeling. Rapid adoption of smartphones and tablet devices in the industry not only confirmed the need for quick information sharing but has also changed the mode of work practices at construction jobsites and offices. Similarly, Building Information Modeling (BIM) has changed the way the buildings are conceived, designed, constructed, and operated. The use of BIM has encouraged the integration of the roles of all stakeholders in a project. This integration has brought greater efficiency and harmony among players who all too often in the past saw themselves as adversaries.

Based on the discussion above, it can be expected that a symbiotic combination of *technology* and *integration* in a construction project can foster better coordination processes and collaboration among the project participants.

3.3 The UAE Context

Let us consider the case of *Blockchain* technology in UAE. First of all, a brief definition (ICE 2018), "Fundamentally, blockchain is a distributed ledger of information, such as transactions of agreements, that are stored across a network of computers. That information is stored chronologically, can be viewed by a community of users, but is decentralized and is not usually managed by a central authority such as a bank or a government, and once published, the information on the blockchain cannot be changed."

In Dubai, one of the seven Emirates in UAE and the largest urban area has an ambition to be the first city in the world powered by blockchain (Week and Online 2019). According to one of the proponents (Prashant Gulati founder of the community innovation hub, The Assembly), "Blockchains has the potential to making the supply chains more efficient and secure, increasing transparency, boosting productivity, and making documents accessible to all parties in a project."

Since blockchain establishes a shared network for all stakeholders, the Dubai Land Department (DLD) adopted this technology to improve, secure, and simplify property transactions (Construction and News 2018). According to its proponent, Tom Rhodes of Cityscape Global, "The technology will drive an era of 'smart contracts' due to its ability to create, authenticate and audit contracts in real time, across the world."

According to (Business and Intelligence 2018). "Digital transformation is happening everywhere and is being driven by many factors, including changing economic necessities, societal shifts and new technologies." It was correctly pointed out that new technologies and commercial pressures are forcing the industry to rethink the way it works.

The assimilation of the digital technologies is dependent on the regulatory support with appropriate laws and regulations to facilitate AI, Blockchain, Big Data, and similar technologies. The goal is to integrate and link public and private sector databases and information portals through digital technologies. Without such integration, supported by regulations, the technology will remain mostly ineffective and underutilized.

Fortunately, in UAE the pace is much faster compared to other global regions in incorporating digital technologies. The government takes a keen interest in proactively

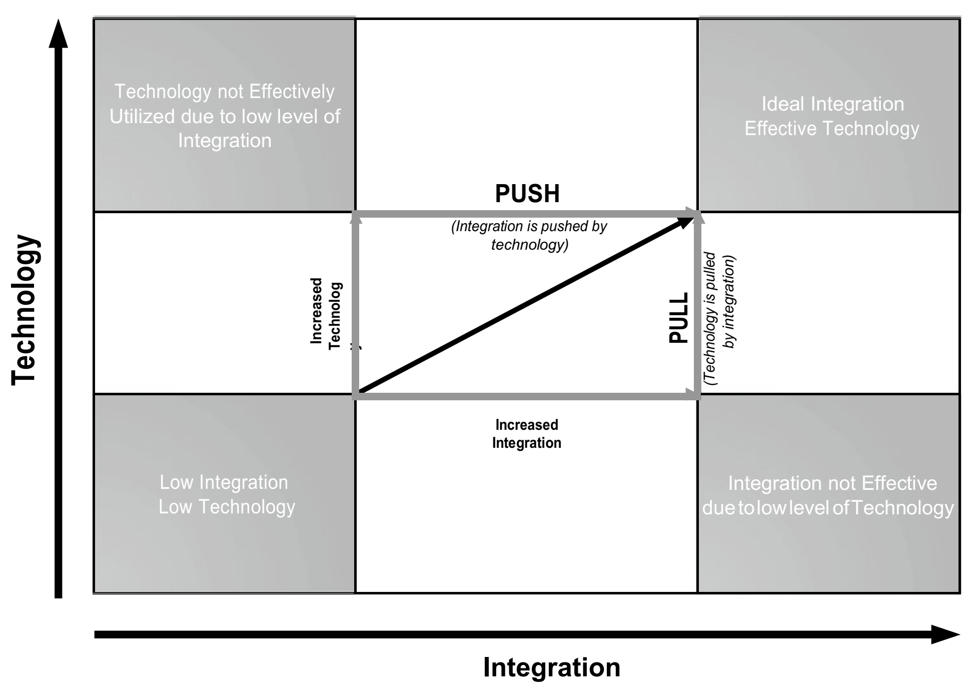

Fig. 1 Technology-integration interaction model (Adapted from Ahmad et al. (2019))

implementing digital technology. The question for the companies (firms and other organizations belonging to the construction industry), the industry, and the public (regulatory/governing) entities is: are they working together to facilitate the "push" of technology and accommodate the market "pull" (commercial pressures as mentioned above)?

4 Discussion

As pointed out above, there is a "push/pull" effect between technology and market forces (integration). Technology as an external force *pushes* improvements; and market forces (commercial pressures, profit motives, and completion) *pulls* technology adoption. Market forces are internal to the sector, while technology forces are external.

It should be realized that only external push will not be effective, if there is no corresponding internal pull. A case in point is artificial intelligence or AI. The concept of AI is not new, but it failed to take off until market pull forces (from a business standpoint) became effective. The Model in Fig. 1 below illustrates this concept.

As shown, technology pushes integration to take place, and integration pulls technology up in order to be effective. It is important to note that, as depicted in the figure, to achieve a high level of integration, effective technology must be deployed.

If not, integration will not be effective as indicated in the lower right corner area in the figure. Conversely, the upper left corner, denotes the situation when a high level of technology is not effective due to a low level of integration. The conceptual model, illustrated in Fig. 1 can be useful in order to understand, describe, prescribe, and/or formulate a strategy for adoption of digital technology at all three levels—organizational, industry-wide, and governmental.

5 Concluding Remarks

The construction industry worldwide is characterized by two endemic issues—fragmentation and low level of technology. The consequence is a pervasive state of low and, in some regions, declining sector productivity. We argue that these two issues although distinct, are interrelated.

Fascinating new digital technologies are becoming available and at the same time new market demands are arising in the construction industry. Today's construction projects are not just larger in size, but also more complex than ever before. The pressure to deliver quality projects on time and at cost is immense. On top of that they must also be sustainable and resilient. Thus, today's reality offers opportunities (technology) as well as challenges (market demands).

New digital technologies are available to provide the impetus needed for these actions, but industry must provide the conducive atmosphere and embrace the new reality. For example, in order to effectively incorporate the Blockchain technology, certain rules and regulations will have to be adjusted or modified at the government and regulatory levels. The stakeholders (owners, engineers, architects, contractors, subcontractors, suppliers, etc.) must also be willing to accept and use the new technology. This is only possible with certain specific changes in organizational norms and procedures as well as modifications in contractual languages. Thus, not just a desire but a paradigm shift in mindset will be necessary.

With proper recognition by the stakeholders, the construction industry can overcome these challenges by taking advantage of the opportunities. The industry, at all levels—firm, industry, and government—must take proactive actions to foster and facilitate a greater extent of *integration* by implementing and adopting *technology*.

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Reviewing and Refining the RGR Model for Quality Management: A Generic Blueprint

Vasantha Abeysekera and Mayur Shelke

Abstract

The RGR framework was synthesised using the 'construction as simile' framework with specific reflections on 'construction as biological cells' simile. A generic blueprint of the model vis-à-vis a write-up was developed to explore its relevance, validity, and applicability as a precursor to an industry survey. The purpose of this study was to assess the comprehensibility of the blueprint. Seven professionals from Tier 1 construction companies, large client organisations, and regulatory authorities were chosen to review the blueprint. Three rounds of reviews were conducted each involving two reviewers at a time integrating feedback received in subsequent reviews. Feedback received identified the need to tone the descriptions to a neutral, non-construction, non-verbiage blueprint. This resulted in further reflections of the concepts leading to further refinement. Additionally, this analysis led to the rationalisation of a global set of 'tools' (concepts) for cellular replication effectiveness and efficiency which are to be explored in the near future. The peer review indicates progress is in the right direction with some reviewers already describing the implementation aspect of this framework to construction encouraging. While the authors profess likely wider application of this model to construction, this study is limited to the issue of developing a generic and a refined blueprint of the RGR framework so to as develop a construction-specific blueprint for application post a detailed industry survey.

Keywords

Cellular • Global • Quality management • Replication • RGR framework

1 Introduction

Living organisms are made of billions of cells. These cells have a limited lifespan. New cells are created through cell division with remarkable accuracy and exceptionally low levels of defects. What is astonishing about this process is that the extent of defective cells created is exceptionally small. This observation kindled a series of new investigations using the simile 'construction as biological cells' inspired by an innovative research method developed by Abeysekera (1997) exploring 'Brickwork as Chaos' now referred to as the 'construction as simile' framework. As years passed, this approach was used for building theories on monetary retentions exploring similes such as *retentions as cash cow, beast, steroid, chaos* etc. (Abeysekera 2008) and also on studies connected with student study-time management (Abeysekera and Abeysekera 2007; Abeysekera and Abeysekera 2015; Abeysekera and Abeysekera 2017). Today, it is seen as a sub-framework of 'construction as images' as suggested by Abeysekera (2018). More recently, construction-as-simile framework has been used for developing new insights on quality management exploring the notion of 'construction as biological cells' (Abeysekera 2018; Abeysekera and Shelke 2017). Methodological issues connected with the use of simile in this study has also been discussed (Abeysekera and Mayur 2018) which commenced in 2013 having argued that construction cells are similar to biological cells in some ways but are different in other ways (Abeysekera and Shelke 2015) This line of inquiry using simile to explore have thus far generated seven refereed conference papers and a journal paper (Abeysekera and Shelke 2017) all of which have reported extensively on the

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exploratory journey on developing the RGR framework for quality management.

The framework consists of three key stages, namely, Rest (R), Growth (G), and Rest (R) along with several sub-concepts with a significant departure to the manner in which quality is traditionally managed. Details of the framework has been described by Abeysekera and Shelke (2018) and Shelke and Abeysekera (2018) with Fig. 2 depicting the model for further clarity.

2 Aims and Objectives

In order to explore the relevance, validity, and applicability of the RGR model, it was necessary to develop a concise description of it so that:

(a) the model and the concepts were comprehensible; and to
(b) conduct an interview survey based on a refined description.

The aim of this study was to focus on sub-objective (a) so as to continue with (b). Accordingly, in order to assess the first objective, a write-up on the model and its associated concepts was presented for review by suitable persons from industry in order to pursue with the (b) objective. The intention was to develop a generic blueprint of the model with succinct descriptions in order to subsequently develop a construction specific blueprint.

3 Review Methodology

In all seven reviewers were selected along with an academic reviewer who is the first author of this paper. The other seven reviewers were selected by the second author using the convenience-sampling approach as it was important to ensure that there was a high response rate. Their selection was based on their expertise in quality management coupled with their long experience in the construction industry. Their designations are given below with four reviewers drawn from Tier 1 construction companies and three from organisations representing client's interests. Incidentally, the second author works for a Tier 1 company as a senior quality advisor.

- R1: Administrator (Engineering Mgmt. System) appointed by the Contractor
- R2: Senior Contract Administrator/Manager appointed by the Contractor
- R3: Project Engineer appointed by the Contractor
- R4: Independent Certifier; a regulatory appointment apppointed by the Client
- R5: Construction Superintendent appointed by the Client
- R6: Independent Certifier; a regulatory appointment appointed by the Client
- R7: Academic reviewer; Independent (First author of the paper)

The process followed is shown in Fig. 2. The model and the concepts were included in two computer files with the first file having a description of the overall framework (with sub concepts) and the second file containing a brief description of the synthesised model concepts. These were sent to R1 and R2 whose feedback was used to modify subsequent write-ups. Reviews included the need to add an introductory section with background and context of study.

Thereafter, these files were provided to R3 and R4 for review. While R3 was physically handed the documents, an email was sent to R4. Both files were integrated into one as per feedback received with intermediate reviews undertaken by the authors as shown in Fig. 1.

Having responded to additional feedback received from R3 and R4, the revised write-up was sent to R5 and R6 for review. In all, six respondents from industry reviewed the documents providing feedback. Additionally, the first author too provided necessary feedback. Their comments are discussed in the next section including how the new write-up on the RGR framework was synthesised.

It needs to be pointed out that the intention was to make the write-up clear without imposing any particular points of view on how the model can be used based on previous findings. Moreover, it was envisaged that more research may need to be undertaken on the sub-concepts to make them clearer.

4 Reviewer Comments

As noted before, there were seven reviewers with six from industry. All responded with feedback with key points summarised below. For brevity, the draft write-up provided to the reviewers and how these were reviewed at each stage has not been provided. The analysis provided in the ensuring paragraphs does not reflect the iterative approach adopted for data collection but is based on the similarity of feedback content. For instance, R1 and R3′s feedback was mainly about the clarity of the draft overall writeup, while R2′s and R4′s comments were on improvements to sub-concept write-ups. R5′s and R6′s comments were mainly on the applicability of the concepts.

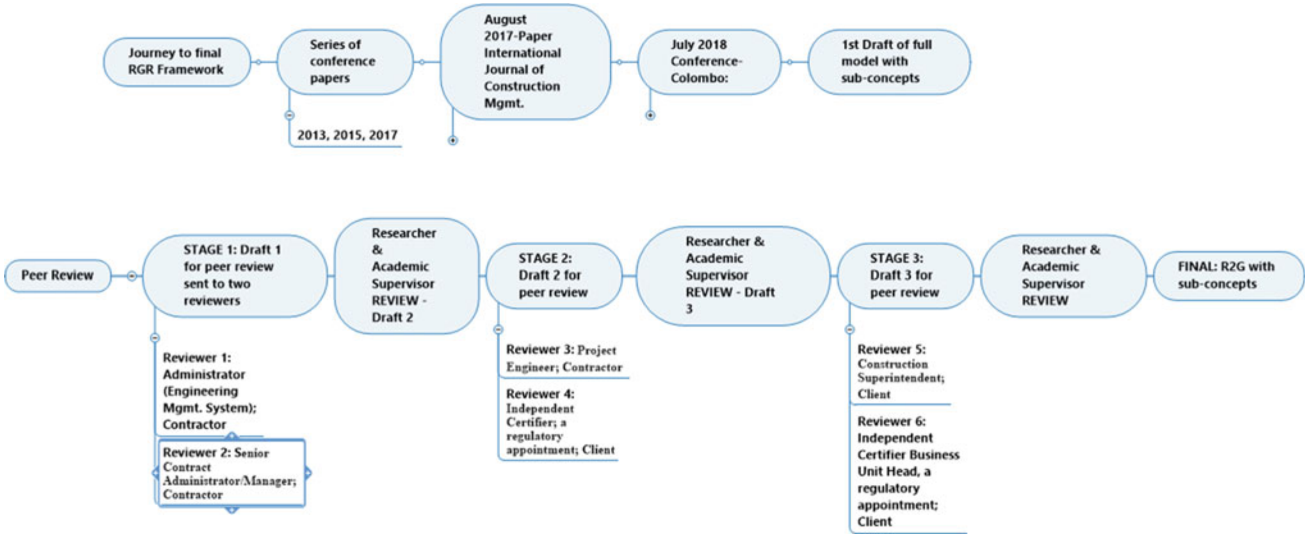

Fig. 1 Methodology mind map

4.1 Reviewers 1 and 3

R1 found the description of the growth stage *'wordy and confusing'*. Further R1 commented that he *'found the beginning of the growth stage difficult to understand … [while] the rest read and flowed well'*. Based on this feedback from R1, the explanation of the growth stage was further simplified including write-ups of the underlying concepts.

As mentioned before, two files were sent in the first phase to R1 and R2 each, one giving the cyclic RGR model and another giving explanation of the sub concepts associated with the model. R2 provided comments on the concepts (see Sect. 4.2) considering the ease of readability within the context of industry. Reflecting on these comments, the updated writeup was sent to R3. Interestingly, the review feedback from R3 was *'well set out, clear language, provides a good explanation of this construction conceptual framework'*. However, R3 commented upon the need to improve the grammatical syntax, spelling errors and general layout of the document. Noteworthy is the fact, R3 found the explanation of the RGR framework well set out in clear language.

4.2 Reviewers 2 and 4

R2 suggested a brief introduction before explaining the concepts, and to simplify concept descriptions further to make it more industry friendly. On the concept of embedded design within the Readiness stage, R2 queried on what was meant by 'rate' which appeared to be a straightforward concept for the authors but not to industry participants. Reference was made to prototype building for trialling and testing of the embedded design, for instance, but R2 suggested adding 'under actual '*functioning conditions i.e. live construction environment* ….'. Similarly, concepts related to Growth and Rest stage were addressed in terms of readability and ease of association with the construction parlance, while expanding the writeup to avoid any ambiguity.

R4 queried about the '*connectivity between EMD & Blueprint'* and that the *Blueprint and EMD being used interchangeably?* with a need to make a better clarification. Initially, the blueprint was literally taken as the design for building. In cellular context, the embedded design is the instruction to achieve error free replication of cell and the confusion between these terms were resolved by removing all reference to 'blueprint'. R4 also suggested using word 'operational' in place of 'functional' for prototype building as in 'A prototype… (ideally under actual *operational* conditions…)'. The designation of conditions under which to build a prototype created some confusion.

This was addressed in the updated writeup, wherein the purpose of the prototype was to check the readiness of the EMD. Similarly, there were challenges with regards to Process Stress. In the biological cell, stress is measured in terms of time taken for the activity; if completed in a shorter time, it was an indication of stress. In construction, a delayed activity is more likely to impact the subsequent planned activities, hence shorter time as creator of stress is counter intuitive.

Furthermore, with reference to sub concept of distress signalling to induce temporary stoppage, R4 commented that he was *'unsure if stoppage (or) halting of construction activity always is possible or practicable'*, with similar comment made for the concept of transient rest. It seems, R4 was considering the application of this to construction pointing out the practical difficulties to *stop* construction which is schedule driven. There were issues related to the clarity of *transient gates* too with the main reason being our attempt to demystify the concepts. Despite the confusions created, an attempt was made to respond to such comments before the draft write-up was provided R5 and R6.

4.3 Reviewers 5 and 6

The feedback from R5 was that the framework and the model was *'well thought out, and has enough detail to understand how the concept relates to quality processes in construction clearly without being confusing, and you can easily see how this framework can be expanded in more detail to grow into the basis of a Quality Management System'*. While R6 commented, while the concepts were good, it was '*hard to understand as terminology'* and that in the '*current form… it was not practical to provide for implementation'*. This is understandable as the write-up is not a working document to manage quality but a document that was being developed to seek views from industry as to how these concepts may be explored in practice when managing quality.

5 RGR Framework and Concepts—Post Review

Reflecting on the feedback received, greater the attempt at clarifying concepts through construction specific examples, greater was the need for further clarification. Accordingly, it was reasoned that the final write-up should have minimal reference to examples or on how such concepts could be explored in practice in an attempt to make the write-up neutral sans construction terminology favouring the use of cell specific terms. The synthesised model is shown in Fig. 2 along with the final concepts while concept as tools is shown in Fig. 3 with cell descriptions shown below under the different model stages.

<u>**Readiness stage**</u>**:**

- **Embedded Design for Cell (EMD):** The outcome of applying the RGR framework along with its associated concepts.
- **Transient Readiness Gate**: Regulates passage to the Readiness Gate ensuring compliance with EMD.
- **Readiness Gate**: Regulates passage to the Growth Stage if EMD is suitable and cell is ready for replication and is a component of cell surveillance.

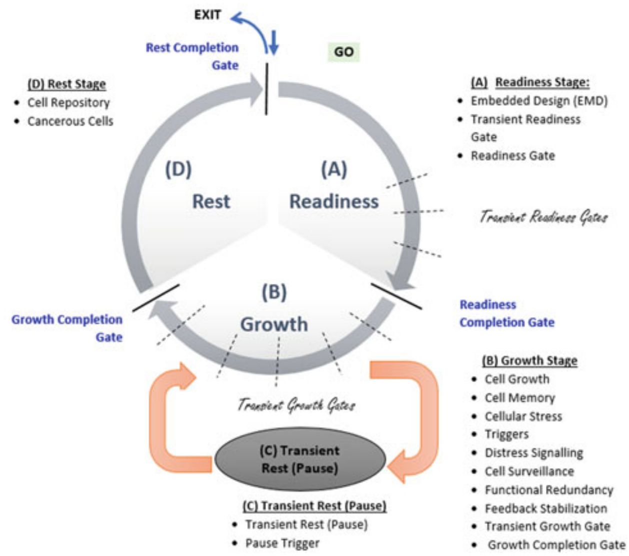

Fig. 2 RGR conceptual framework post review

<u>**Growth Stage**</u>**:**

- **Cell Growth**: Uniform or variable rates of growth according to EMD.
- **Cell Memory:** Records growth of cells, cell cycles. synthesising strategies for perfect cell growth.
- **Cellular Stress:** Cellular stress is created by departures from EMD.
- **Triggers**: Induce signals when cell is stressed.
- **Distress Signals:** Pauses cell cycle when growth deviates from EMD as per triggers.
- **Cell Surveillance:** Constant vigil over cell growth responding to negative stimuli (internal and external) inducing distress signals automatically or otherwise to prevent a breakdown of the EMD
- **Functional Redundancy:** An arrangement for failsafe-cell-function (such as surveillance, gates operations, distress signalling, cell memory) by more than one way.
- **Feedback Stabilisation:** A response to cellular stress activated by distress signalling induced by triggers in order to stabilise growth through cellular pathways.
- **Transient Growth Gate:** Regulates passage to the Growth Gate ensuring compliance with EMD with cycle paused if non-compliant.
- **Growth Completion Gate:** Based on surveillance feedback the cell has been perfected fully as per EMD, the gate allows passage to the Rest Stage.

Transient Rest and Rest Stage:

- **Transient Rest:** A pause in cell cycle due to distress signals providing an opportunity to address the cause of such distress signals and restore the cell to EMD using the transient growth gate.
- **Pause Trigger:** Pauses cell cycle when growth deviates from EMD
- **Cell Repository:** Non-cancerous cells either awaiting re-entry to the cell cycle, or in Rest Stage.
- **Cancerous Cells**: A completed cell but outside the cell cycle leading to more cancerous cells.

6 Conclusions

The responses received indicated that the RGR framework has found resonance with construction professionals. The progressive integration of the feedback in stages has added value to the framework and provided further clarification on the embedded design and concepts simplifying the write-up to connect with the 'construction world' using language that is neutral. R1 and R2 reviewers provided the initial impetus in expanding the introduction to the model, which was endorsed by R3. The review comments from R4 helped further add depth with respect to embedded design, transient rest, gates, process memory, process stress and abnormal growth by refining the write-up and also selecting appropriate terms, for example, replacing 'transient rest' to 'pause'. There were divergent views expressed by R5 and R6, where R5 was eager to see the outcome of the implementation of this framework, while R6 found this as 'good' but not practical to provide for implementation which is understandable as the document developed was not aimed so but solely for further exploration as a precursor to achieving the second objective listed in Sect. 2.

In summary, the final write-up on the model has been amended to reflect the feedback provided as outlined above.

In doing so, special care has been taken to avoid verbiage and to infuse construction management terminology.

Additionally, any examples to illustrate potential ways in which the concepts can be applied (as seen by the authors) have been avoided so as to permit creative and free interpretation by the interviewees to be surveyed. However, if the interviewees need any clarifications, steps will be taken to have notes to support the semi-structured interviews to follow.

Interestingly, while the researcher has sought comments on the model and has not asked about how to implement this to construction, the fact some reviewers (R4, R5, R6) have commented about its applicability points to the direction of further study, i.e. getting the construction industry's views on its applicability. Such feedback is indicative of the study in the right direction, with the next stage planned for understanding how the construction industry interprets the application of this framework to achieve quality in construction.

7 Reflections

A constructed facility is a multi-cellular structure (Abeysekera and Shelke 2015). The RGR model synthesized using the 'construction as biological cells' simile provides a cell-focused cyclic approach for achieving quality by bringing into motion 17 sub-concepts. Cellular replication effectiveness and efficiency is due to the unique way a cell is expected to operate using these sub-concepts. The cell growth does not commence unless the readiness gates allow passage to the growth stage, wherein the gates ensure that the preparation for the proper replication or growth of the

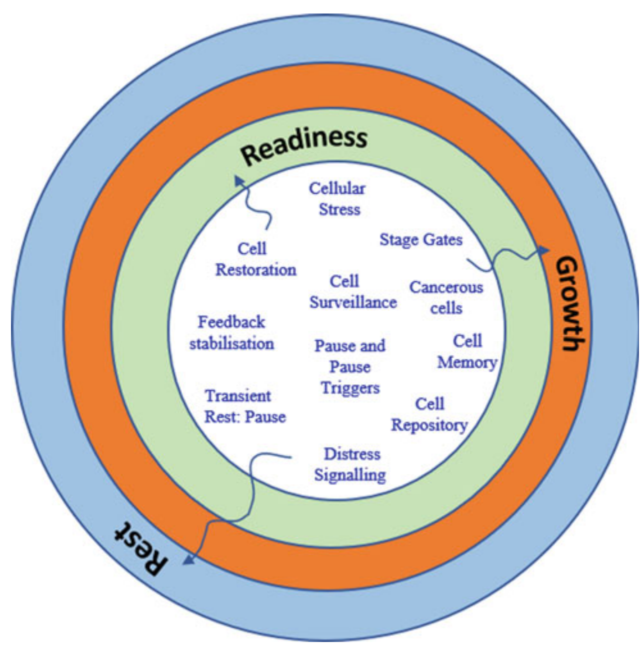

Fig. 3 Cell concepts with global presence across RGR stages for quality management

cell is satisfactorily completed and the essential 'growth factors' available.

Subsequently, in the growth stage the actual construction of the cell occurs, manifesting the abstract cell lying dormant within the EMD. Various concepts are used during the growth stage such as cell surveillance, cell memory, distress signalling, feedback stabilisation, transient rest, as shown in Figs. 2 and 3 along with their descriptions thereafter. Following completion of the construction of the cell, there is a gate at the end of the growth stage which allows passage to the subsequent rest stage, subject to the growth completion or construction is as per the EMD.

The transient pause allows for the cell restoration to EMD, thus ensuring integrity in replication. Subsequent passage to the rest stage, allows for the construction cell to exit the cycle or wait for the entry to the next cycle if the EMD so dictates. This also provides an opportunity to reflect on the outcome of the EMD or the constructed cell and imbibe lessons learnt in the EMD. Likely, some cells have evaded the gates and the surveillance and various tools to ensure proper replication, and have been completed, albeit in a defective manner, i.e. not as per EMD. The rest stage allows for identification of such 'cancerous' cells and its redressal, either destruction, restoration or at the least imbibe lessons learnt for improving the EMD for subsequent replication.

The ubiquitous nature of the tools like cell surveillance, stress, memory, distress signalling, transient rest, feedback stabilisation used for the cellular replication efficiency is depicted in Fig. 3. These can be considered as having global presence across the three stages viz. Readiness, Growth and Rest Stage while emanating appropriate signals for gates to allow the passage from one stage to another; thus, ensuring proper synchronisation of activities of each stage and subsequently maintain the integrity of the manifestation of the EMD. This is especially true, of the first cell which is lying dormant within the EMD.

However, there could be rogue cells which evade such robust cellular scrutiny, leading to defective construction cells. Such cells, operating outside of cellular control can be considered as cancerous, draining resources with detrimental effects if allowed to replicate in an unchecked manner. The Rest stage of RGR framework allows for identification of such cells, restoration or destruction and imbibing lessons learnt in the EMD for subsequent replication, sans any defect.

Authors profess that this framework may have wider relevance and application to how construction may be managed, particularly in cellular-construction.

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A Methodology for Establishing the Relevance of the RGR Model to Construction

Mayur Shelke and Vasantha Abeysekera

Abstract

Managing quality has traditionally been problematic. A new conceptual framework, Readiness, Growth, Rest (RGR) has been developed with the intention of managing quality in construction. Various options were identified to elicit views from the construction industry with regard to the relevance of this framework. A new framework referred to as the SAF framework has been developed for evaluation of the options within the research paradigm selecting semi-structured interviews as the basis for proceeding with this study. In order to pursue further, this study reports the use of the Six-Honest-Men framework as the guiding light for framing questions on RGR model concepts.

Keywords

Quality management • RGR framework • SAF framework • Six-honest-men framework

1 Background

Managing quality has traditionally been problematic with defects during construction and thereafter, with various studies estimating rework costs in the range of 10% to 20% of the project cost (Love et al. 2017; Josephson et al. 2002). The cost of quality can only increase further if the intangible cost of poor quality is also considered. This is despite the traditional wisdom to manage quality in construction. Accordingly, a new framework has been developed to address this issue reflecting on the Construction as Biological cell simile, given the nearly flawless replication of biological cells (Abeysekera and Shelke 2017,2018). Since then, Abeysekera and Shelke (Abeysekera and Shelke 2017) synthesized a new model labeled as the RGR model and updated it based on the peer review as depicted in Fig. 1 below (Abeysekera and Shelke 2019).

2 Study Objectives

Assessing the relevance of the RGR model and its concepts to (cellular) construction with specific reference to quality management is the focus of this paper. Several plausible options have been considered as a way forward but selecting a suitable option was challenging. This paper describes these challenges and how these were overcome taking a rational approach.

3 Synthesized RGR Framework

The exploration of the construction as biological cell simile, in the quest to achieve defect-free replication of construction cells, has resulted in the RGR framework. Abeysekera and Shelke (Abeysekera and Shelke 2019) have described this framework and the associated seventeen sub-concepts, and the model is depicted in Fig. 1 below (Abeysekera and Shelke 2019). Essentially, this is a cyclic model comprising three phases, Readiness, Growth, and Rest, with transit from one phase to other through the 'gates' which ensure activities of that particular phase has been satisfactorily completed. The transient rest, in growth phase, allows for reestablishing the errant construction activities to normal, by pausing the progress based on signals from surveillance mechanism.

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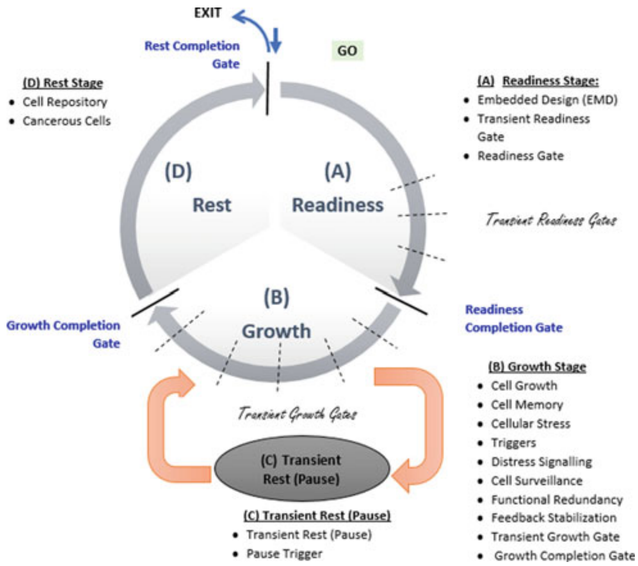

Fig. 1 RGR Framework to Achieve Quality in Construction

4 Research Paradigm

The second author developed a new paradigm which is referred to as the 'simile cum metaphorical' approach initially and now referred to as the 'construction as simile' framework (Abeysekera and Shelke 2019), essentially comparing two seemingly dissimilar items to understand another to generate new ways of thinking about a phenomenon (Abeysekera and Shelke 2018,2019; Abeysekera 1997) and application under such research paradigm has led to the development of RGR framework (Abeysekera and Shelke 2017). Such an approach can be used for investigating a perennial construction phenomenon, which is neither inductive nor deductive, but a hybrid approach for building theory as practice, particularly practice as science to generate scientific-practice (Abeysekera and Shelke 2017,2018). Accordingly, the RGR framework has been developed using the above paradigm.

Epistemologically, the application of science is used to create knowledge, in that 'science applies logic [reason] to questions constantly' for right understanding (Shoemaker et al. 2003). It is proposed therefore that knowledge created must be science if it is to be of value to professions involved with the built environment. Accordingly, when exploring the simile construction as biological cells, the authors assert the application of logic to questions constantly in justifiable ways with a 'specially firm determination not to persist in error if any exertion of hand or mind can deliver us from it' as noted by the Nobel Laureate biologist Peter Medawar with respect to the scientific method (Abeysekera 2008). The ontological view is that of postmodernism; the 'truth' in this sense is seen as an imagination of the researchers as drawn through evidence: There is no objective reality; there are only our several subjective views. According to Babbie (2001), nature of reality is more complex than what can be imagined and all that's 'real' are the images we get through our points of view. There is no 'objective' reality to be observed; there are only several subjective views.

For eliciting such subjective views on the developed RGR framework from the construction industry, various options have been considered as described in next section, thus adding to the existing knowledge. The progression of this study and generation of knowledge, at best can be described as spiral, unlike a simple input–output mechanism, where the destination is not visible unless the spiral is traversed with each step unfurling the next pathway to reach the pinnacle, and in process discovering new concepts to address the research question.

5 Option for Assessing Relevance of RGR Framework

Given the stand, there are multiple subjective realities, results in multiple choices to discover such realities, with the best source the construction industry and the professionals, who are living this 'reality' of construction world. To elicit views from the 'construction world', for establishing the relevance of the RGR framework to achieve quality in construction, various options are listed in Table 1. The listed options align with the research paradigm where the ontological view allows for multiple subjective views of reality, however, the evaluation of each of these is required for the selection of an appropriate option to be accomplished within a reasonable time frame. It must be pointed out that the first author works as a senior quality advisor for a first-tier construction company in Australia and has had access to some of the case studies published earlier and potentially in the future too. This is the one of the drivers in considering the participant-observer option listed in Table 1. Selecting one of the eight options presented a challenging task. Accordingly, a suitable strategy had to be developed. Having considered various options, a framework used for evaluating various business management strategies was found useful which is described in the next section.

6 Methodology for Evaluating the Options

Three methods, namely, SWOT, Analytic Hierarchy Process (AHP), and SAF were considered for evaluation of the options. Whilst SWOT, profiled by Helms and Nixon (Helms and Nixon 2010) has its pervasive use in academic research, was not used because it does not prioritize the identified factors leading to improper actions and is not a substitute for more rigorous analysis (Phadermrod et al. 2019; Johnson and Scholes 1999). In contrast, AHP

Table 1 Various options for establishing RGR model relevance to achieving quality in construction

Options	Option description
1	As participant-observer (PO) re-evaluate case study projects using RGR model
2	Apply RGR model to a new project and assess impact (as in action research)
3	Semi-structured interviews and focus group meetings to evaluate RGR
4	Semi-Structured Interviews followed by updates to model if any; presentation to the participants in case of major changes to the model
5	Application of RGR (and concepts) to problematic processes as a PO (similar to Option 1)
6	Application of RGR (and concepts) to problematic processes and assess impact (similar to Option 2)
7	Application of RGR (and concepts) to an ongoing project as a PO (as in options 1 & 2)
8	Application of RGR (and concepts) to an ongoing project and processes (as in options 1 & 2)

Source Abeysekera and Shelke (2018)

establishes significance of identified factors using pairwise comparison and subsequent analysis of matrix using eigenvalue method (Görener et al. 2012; Whitaker 2007). However, this was not used because the criteria for factors are not provided here, which interestingly the SAF frameworks provide (Johnson and Scholes 1999). Such providence of criteria enables focus on each of the aspect, whilst allowing appropriate evaluation of each option has found purchase for this study. Accordingly, the authors named it as the SAF framework, and the meanings are described in Table 2.

6.1 The SAF Framework

This framework has three elements which as noted before is described in Table 2. The purpose of the SAF framework is to evaluate each available option against the three criteria of Suitability, Acceptability, and Feasibility, as depicted in Table 2.

6.2 SAF Framework and Options Matrix

The qualifying option is the one which meets all the three criteria. Such evaluation strategy ensures logical elimination of unviable options from amongst the many available whilst allowing for justification of the selected choice. This is particularly conducive to demonstrate the application of rigor to select a suitable option at this critical stage of the study, following the arduous journey to develop and refine the RGR model. Briefly, the SAF framework will check each of the options against the three pillars of fitness for the purpose, performance outcomes, and the 'workability' of the option, effectively providing a matrix for logical evaluation, as is described next. Table 3 below depicts the matrix for evaluating the options using the SAF framework.

6.3 Selected Option

The option number four, semi-structured interviews followed by updates to model if any and presentation to the participants in case of major changes to the model has qualified using the SAF framework as depicted in Table 3 above. Such an approach allows to get in-depth views and insight from the industry professionals. With properly selected participants, and an appropriate interview guide a rich data can be collected with regard the RGR framework. This approach aligns well with the postmodernist ontological stance wherein multiple reality exists provides an avenue to explore the existence of such multiple realities if any. This would allow for convergence of various 'realities' and assist

Table 2 SAF-elements

Element	Description
Suitability	This is concerned whether the option addresses the circumstances under which the study is being undertaken. It considers whether the option is appropriate and whether it is fit for purpose, for example, surveys or interviews in a broad sense; are the research methods suitable
Acceptability	This is concerned with whether the research question is answered and the ability to generate reliable and valid responses to the questions pursued. Are the risks acceptable or too risky? Is sufficient data available to make conclusions, is it acceptable to the research community, and is in alignment with the research paradigm?
Feasibility	This is concerned with whether the option is workable to achieve the research objectives. Are there sufficient funds and resources available (such as interviewees); can data be collected; is it time heavy (can it be completed within the available time)?

Table 3 SAF framework-options matrix

Option	Suitability	Acceptability	Feasibility	Result
1	Yes	No	Yes	Rejected
	Reflective case study revaluation using the RGR framework is an appropriate method which also meets the feasibility criteria. However, this option does not meet the acceptability criteria. This is because this option will not provide the researcher an opportunity to interact with the construction industry professionals to gain their views on the matter. Whilst such revaluation of case analysis is value adding, this option falls short of satisfying the research design			
2	Yes	No	No	Rejected
	Application of RGR as part of action research allows for collaborative dialogue, participatory decision making, democratic deliberations with research becoming practical, reflective, pragmatic action directed towards solving the problem Denzin and Lincoln (2000). According to Kemmis (2009), action research aims to change practices, people's understanding of their practices, and the conditions under which they practice. Based on this, the action research aims to improve the practices of the practitioners, with their active involvement; and meets the suitability criteria. So far as acceptability is concerned, this approach limits the interaction to the limited practitioners of the selected project, whilst excluding access to all other practitioners outside of that project. This presents a risk of basing the interpretation on only one typical type of selected project, whilst missing out on the collective wisdom of other practitioners who would have exposure to a variety of projects and the quality issues encountered. There exists the risk with regard the choice of the project selected, especially with the requirement that it is a new project. This is likely to diminish the choice of projects or to wait for the suitable project to start. Based on this, both the acceptability and feasibility criteria are not met. Hence, this option is rejected			
3	Yes	Yes	No	Rejected
	Semi-structured interviews and focus group meet both the suitability and acceptability criteria, because interview participants are 'actively' constructing knowledge around questions and responses (Holstein and Gubrium 1995), cited in Fontana and Frey (2000). Both these methods are part of qualitative research, and according to Liamputtong (2009), such research is concerned with in-depth understanding of the issue under examination, with heavy reliance on individuals who are able to provide rich accounts of their experience. For this reason, it usually works best with small numbers of individuals. The semi-structured interview has a more specific research agenda and a more focused, but the informants in this type of interview, too, describe the situation in their own words and in their own time. Although researchers do not ask questions in the same way and form of each participant, they can ensure through the tighter structure of semi-structured interviews that they collect all important information about the research topic whilst still giving informants the opportunity to report on their own thoughts and feelings (Holloway 1997) However, when it comes to the feasibility for the use of focus group, according to Morgan, D L; cited in Gill (2008) has cautioned that unease of participant with each other will prohibit open discussion of their feelings or opinions. Additionally, Vaughan and collegues, cited in Puchta and Potter (2004) have identified core requirement of a trained moderator and the goal of eliciting participants' feelings, attitudes, and perceptions about a selected topic. The researcher does not profess to be a trained moderator, and the fact within limited time assembling an appropriate focus group of busy construction professionals to discuss a conceptual model would tender this infeasible			

(continued)

Table 3 (continued)

Option	Suitability	Acceptability	Feasibility	Result
4	Yes	Yes	Yes	Selected
	The semi-structured interviews on the RGR framework with the construction professionals following appropriate sampling process meets the suitability and acceptability criteria. This method, as discussed in point three above, can provide in-depth understanding of the relevance of the RGR framework; and the researcher can sustain the focus on the research question using well-designed semi-structured questionnaire. This option is feasible because it works best with fewer participants who can provide rich accounts of their experience (Liamputtong 2009). The knowledge created thus depends on the exchange with the participants and accordingly associated risk is that of the quality of participants. However, this risk can be suitably mitigated by using robust selection criteria for the participants and well-designed interview guide to ensure rich data from the selected participants. Based on the data analysis, RGR framework will be updated as required and in case of significant changes, it is proposed revised model will be presented to the industry,l and the case study reevaluated using such revised model			
5	Yes	No	No	Rejected
	This option of application of RGR framework and concepts as a participant-observer to problematic processes meets the suitability and acceptability criteria. According to Ritchie (2003), *Participant observation is one of methods to allow investigation of phenomenon in their natural setting where the researcher joins the constituent study population to record actions, interactions or events that occur. This not only allows phenomena to be studied as they arise, but also offers the researcher the opportunity to gain additional insights through experiencing the phenomena for themselves. Jorgenson cited in* Ritchie (2003) *explains this method as providing direct experiential and observational access to the insiders' world of meaning.* However, to make this workable, the researcher must identify ongoing project with problematic processes and get the team buy-in on this framework before application. The challenges are finding such projects and identifying problematic processes responsible for quality issues. Correct identification of such processes is important, else application of this option will not help in addressing the research question. There exists the issue of getting the project team buy-in on this framework for application to the ongoing project. It is likely the project already has an existing team implementing the quality management system One of the disadvantages of using participant observation is the quality of key informants used in the study because the researcher gains information based on key informants which can impact the quality of representation of events and the subsequent interpretations of data collected (Barbara 2005). Whilst Bernard (as cited in Barbara 2005) has suggested pretesting informants or selecting the participants who are actually competent in the topic being studied to overcome this bias, however, researcher has no control over the participants because the people managing the quality are already in place for an existing project. This option is thus rejected			

(continued)

Table 3 (continued)

Option	Suitability	Acceptability	Feasibility	Result
6	Yes	No	No	Rejected
	This option is about the application of RGR concepts as part of action research to problematic processes on a new project. Like option 2 above, whilst this is suitable, it fails to meet the acceptability and feasibility criteria. Apart from identifying a new project, there is the need to identify a problematic process. On a new project, there are existing systems ready for implementation. So how do we identify a problematic process at the very start, without knowing the outcome of the process. Furthermore, new projects may have fresh people inducted who may not have in-depth knowledge of the system to identify any such issues at the start. This option is rejected because it is unfeasible, with difficulty in identifying problematic processes and evaluate the ensuing effect of application of the RGR concept			
7	Yes	No	No	
	Application of R2R on the ongoing project as a participant-observer is a suitable and acceptable method. As mentioned in line item 5 above, the acceptability of this is in question as the researcher does not have any control over the selection of the informants when working with the selected project, and the poor quality of participants will impact the representation of events and subsequent interpretation (Barbara 2005) The workability of this options as part of action research presents few challenges. Application of RGR to an ongoing project will require getting the project team on-board whilst in the middle of delivering the project outcomes based on the existing system. It presents issues of coordinating such an exercise halfway and the likely impact of RGR is hard to determine. It is not practical too, because of the time for the completion of the project is not in control of the researcher. The researcher has finite time whilst project completion date is fixed based on the project duration. How to evaluate the outcome of RGR then? Waiting for project to complete is likely to overrun the available time with the researcher			
8	Yes	No	No	Rejected
	This option now includes the application of RGR to both ongoing project and processes as part of action research. From the feasibility viewpoint, on boarding the project on the RGR framework once the project has started presents a challenge. A *buy-in* from relevant team is required, but prior to that an agreement is required that there is a problem with the project or a process. Definitive identification of problem will require root cause analysis, and once identified the mitigating effect of implementation of the RGR needs to be evaluated, if any. Such evaluation will have to wait till the project completion, which is not in the control of the researcher. Given the finite time available with the researcher, this option is infeasible, and hence rejected			

in providing valuable input for determining the suitability of RGR frame to achieve quality in construction.

6.4 Development of the Blueprint

The peer review of the RGR model has assisted in its development as the blueprint as a generic model for quality management in construction, with 17 associated sub-concepts (Abeysekera and Shelke 2019). During such development, authors considered using the Analytic Hierarchy Process (AHP) for prioritizing the sub-concepts. However, these are now listed sequentially in terms of one concept leading to another; and such linkages amongst the various concepts, analogous to network of concepts working in tandem, has led the authors to keep in abeyance the application of AHP. However, there is possibility of developing a cluster of sub-concepts, which is a likely one of the questions for inclusion during the survey of construction industry professionals; or may appear as an outcome of analysis of the feedback from the industry.

6.5 The Six-Honest-Men Approach

Sloane (2006) has borrowed the 'six serving men', from the Rudyard Kipling's poem 'I Keep Six Honest Serving Men', viz., What, Why, When, How, Where, and Who, whilst driving the importance of asking the right questions and avoid jumping to the wrong conclusion, terming it natural but fatal tendency. Whilst these are problem solving tools promoting lateral thinking, these can be useful for creating a question bank to interrogate the RGR framework because application of such an approach obviates predictable courses based on existing assumptions and prejudices whilst asking fundamental questions of the model (Sloane 2006). These tools are forcing one to think about every aspect of the sub-concept, thus serving as a checklist too. These 'six serving men' are assisting the authors to further get clarity when approaching the construction industry for survey about the relevance of this RGR model to construction.

7 Conclusion

The development of the SAF framework by the authors for research purposes (as against in strategic management studies) has been a useful tool for the evaluation of various options. The framework has enabled to shortlist suitable options for such evaluation at this critical juncture in the study of exploring the relevance of the RGR framework for managing quality. In other words, the SAF framework has ensured conscious consideration and subsequent elimination of options. This outcome is aligned with the epistemological and ontological stance of the study which will result in sourcing data that is reliable and relevant. The limitation of this study is, its scope is narrowed down to address the quality issues of construction. However, it is suggested for future research to expand this scope to include construction project and production management including construction business management.

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