Lecture Notes on Data Engineering and Communications Technologies 160

Fausto Pedro García Márquez
Isaac Segovia Ramírez
Pedro José Bernalte Sánchez
Alba Muñoz del Río *Editors*

IoT and Data Science in Engineering Management

Proceedings of the 16th International Conference on Industrial Engineering and Industrial Management and XXVI Congreso de Ingeniería de Organización

Springer

Lecture Notes on Data Engineering and Communications Technologies 160

Series Editor

Fatos Xhafa, *Technical University of Catalonia, Barcelona, Spain*

The aim of the book series is to present cutting edge engineering approaches to data technologies and communications. It will publish latest advances on the engineering task of building and deploying distributed, scalable and reliable data infrastructures and communication systems.

The series will have a prominent applied focus on data technologies and communications with aim to promote the bridging from fundamental research on data science and networking to data engineering and communications that lead to industry products, business knowledge and standardisation.

Indexed by SCOPUS, INSPEC, EI Compendex.

All books published in the series are submitted for consideration in Web of Science.

Fausto Pedro García Márquez ·
Isaac Segovia Ramírez ·
Pedro José Bernalte Sánchez ·
Alba Muñoz del Río
Editors

IoT and Data Science in Engineering Management

Proceedings of the 16th International Conference on Industrial Engineering and Industrial Management and XXVI Congreso de Ingeniería de Organización

Springer

Editors
Fausto Pedro García Márquez
Ingenium Research Group
University of Castilla-La Mancha
Ciudad Real, Spain

Isaac Segovia Ramírez
Ingenium Research Group
University of Castilla-La Mancha
Ciudad Real, Spain

Pedro José Bernalte Sánchez
Ingenium Research Group
University of Castilla-La Mancha
Ciudad Real, Spain

Alba Muñoz del Río
Ingenium Research Group
University of Castilla-La Mancha
Ciudad Real, Spain

ISSN 2367-4512 ISSN 2367-4520 (electronic)
Lecture Notes on Data Engineering and Communications Technologies
ISBN 978-3-031-27914-0 ISBN 978-3-031-27915-7 (eBook)
https://doi.org/10.1007/978-3-031-27915-7

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

This book is a compilation of the extended abstracts presented at the 16th International Conference on Industrial Engineering and Industrial Management (ICIEIM) and XXVI Congreso de Ingeniería de Organización (CIO) in 2022. The Conference was promoted by ADINGOR (Asociación para el Desarrollo de la Ingeniería de Organización), organized by Ingenium Research Group from Universidad de Castilla-La Mancha, Spain, and it took place on 7 and 8 July 2022, Toledo.

The book highlights some of the latest research advances and cutting-edge analysis of real-world case studies on Industrial Engineering and Industrial Management from a wide range of international contexts. It also identifies business applications and the latest findings and innovations in Operations Management and the Decision Sciences, e.g.

- Sustainability, Eco-efficiency and Quality Management
- Strategy, Innovation, Networks and Entrepreneurship
- Operations Research, Modelling and Simulation
- Supply Chain Management and Logistics
- Production Planning and Control
- Management Information Systems and Knowledge Management
- Project and Process Management
- Service Systems
- Human Resources and Organizational Design
- Product Design, Industrial Marketing and Consumer Behaviour
- Education in Organizational Engineering
- IT-enabled Education in Organizational Engineering
- Circular Economy

Fausto Pedro García Márquez
Isaac Segovia Ramírez
Pedro José Bernalte Sánchez
Alba Muñoz del Río
Ana Maria Peco Chacon

Organization

General Chair

Mincong Tang	International Center for Informatics Research, Beijing Jiaotong University, China

International Programme Committee

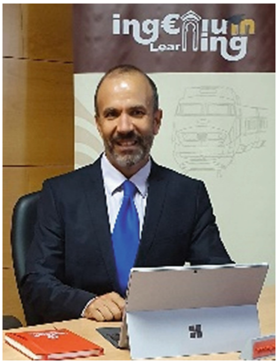
Alba Muñoz del Rio	Universidad de Castilla-La Mancha, Spain
Alejandro Escudero Santana	Universidad de Sevilla, Spain
Alfonso Durán Heras	UC3M, Spain
Alicia Robles Velasco	Universidad de Sevilla, Spain
Álvaro García Sánchez	Universidad Politécnica de Madrid, Spain
Amaia Lusa	Universitat Politècnica de Catalunya, Spain
Ana María Peco Chacón	Universidad de Castilla-La Mancha, Spain
Andrés Boza	Universitat Politècnica de València, Spain
Angel Ortiz Bas	Universitat Politècnica de València, Spain
Antonio López Arquillos	Universidad de Málaga, Spain
Antonio Sartal Rodríguez	Universidad de Vigo, Spain
Carmen Avilés Palacios	Universidad Politécnica de Madrid, Spain
Cristina Ruiz Martin	Carleton University, Canada
David Gonzalez Asenjo	Universidad de Burgos, Spain
David Hermida	Universidad de Oviedo, Spain
David Peidro	Universitat Politècnica de València, Spain
David Poza García	Universidad de Valladolid, Spain
Diego Ros Mcdonnell	Universidad Politécnica de Cartagena, Spain
Elena Barbadilla	Universidad de Sevilla, Spain
Elena Navarro Astor	Universitat Politècnica de València, Spain
Emiliano Acquila-Natale	Universidad Politécnica de Madrid, Spain
Enara Zarrabeitia	University of the Basque Country, Spain
Ester Guijarro	Universitat Politècnica de València, Spain
Eugenia Babiloni	Universitat Politècnica de València, Spain
Faustino Alarcón	Universitat Politècnica de València, Spain
Fernando Acebes Senovilla	Universidad de Valladolid, Spain
Francisco Campuzano Bolarín	Universidad Politécnica de Cartagena, Spain
Francisco Salguero Caparros	Universidad de Málaga, Spain
Francois Vernadat	University of Lorraine, France

Gregorio Rius Sorolla	Universitat Politècnica de València, Spain
Isaac Segovia Ramírez	Universidad de Castilla-La Mancha, Spain
Isabel García Gutiérrez	Universidad Carlos III de Madrid, Spain
Izaskun Alvarez-Meaza	University of the Basque Country UPV/EHU, Spain
Jabier Retegi	Mondragon University, Spain
Jairo R. Montoya Torres	Universidad de La Sabana, Colombia
Javier Puente	Universidad de Oviedo, Spain
Javier Santos	Tecnun—University of Navarra, Spain
Jesús García Arca	Universidad de Vigo, Spain
Jesús Morcillo Bellido	Universidad Carlos III de Madrid, Spain
Jesus Morcillo Garcia	UNED, Spain
Jesús Muñuzuri	Universidad de Sevilla, Spain
Joaquín Bautista	Universitat Politècnica de Catalunya, Spain
Jorge Armando Ramos Frutos	CIATEC, Spain
José Alberto Eguren	Mondragon University, Spain
José Antonio Comesaña Benavides	Universidad de Vigo, Spain
José Carlos Prado Prado	Universidad de Vigo, Spain
José Guadix	Universidad de Sevilla, Spain
José Ignacio Santos Martín	Universidad de Burgos, Spain
José Luis Roca Gonzalez	Centro Universitario de la Defensa en la Academia General del Aire, Spain
José Manuel Galán	Universidad de Burgos, Spain
José Manuel González Varona	Universidad de Valladolid, Spain
Joséfa Mula Bru	Universitat Politècnica de València, Spain
Josép Llach	Universitat de Girona, Spain
Juan Antonio Torrecillagarcía	Universidad de Málaga, Spain
Juan De Antón Heredero	Universidad de Valladolid, Spain
Juan Ignacio Igartua	Mondragon Unibertsitatea, Spain
Juan Ramón Trapero	University of Castilla-La Mancha, Spain
Julien Maheut	Universitat Politècnica de València, Spain
Lourdes Canós Darós	Universitat Politècnica de València, Spain
Luis Isasi	Universidad Carlos III de Madrid, Spain
Luis Rodrigo Izquierdo Millán	Universidad de Burgos, Spain
Manuel Cardós Carboneras	Universitat Politècnica de València, Spain
Manuel Díaz Madroñero	Universitat Politècnica de València, Spain
Manuel Mateo	Universitat Politècnica de Catalunya, Spain
Mar Fernández Vázquez Noguerol	Universidad de Vigo, Spain
María Del Mar Alemany Díaz	Universitat Politècnica de València, Spain
María José Verdecho	Universitat Politècnica de València, Spain
María Martínez Rojas	Universidad de Málaga, Spain

María Pereda García	Universidad Politécnica de Madrid, Spain
María Victoria De La Fuente	Universidad Politécnica de Cartagena, Spain
Marta Ormazabal	Universidad de Navarra, Spain
Meisam Ranjbari	University of Turin, Italy
Mercedes Grijalvo	Universidad Politécnica de Madrid, Spain
Pablo Aparicio Ruiz	Universidad de Sevilla, Spain
Pascual Cortés	Universitat Politècnica de València, Spain
Patxi Ruiz-De-Arbulo-López	Universidad del País Vasco (UPV/EHU), Spain
Pedro Gomez-Gasquet	Universitat Politècnica de València, Spain
Pedro José Bernalte Sánchez	Universidad de Castilla-La Mancha, Spain
Pilar I. Vidal-Carreras	Universitat Politècnica de València, Spain
Rafael Rosillo	Universidad de Oviedo, Spain
Raquel Sanchis	Universitat Politècnica de València, Spain
Raúl Poler	Universitat Politècnica de València, Spain
Ricardo Chalmeta	Jaume I, Spain
Ricardo Del Olmo Martínez	Universidad de Burgos, Spain
Rodolfo De Castro	Universitat de Girona, Spain
Rosa Riobelver	Universidad del Pais Vasco UPV/EHU, Spain
Salvador Castillo-Rivera	Universidad de Valladolid, Spain
Salvatore Cannella	University of Catania, Italy
Simon Fernandez	Universidad de Oviedo, Spain
Teresa Sánchez-Chaparro	Universidad Politécnica de Madrid, Spain
Virginia Ahedo García	Universidad de Burgos, Spain
Zahra Shams Esfandabadi	Politecnico di Torino, Italy

Contents

About the Editors



Fausto Pedro García Márquez Fausto works at UCLM as Full Professor (Accredited as Full Professor from 2013), Spain, Honorary Senior Research Fellow at Birmingham University, UK, Lecturer at the Postgraduate European Institute, and he has been Senior Manager in Accenture (2013–2014). He obtained his European PhD with a maximum distinction. He has been distinguished with the prices: Grand Prize (2021), Runner Prize (2020) and Advancement Prize (2018) for Management Science and Engineering Management Nominated Prize, First International Business Ideas Competition 2017 Award (2017); Runner (2015), Advancement (2013) and Silver (2012) by the International Society of Management Science and Engineering Management (ICMSEM). He has published more than 170 papers (103 JCR(49Q1; 27Q2; 24Q3; 3Q4), 65 % ISI, 30% JCR and 92% internationals), some recognized as "Applied Energy" (Q1, IF 9.746, as "Best Paper 2020"), "Renewable Energy" (Q1, IF 8.001, as "Best Paper 2014"); "ICMSEM" (as "excellent"), "Int. J. of Automation and Computing" and "IMechE Part F: J. of Rail and Rapid Transit" (most downloaded), etc. He is Author and Editor of more than 40 books (Elsevier, Springer, Pearson, Mc-GrawHill, Intech, IGI, Marcombo, AlfaOmega,…), 90 international chapters and six patents. He is Editor of five international journals and Committee Member more than 60 international conferences. He has been Principal Investigator in four European projects, eight national projects, and more than 150 projects for universities, companies, etc.

He is being Expert in the European Union in AI4People (EISMD), and ESF.; Director of www.ingeniumgroup.eu.; Senior Member at IEEE, 2021-… ; Honoured Honourary Member of the Research Council of Indian Institute of Finance, 2021-… ; Committee Chair of The International Society for management science and Engineering Management (ISMSEM), 2020-…. His main interests are artificial intelligence, maintenance, management, renewable energy, transport, advanced analytics and data science.

Isaac Segovia Ramírez is Industrial Engineer at ETSII of the University of Castilla-La Mancha, Ciudad Real (2015), Master of Industrial Engineering at ETSII of the University of Castilla-La Mancha, Ciudad Real (2019), and Associate Professor of electronic courses in 2019–2020 in ETSII of the University of Castilla-La Mancha, Ciudad Real. Current PhD student, he is in collaboration with several national and European projects with the Department of Business Administration of the University of Castilla-La Mancha and the (June 2013–present) Ingenium group. He is Winner of the international contest "Entrepreneurship 5+5" in Tunisia. He has been awarded with the "Advancement Prize for Management Science and Engineering Management with the Nominated Prize (2018)" for the article "Remotely Piloted Aircraft System and Engineering Management: A Real Case Study". His main research interests are related to maintenance management, UAVs, renewable energy, detection of elements in surface by infrared radiation, etc.

Pedro José Bernalte Sánchez is Industrial Engineer at ETSII of the University of Castilla-La Mancha, Albacete (2016), and High Schools Teacher Capacitation master's degree at Education College of Castilla-La Mancha, Ciudad Real (2017). Collaborating on several national and European projects with the Department of Business Administration of the University of Castilla-La Mancha and the Ingenium Research Group (November 2018–present). His main research interests are related to maintenance management, condition monitoring systems and machine learning methods for renewable energy installations, developing patents and novel techniques of inspection, also working in a novel European project (ENDURUNS) about batteries endurance and seafloor mapping with autonomous underwater vehicles (AUV) and encompassed with the interest and application of these studies in the scope of Industry 4.0 with Internet of Things (IoT) forefront technologies.

Alba Muñoz del Río graduated in Mathematics by the Complutense University of Madrid, Spain, and has MSc in Big Data and Business Analytics. Collaborating on several national and European projects with the Department of Business Administration of the University of Castilla-La Mancha and the Ingenium Research Group (March 2021–present). Her main research interests are related to advance analytics, big data, artificial intelligence and maintenance management for renewable energy installations, developing patents and novel techniques of inspection. Encompassed with the interest and application of this studies in the scope of Industry 4.0 with Internet of Things (IoT) forefront technologies.

Ana Maria Peco Chacon is Industrial Engineer at ETSII of the University of Castilla-La Mancha, Ciudad Real (2013) in Business Administration. She worked in maintenance and aeronautical industry, developing different projects as Quality Engineer. Her main research interests are related to renewable energies, maintenance management, statistical methods and artificial intelligence.

Barriers to Technology Deployment for Sustainable Water Management in the Spanish Food Industry

Javier Santos(✉), Elisabeth Viles, and Florencia Kalemkerian

Tecnun (University of Navarra), San Sebastián, Spain
{jsantos,eviles,fkalemkerian}@tecnun.es

Abstract. This paper presents the results of a research project based on water consumption monitoring, in the food industry, using low-cost technology. The project carried out forty-three monitoring campaigns in 17 companies. The project has identified a potential saving of more than 1 million liters of water per day for those companies. The project also certified important savings in water use for some companies in the cleaning or sterilization processes. Furthermore, we present four barriers identified during data collection and during the analysis of process improvement opportunities, which hinder the use of technology to make water management more sustainable.

Keywords: Circular economy · Monitoring · Continuous improvement

1 Introduction

Climate change affects all areas of society, and the European water system (flood defenses, irrigation systems, drinking water, or wastewater networks) is not an exception. The future water system will have to withstand and be resilient to an increase in extreme weather events, including less frequent but more intense precipitation, alternating floods and droughts.

Spain is the European country with the highest tendency to water stress with a consumption per inhabitant and day of 6,700 L. According to some estimations, by 2030, 65% of the Spanish population will suffer the consequences of water scarcity [1]. In the EU economy, the water sector represents 3.4 billion euros (26% of the EU's annual gross value added) and employs 44 million people [2].

Current technological advances based on digitalization, data analysis and artificial intelligence cannot be ignored when analyzing water consumption, management, and governance [3]. By combining monitoring, communication, and data analysis systems with the best available techniques (BREF), companies would be able to reduce, or at least rationalize water consumption to ensure that the catastrophic forecasts being put forward do not come true.

This paper presents the results of a project about water consumption monitoring carried out in 17 food companies in northern Spain (Basque Country, La Rioja, Navarra,

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 1–6, 2023.
https://doi.org/10.1007/978-3-031-27915-7_1

and Castilla León), which produce bread, sauces, salads, pickles, seafood and poultry products, canned vegetables or fish, chocolate and juices.

The work will show how investment in technology which leads to the identification and implementation of improvements in water use in the food industry, faces four main barriers: low level of maturity in continuous improvement practices, reluctance to use regenerated water, restrictive legislation, and consumers' lack of awareness.

This paper is organized into five sections, including this introductory section (Sect. 1). The research starts with Sect. 2, where the challenges faced by the agri-food sector within the framework of circular economy strategies are presented. Section 3 explains the MCUBO project and its implications in terms of water savings obtained through overcoming the challenges presented in the sector. However, most of the identified improvements will not be implemented if the barriers identified in the project (Sect. 4) are not overcome. Finally, Sect. 5 presents the conclusions of the study followed by the limitations.

2 Circular Economy in Water Use

Water is one of the fewest irreplaceable natural resources. However, this resource receives little attention when assessing environmental performance after implementing circular economy strategies. The main reason for this it's the low price, which in Spain is 1.91 €/m^3 [4].

In the context of the circular economy, the 9R strategies are presented (Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover) [5]. Water can be Recycled, Reused, or Reduce its consumption [6]. A fourth-R, Rethink, could be added, which means redesigning the process that consumes water following circularity and sustainability principles.

Focusing the analysis on the first 3 R's (Recycle, Reuse, and Reduce), it will be understood that Recycling water consists of purifying it and returning it to the environment through wastewater treatment plants (WWTP). If process water Reuse is considered, the water hygienic requirements for human consumption must be taken into account (RD 140/2003), in addition to complying with European regulations (EU 2020/741) which governs water reuse. Finally, the most implemented strategy is to analyze consumption and Reduce water use by implementing more efficient technologies or procedures.

The main water-consuming processes in food companies, as observed during the project, are facility cleaning (manual, CIP, etc.), raw materials washing and conditioning (blanching, hydrating, etc.), and heat treatments to ensure their durability (sterilization).

In any proposal of improvement in water performance, the step before the implementation of any strategy is to know the current consumption. Surprisingly, most companies do not have installed flowmeters to discriminate consumption by process, to know the consumption pattern, and to identify the main water wastes.

3 MCUBO Project

In this context, LIFE MCUBO project [7] has been developed, financed by the European Commission in its LIFE call. During 3 years (2016–2019) and in its extension in the after-LIFE program (2020–2022) a total of 46 monitoring campaigns, in 17 food companies were carried out. The main aim was knowing how water is consumed in the processes (pattern of consumption), to identify opportunities for improvement, and to certify some improvements proposed by the companies through the use of low cost technology.

The monitoring step was performed using a device developed in the project, called Plug&Lean. This device can collect and convert signals into data every minute (real-time); it does not require cuts or holes in the pipes (non-invasive); only the parameters needed to characterize the problem are recorded (problem-oriented); and, in less than 2 h, it is possible to start collecting 4 points of water consumption (quick installation).

The following figure (Fig. 1) shows an example of the flowmeters installation and the consumption pattern obtained (the scales are omitted for confidentiality reasons). In this case, each chart show grouped the monitoring pattern of seven cleaning cycles. The lower chart show grouped the pattern of seven days of cleaning once low consumption nozzles were installed.

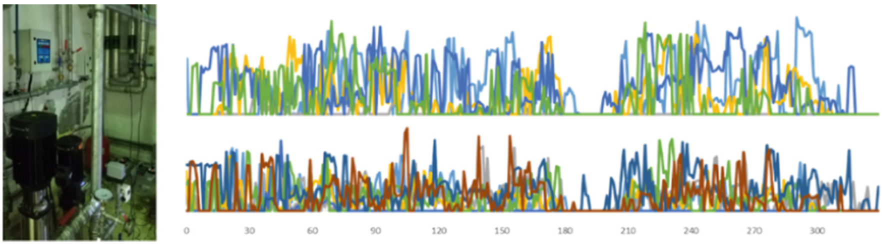


Fig. 1. Example of an installation and water consumption pattern obtained in the project

The campaigns recorded, during 568 days, more than 5 million data. Once analyzed, this information made it possible to obtain, in collaboration with the companies, significant savings.

In three of the 17 companies, a 40% of water saving using different nozzles in the cleaning processes; a 50% saving through a change of cleaning procedure that avoided a second cleaning day, without increasing consumption during the first cleaning day; a 50% saving in the final rinse in a CIP (Clean-in-process facility).

In other two companies, potential savings between 10% and 20% have been identified by changing the cooling cycle or taking advantage of the maximum autoclave capacity in autoclave sterilization processes.

Those savings could be replicated in the rest of the companies because the cleaning and sterilization are similar in the studied companies, but the project focused on a different process or the company was interested only in identified water consumption.

Finally, and as the main contribution of the project, a potential saving of more than 1 million liters of water per day has been identified, in the 17 companies. This saving is obtained by combining the water reduction described in the previous paragraphs with the possibility of incorporating a water recirculation system in the process, which complies with RD 1620/2007 (which establishes the legal regime for the reuse of treated water) and RD 140/2003 (which establishes the sanitary criteria for the quality of water for human consumption).

4 Barriers

Although it is not possible to generalize from a reduced number of experiences, the presentation of the result of this project in different forums has allowed the identification of some barriers in the achievement of many of the proposals to improve water circularity towards sustainable management.

The barriers identified are similar to those found in other studies within the framework of circular economy [8] or supply chain 4.0 in the food and beverage sector [9], where cultural, legislative and economic barriers are identified.

4.1 Low Level of Maturity in Continuous Improvement Practices

The agri-food sector, with some exceptions, has not undergone the evolution toward worker involvement in continuous improvement systems. Improvements are usually focused on technical aspects and are led by management boards. The return on investment is the main decision issue and, therefore, investing in diagnostic systems, even if they are low-cost, is not contemplated.

On the other hand, the training profile of the workers is not so completed, companies subcontract people for critical processes in water consumption such as cleaning, and both the working hours and the training resources available do not facilitate the creation of improvement teams.

4.2 Reluctance to Use Recirculated Water

Water reuse, after treatment, is presented as the most effective option for reducing the consumption and the environmental impact of excessive water use in the sector.

In some cases, water reuse is not viable because of the investment required for water treatment compared with the cost of water and the discharge fee (both cases more expensive than collecting and discharging into a watercourse). Raising the discharge fee or the cost of water would reduce the competitiveness of the sector, which has to compete with products manufactured in countries with more lax policies. However, the water savings that it would entail should mobilize public entities to finance partially the investment in the recirculation water facility, leaving the facility maintenance and operation costs to the company.

Even if in some cases water reuse was considered as an economically viable alternative, it is not conducted because of the consequences it could have, which are related to the last two barriers (4.3 and 4.4).

4.3 Restrictive Legislation

Legislation and regulations in the agri-food sector regarding the use of recirculated water in Spain in the production process (not being part of the product but in contact with it) is very restrictive and discourage reuse practices. If the investment in new water recirculation technologies in the process is high and not viable, many companies have WWTP capable of purifying the water and reintroducing it into the process with much lower investments, but the legislation does not allow it.

In those cases where water recirculation actions are implemented, the analytics required to comply with the standard are expensive and, in many cases, involve a higher operating cost, therefore at the end they are not implemented. If the value recorded by probes and sensors installed in the companies, which already allow real-time analysis, were accepted, a large amount of time and money would be saved. This would mean that even some improvement proposals that are not profitable today would be profitable only because of the cost savings of the analytics.

4.4 Consumer Lack of Awareness

Society is increasingly demanding that companies implement environmental sustainability measures, but in most cases, it is not willing to assume part of the cost of these measures.

On the other hand, reducing water consumption or using recirculated water can lead to changes in production processes or in product labeling, which could even slightly vary the organoleptic characteristics of the product. Customers, which are used to a specific taste or aroma could reject products that have been manufactured with recirculated water, even if it complies with health regulations.

5 Conclusions and Limitations

This research project has shown how technology can help to identify and quantify the impacts of improvements on water use which, in general, are translated as a reduction in its consumption. However, these reductions will not be implemented unless at least the four barriers identified are removed. Restrictive legislation and fear of end-customer reaction are the most important barriers because they hold back the others. The potential saving for improvement would increase if the water could be reused by accepting the results of the analysis offered by the systems available. Once this barrier has been overcome, companies would promote customer awareness to avoid rejecting products made with reused water.

Although this sample of 17 companies may be relevant for proposing good practices in water management in Spain or even in Europe, its extrapolation to other countries will depend on the context. However, it has been found that Europe has very restrictive legislation on the use of reclaimed water in production processes.

Acknowledgments. The work presented in this paper was carried out within the framework of the LIFE MCUBO (LIFE15 ENV/ES/000379) research project funded by the European Union, through the LIFE program.

References

1. Sandoval, M.: La escasez del agua en España: el reto de la sostenibilidad hídrica. www.identcityconsulting.com/la-escasez-del-agua-espana-reto-la-sostenibilidad-hidrica/. Accessed 17 Feb 2022

2. Schellekens, J., Heidecke, L., Nguyen, N., Spit, W.: The Economic Value of Water-Water as a Key Resource for Economic Growth in the EU; ECORYS, Rotterdam (2018)
3. Meenu EG The Promise of Artificial Intelligence in Water Management. https://www.analyticsinsight.net/the-promise-of-artificial-intelligence-in-water-management/. Accessed 17 Feb 2022
4. Manuel Ferro Precio de agua en España: Toda la información. https://tarifasdeagua.es/info/precio. Accessed 17 Feb 2022
5. Potting, J., Hekkert, M., Worrell, E., Hanemaaijer, A.: Circular Economy: Measuring innovation in the product chain - Policy report. PBL Netherlands Environ. Assess. Agency 42 (2017)
6. Viles, E., Santos, J., Arévalo, T.F., Tanco, M., Kalemkerian, F.: A new mindset for circular economy strategies: case studies of circularity in the use of water. Sustainability **12**, 1–12 (2020). https://doi.org/10.3390/su12229781
7. Santos, J., Viles, E., Muñoz-Villamizar, A., Grau, P., Arévalo, T.F.: MCUBO. A sustainability and Industry 4.0 project. In: De la Fuente D., Pino R., Ponte B., Rosillo R. (eds.) Organizational Engineering in Industry 4.0., pp. 213–220. Springer, Switzerland (2021). ISBN 978-3-030-67707-7
8. Kumar, V., Sezersan, I., Garza-Reyes, J.A., Gonzalez, E.D.R.S., AL-Shboul, M.A.: Circular economy in the manufacturing sector: benefits, opportunities and barriers. Manage. Decis. **57**(4), 1067–1086 (2019). https://doi.org/10.1108/MD-09-2018-1070
9. Ali, I., Aboelmaged, M.G.S.: Implementation of supply chain 4.0 in the food and beverage industry: perceived drivers and barriers. Int. J. Product. Perform. Manage **71**(4), 1426–1443 (2022). https://doi.org/10.1108/IJPPM-07-2020-0393

An UCC Network Design for Sustainable Urban Logistics in Bilbao

Maria Savall-Mañó(✉) and Imma Ribas

Departament d'Organització d'Empreses, Universitat Politècnica de Catalunya, BarcelonaTech, Avda. Diagonal, 647, 7th Floor, 08028 Barcelona, Spain
{maria.savall,imma.ribas}@upc.edu

Abstract. Urban consolidation centres (UCC) are a sustainable solution for last mile delivery. However, achieving its economic sustainability is not easy. In this paper, we analysed different UCC real cases in Europe. With the outcomes, we proposed a solution to improve urban freight distribution in the city of Bilbao. The attributes studied are the location, UCC size, the delivery area, the vehicle used for distributing, the type of freight and the volume handled.

Keywords: Urban consolidation centres · City logistics · Benchmarking · Last mile · Urban freight

1 Introduction

European environmental objectives for 2030 include reducing at least 40% of greenhouse gas emissions (from 1990 levels). One of the concrete proposals of the European Commission to directly tackle this concern is prioritising zero-emission solutions in last mile distribution [1]. In this way, different European cities are implementing new urban models to reduce congestion, noise, and pollution, i.e. the ultra-low emission zone in London, the superblocks in Barcelona, and the 15 min city in Paris. In this paper, a new model based on a network of urban consolidation centres (UCCs) is proposed for reducing the negative impacts of freight distribution in the city of Bilbao.

"A UCC is best described as a logistics facility that is situated in relatively close proximity to the geographic area that it serves be that a city centre, an entire town, or a specific site (e.g., shopping centre), from which consolidated deliveries are carried out within that area" [2]. Despite theoretical advantages, in practice finding the economic sustainability for the long-term operability of these centres is not simple [3]. Therefore, this research started analysing different urban consolidations centres (UCC) implemented in European cities to identify critical factors to consider.

The paper is organized as follows. Section 2 presents the methodology to identify different UCC implementations. Section 3 presents the Benchmarking analysis. Section 4 provides the approach for Bilbao. Conclusions are provided in Sect. 5.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 7–12, 2023.
https://doi.org/10.1007/978-3-031-27915-7_2

2 Methodology

In this part, the methodology applied to find appealing UCC cases is presented (Fig. 1). The methodology followed is based on the four steps presented by [4]: designing the review (we chose the terms directly related to the topic), conducting the review (we used Scopus, Web of Science, and Google), doing the analysis (we reviewed the papers and the relevant cases found) and writing the review (in this case, the real cases reviewed).

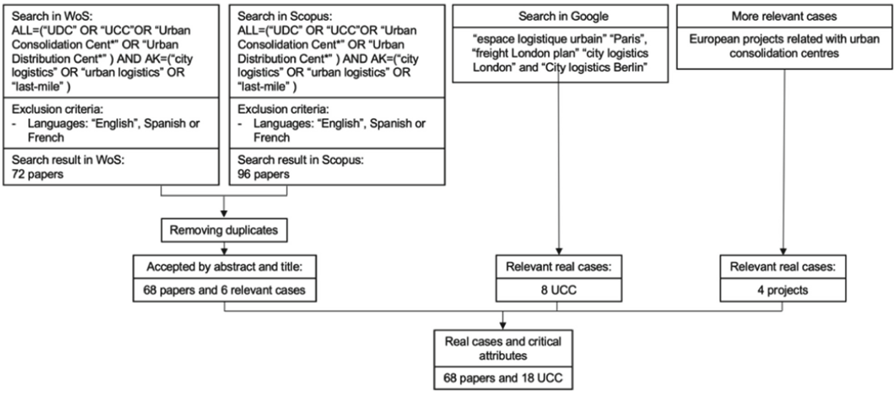


Fig. 1. Research methodology

First, a literature review was performed in Scopus and Web of science (WoS) using the words "UCC", "UCD", "Urban Consolidation Cent*" and "Urban Distribution Cent*" as the topic searched and "city logistics", "urban logistics" or "last-mile" as keywords. The papers were limited to those written in English, Spanish, and French. 72 papers were found in WoS and 96 in Scopus. Duplicate articles found in both databases were removed and the abstracts of those remaining read. After excluding from the analysis those unrelated to the subject, 68 papers were reviewed. We detected 6 relevant UCC cases: the UCC of CityPorto in Padua, MoCC in Monaco, Binnenstadservice in Nijmegen, BBFCC in Bristol and Bath, Ecocity in Parma, and The Green Link in Paris.

Additionally, we searched on Google, in order to include grey papers and other UCC cases, pilots or funded projects not published in referenced journals, using the terms: "espace logistique urbain" "Paris"; "freight London plan"; "city logistics London"; and "city logistics Berlin". We also used the name of some European capitals intending to find a network of UCCs. Thus, we identified two UCC networks: Shoreditch, Hyde Park, and Westminster in London that are part of the company dpd, and Beaugrenelle, Concorde, Bercy, and Chronocity in Paris that belong to the company Chronopost. Moreover, we found Komodo in Berlin as an example of UCC used by different companies (DHL, dpd, GLS, Hermes, and UPS). Finally, we included other examples from innovative European projects: the 7 Microhubs in Amsterdam, Stadsleveransen and Nordstan in Göteborg, and Vanapedal in Barcelona.

3 Benchmarking Analysis

From the cases studied, the factors to set an UCC and their variables were identified: location, size (m^2), delivery area (km^2), vehicles for distributing, features of the freight, and volume handled (orders/day). Table 1 shows the values of these attributes, for each of the analysed UCC.

Notice that 60% of the UCCs analysed, independently of their size, are in central places close to the area they serve. UCCs located outside the city, except in the case of Bercy, are initiatives led by public administrations [5]. In contrast, the location of Bercy is the historical site used by Chronopost to do the distribution in Paris [6]. It is worth mentioning that the location of the MoCC outside the city of Monaco lies in the necessity to remove the vans from inside the city [7].

Regarding the *size*, it is worth noting that 75% of UCCs with centric locations are 500 m^2 or smaller while the UCCs outside the city are 1000 m^2 or larger. We assessed from the analysis that centric UCCs are located strategically to benefit from being in pedestrian, with little traffic, and dead-end streets, as they can use the space in front of the doorway for loading and unloading. In addition, these UCCs are frequently part of a UCC network, like, as mentioned before, Shoreditch, Hyde Park, and Westminster in London. Instead, UCCs outside the city, except Bercy, are a single platform from where the freight is distributed in an entire city or in more than a city. Another common location for UCCs is the shopping centres' parking, as in the case of the MoCC [7]. The economic sustainability of these centres can be strengthened in case of being mandatory for the shopping centre businesses to use this platform [2].

Over half of the *delivery areas* studied are between a range of 6.4 km^2 and 14.0 km^2 (Table 1). Assuming a distribution area with a circular shape, we estimated that the average radius of UCC distribution is about 1.7 km. Centres that distribute in larger areas than 14.0 km^2, except Komodo, have major facilities. On the other side, UCCs with areas smaller than 6.4 km^2 are especial cases, i.e. the MoCC that, as mentioned before, has the aim of removing all the delivery vehicles inside Monaco [9].

Notice that, in the 60% of the cases assessed, *vehicles used for distributing* are cargo bikes. In centric UCC, only cargo bikes are used while the cargo bikes are combined with other vehicles (such as electric vans) for distributing in larger areas or from a UCC located outside the city. This is because the fleet needed for covering large areas are vehicles with high load capacity and great autonomy.

The *freight volume* is a critical feature of the UCC that contributes to making the centre profitable [10]. When more orders are handled it is possible to distribute in more condensed areas by making use of the same resources [8]. However, the *type of freight* to distribute constrains the infrastructure employed for delivering the orders to the end consumer. Centric UCCs usually do a business-to-consumer (B2C) distribution that is commonly parcels. Hence, we assumed that this type of freight is easier to manage. However, larger UCCs, except Beaugrenelle, deliver business-to-business (B2B) freight, which can include fresh or frozen products (that are more difficult to handle). From the case of Chronopost in Paris, we realized that when creating a network of UCC the first facilities are devoted to distributing parcels and when these centres are well established, the centres for fresh and frozen are opened [11].

Table 1. Attributes of the different real cases analysed

UCC	City	Location	Size (m2)	Volum (orders /day)	Freight	Delivery area (km2)	Vehicle distribution
7 microhubs	Amsterdam	Centric	150	2200	B2C	-	Cargo bikes
Beaugrenelle	Paris	Centric	2600	6500	B2C	22.0	Electric vehicles
Chronocity	Paris	Centric	368	1000	B2C	-	Cargo bikes and electric vehicles
Concorde	Paris	Centric	950	1800	B2C	9.5	By foot and electric vehicles
Hyde Park	London	Centric	790	7000	B2C	8.9	Cargo bikes, small electric vehicles and vans
Komodo	Berlin	Centric	100	700	B2C	28.0	Cargo bikes
Nordstan	Gothenburg	Centric	-	-	B2C	-	Cargo bikes
Shoreditch	London	Centric	325	5000	B2C	14.0	Cargo bikes, small electric vehicles and vans
The Green Link	Paris	Centric	-	2500	B2C	-	Cargo bikes and electric vans
Vanapedal	Barcelona	Centric	100	800	B2C	4.1	Cargo bikes
Westminster	London	Centric	470	2000	B2C	7.6	Cargo bikes, small electric vehicles and vans
Stadsleveransen	Gothenburg	Centric	500	500	B2C	0.3	Electric vehicles
Bercy	Paris	Outside	4000	6000	Fresh	9.0	Cargo bikes, electric and refrigerated vans
CityPorto	Padua	Outside	1000	1300	Fresh	6.4	Vans
MoCC	Monaco	Outside	1320	500	All	2.0	Electric and non-electric vans
BBFCC	Bath & Bristol	Outside	3500	-	-	-	Electric and non-electric vans
Binnenstadservice	Nijemgen	Outside	-	-	B2B	23.0	Cargo bikes and one van
Ecocity	Parma	Outside	5000	-	Fresh	-	Vans

4 Implementation for the City of Bilbao

Based on the outcomes of the benchmarking presented, using the data provided of the freight percentage distributed in each zip code of Bilbao, we developed the winner proposal for the EIT Urban mobility Citython 2021. The model proposed for increasing the efficiency of last mile distribution and reducing the negative impacts of the ecommerce distribution in the city of Bilbao was based on a UCC network integrated by three UCCs (Fig. 2). The locations considered were close to the borderline of the city, as in the case of Monaco, to avoid the delivery vehicles to enter the city, accessible to a main road (in this case: N-634, A-8 or AP-8 and N-637) and close to the area they served. Despite the size, as each facility can be handled by different companies, to offer equal economical chances the freight volume was equally divided (~33% of the total volume for each centre). The delivery areas (highlighted in Fig. 2) are comparable with the regarding UCC network in Paris. Hence, similar distribution vehicles are proposed: cargo bikes for centric UCCs and cargo bikes and electric vehicles for the UCC on the outside.

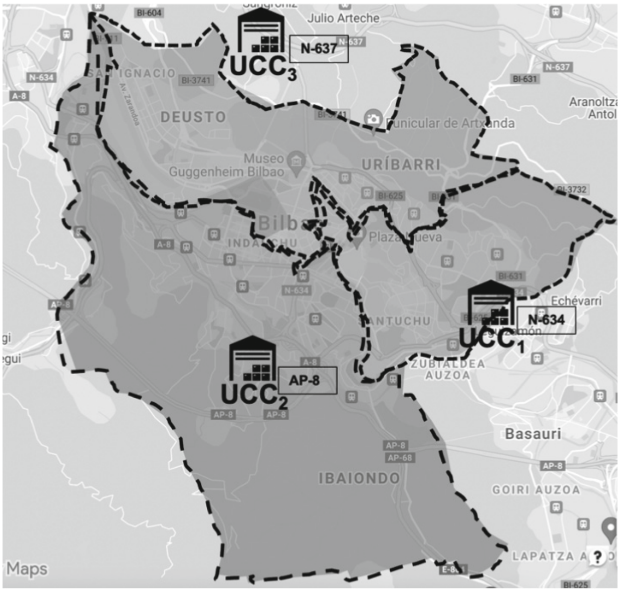


Fig. 2. Network of UCCs in Bilbao

5 Conclusions

UCCs are a solution for achieving a sustainable and efficient last mile distribution. However, achieving the economic sustainability of these centres in the long-term is not simple. In this paper, the UCC factors to implement this type of facilities were analysed. The findings were considered for developing a network of UCCs in the city of

Bilbao for the Citython challenge of the EIT Urban Mobility. This solution will help to reduce congestion, pollution, and noise in the city to achieve the European environmental objectives of 2030.

Future lines of research include UCCs business models and regulation to facilitate the financial sustainability of this solution.

Acknowledgement. This work is supported by the grant DI 2020 053. The authors gratefully acknowledge the opportunity to participate in the EIT Urban Mobility Cityhon 2021.

References

1. European Commission: New transport proposals target greater efficiency and more sustainable travel [Internet] (2021). https://ec.europa.eu/commission/presscorner/detail/en/ip_21_6776. Accessed 11 Apr 2022
2. Browne, M., Sweet, M., Woodburn, A., Allen, J.: Urban freight consolidation centres final report. University of Westminster (2005)
3. González-Feliu, J., Malhéné, N., Morganti, E., Morana, J.: The deployment of city and area distribution centers in France and Italy: comparison of six representative models. Supply Chain Forum **15**, 84–99 (2014)
4. Snyder, H.: Literature review as a research methodology: an overview and guidelines. J. Bus. Res. **104**, 333–339 (2019)
5. Paddeu, D.: Sustainable solutions for urban freight transport and logistics: an analysis of urban consolidation centers. Operations Research/Computer Science Interfaces Series (2017)
6. Patier, D., Browne, M.: A methodology for the evaluation of urban logistics innovations. Procedia Soc. Behav. Sci. **2**, 6229–6241 (2010)
7. Monaco Logistique: Le CDU [Internet]. https://www.monacologistique.mc/nos-metiers/la-distribution-urbaine/le-cdu/. Accessed 3 Mar 2021
8. Janjevic, M., Ndiaye, A.: Investigating the financial viability of urban consolidation centre projects. Res. Transp. Bus. Manag. **24**, 101–113 (2017)
9. Trentini, A., González-Feliu, J., Malhéné, N.: Développement des espaces logistiques Urbains: CDU et ELP dans l'Europe du Sud-Ouest (2011)
10. Paddeu, D., Parkhurst, G., Fancello, G., Fadda, P., Ricci, M.: Multi-stakeholder collaboration in urban freight consolidation schemes: drivers and barriers to implementation. Transport **33**, 913–929 (2018)
11. Chronopost. Dossier de presse: Inauguration de l'Espace Logistique Urbain (ELU) de Paris-Bercy [Internet] (2018). http://www.chronopost.fr/transport-express/webdav/site/chronov4/users/chronopost/public/pdf/presse/dp/DPRSEAvril2014.pdf. Accessed 3 Mar 2021

The Line Back Principle as a Means of Optimising Logistical Production Processes: A Case Study of a Household Appliance Manufacturer

Ivan Navarro(✉), Gorka Unzueta, and José Alberto Eguren

Faculty of Engineering, Mechanics and Industrial Production, Mondragon Unibertsitatea, Loramendi 4, 20500 Gipuzkoa, Mondragon, Spain
inavarro@mondragon.edu

Abstract. This paper shows the application of a process of analysis and optimisation of logistic-productive processes based on the Line Back Principle as applied to a household appliance manufacturing company. The implementation has been based on a case study methodology, in which the researcher has led and actively participated in the implementation process. The implementation process was structured according to the four stages defined within the Line Back Principle. Through this implementation, productivity improvements, reductions in the stock, and reductions in the space occupied by the stock were obtained. The study has therefore demonstrated the validity of the Line Back Principle as a means of improving operational parameters.

Keywords: Line Back (LB) · Lean Production System (LPS) · Lean Manufacturing (LM) · Lean Logistics (LL)

1 Introduction

Basque industry in Spain has historically been committed to research and development in production processes, showing leadership in industrial and training technologies, information and communication technologies (ICTs), nanotechnologies, advanced materials, and advanced manufacturing and processes. The region's industry has committed few resources, however, to the development of models that integrate efficient and integrated logistical-productive solutions [1]. Consequently, it is essential to provide industrial organisations with a model that guides them in the integration of dynamics, methods, and tools in the design of logistical-productive processes from a global and integral perspective in order to enhance competitiveness [2].

Furthermore, the ability to design production and logistics processes from a holistic perspective [3] could lead to future operational excellence. The aim of this integration is to achieve adaptable, flexible, and mobile processes [4], and to this end, industrial companies have adopted many strategies, methods, and techniques, with varying degrees

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 13–18, 2023.
https://doi.org/10.1007/978-3-031-27915-7_3

of success. The most successful of these techniques has been the lean production system (LPS) or lean manufacturing (LM) [5]. Consequently, the research team devised and developed a method based on the Line Back Principle (LBP), which can achieve the design of efficient logistical-productive processes in a global and integral way by integrating the principles of LM and lean logistics (LL).

This article describes how a household appliance manufacturing company proved the validity of the LBP by using it to obtain operational improvements. The paper is organised as follows: Sect. 2 describes the research methodology; Sect. 3 presents the theoretical framework and explains the LBP; Sect. 4 describes the LBP debottlenecking process; Sect. 5 presents the case study; and Sect. 6 presents the conclusions.

2 Methodology

The methodology followed in this paper is based on 'case study research' [6] in the action research (AR) modality. According to AR methodology, the researcher is a participant in the process and not merely an independent observer—he or she helps create organisational change while studying the corresponding process [7]. To this end, the phases that were followed were a review of the existing literature to identify the key elements of LM and LL, followed by the design of the LBP-EMPHOBEK implementation process. Subsequently, the business and units under study were determined.

3 Theoretical Framework

The fundamental principle on which LM is based is the systematic reduction of all operations that do not add value (muda) [8]. To achieve this, it is essential that our organisation—and therefore our value chain—be fully customer-oriented, which means that all efforts must be geared towards satisfying customer needs [9]. On the other hand, LL is about eliminating waste, reducing costs, and striving for perfection to achieve value transfer and create maximum value for users [10]. An important aspect that stands out in both cases is the need to analyse the whole chain from a holistic approach [11].

Value stream mapping (VSM) is a tool that helps perform this analysis in a global way, prioritising the steps and tools to be used at each stage of the lean transformation [12]. However, there is little empirical research on the implementation and management of VSM and, above all, there is a lack of empirical evidence demonstrating the transition from conceptual to realization [13]. Therefore, when dealing with any lean transformation project, we must consider the production and logistics processes in an integrated and not separate way. We must also consider the different lean tools as a group, or globally, since these tools are nothing without the systemic thinking that supports them [14]. Consequently, the LBP is suitable for achieving such integration and prioritisation of actions, as this idea is rooted in the fact that the starting point is consumption and the place of supply of materials is the value-generating process. Therefore, the LBP (Fig. 1) deals with optimisation (waste reduction) from the core process (CP) backwards (analysing the entire logistics value chain in reverse, i.e., from the workstation to the supplier) [15–17] using the principles of LM and LL.

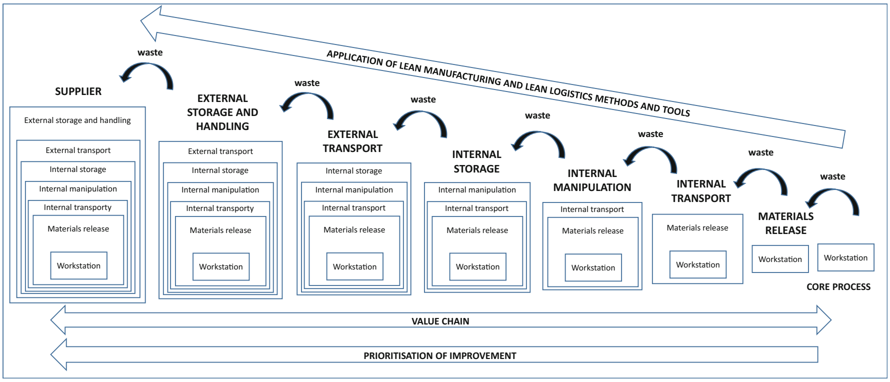


Fig. 1. The Line back process, based on [16]

4 The LBP Deployment Process: PDLB-EMPHOBEK

To integrate the different solutions proposed by the LM and LL as well as under LBP, a systematic and structured process called PDLB-EMPHOBEK has been designed (Fig. 2). It consists of the following stages:

STAGE 0: Identification and planning. This involves defining the project team and informing the company management and staff of the scope and implications of the project [18], and determinate de CP.

STAGE 1: Diagnostics of the initial situation. This step consists of analysing the impact of the improvement on the company, starting by determining the production rate, or takt time (TT). After that, the operations carried out at each post are analysed from the points of view of value-added (VA) and non-value-added (NVA) [19].

STAGE 2: Implementation. This stage is divided into three phases:

1. Deciding how to use the programme (i.e., it must be launched only to the core process, or CP, defined in stage 0).
2. Launching the needs to the rest of the links. One criterion is that all parts used in the workstation must be located in the workstation and in a space that minimises operator waste. To this end, we will base ourselves on what we have called the ‘4Bs’: container design, micro-distribution of the workstation, an information transmission channel, and a supply system.
3. Designing and standardising logistics processes.

STAGE 3: Continuous improvement. Improvement teams are set up. These teams take on daily operational management, so a system of work meetings is established to maintain continuous improvement. To this end, team members must be trained in terms of operational tools and basic management knowledge [20].

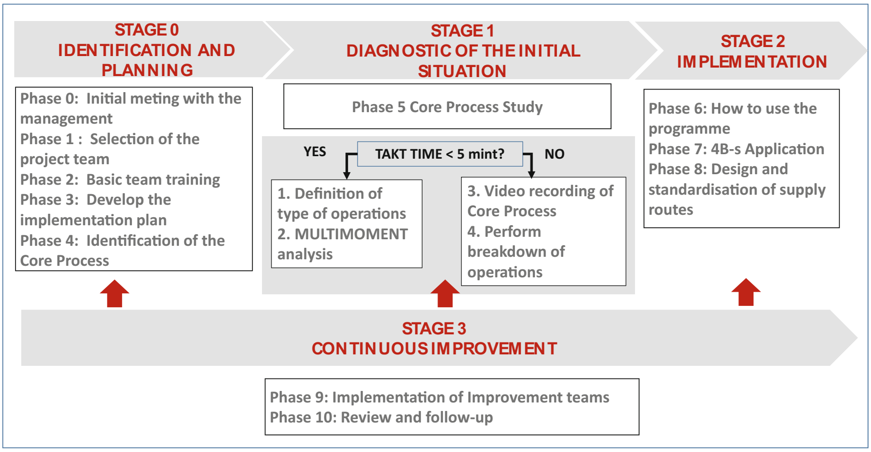


Fig. 2. PDLB-EMPHOBEK (own elaboration)

5 Case Study: Household Appliance Manufacturing Company

The company that developed this project is a cooperative organisation in Spain's Basque Country. It is a large company, with several plants around the world, and a leader in its sector. The PDLB-EMPHOBEK deployment process was carried out at one of the company's refrigerator manufacturing plants following the steps indicated by the process.

Stage 0: The project team was created, consisting of two industrialisation engineers, two process technicians, two area managers, and the researcher. After that, the team, management staff, and approximately 550 people were trained in aspects related to LM, LL, and the fundamental principles of the LBP. Finally, it was determined that the CP would be the common areas of the assembly lines, where the products enter in a mixed and random manner.

Stage 1: The first variable estimated was the TT at which the assembly lines had to produce, which was 60 s. Taking this TT into account, the types of operations the CP stations perform were analysed from a lean VA and NVA perspective, resulting in an improvement potential of a reduction of 3.37 resources per common zone. Therefore, the total resource reduction between the two common zones was 6.74 resources, which represents an improvement in productivity of 12.96%.

Stage 2: To reduce these NVA operations, we followed the deployment process, which determined that 100% of the parts consumed in the stall had to be in the stall and within three linear metres of occupation. To do this, and following the 4Bs, we defined the container to supply the parts, designed the stall shelving, determined the appropriate line supply systems according to the number of references to be supplied and located.

We also designed the system to communicate to logistics and the remaining processes the moment at which to supply and/or produce, thus achieving a pull system. This stage eliminated the need for logistics and the processes manufacturing components for the assembly area to use the programme and decreased space occupied by parts from 144 m^2 to 28 m^2—an 80.55% reduction. We also located 100% of the parts in the workstation.

Finally, we defined and standardised supply routes by quantifying their operations time and saturation.

Stage 3: At this stage, the work was quite simple, as the company had been working in improvement teams for years, so the only task was to explain what had been done and why. On the other hand, team members were trained to be responsible—with the support of the project team—for the future improvement of their processes based on LBP methodology.

6 Conclusions and Discussion

The results demonstrated the validity of the PDLB-EMPHOBEK process as a means of improving operating parameters. This was done by adopting different logistical solutions in line with the real needs of the production process. Solutions such as the use of Kanban, sequences, commissioning, and/or kittings eliminate NVA operations carried out by the assembly operator: some are taken over by logistics operators and some are taken over by the supplier. This principle is called LBP. At first, this change may generate doubt or tension, as passing certain operations from the production operator to the logistics operator may require an increase in logistical resources. The question is whether the reduction in resources in the production process is greater than the increase in resources in the logistics processes. This is important, since the professional qualifications of employees in the processes differ; the cost of this NVA operation is lower if it is carried out by logistics. Another fundamental aspect of the evaluation and consolidation of this improvement is the standardisation and measurement of logistics processes, a task in which very few companies participate. This is an important step, as it provides a means of knowing whether an operation we want to extract from the production process or CP can be taken on by logistics. In conclusion, by adopting this principle, we can achieve value chains that function as pull systems.

References

1. CVCTI: Bases Estratégicas y Económicas del PCTI Euskadi 2030 (2019)
2. Elorza, U., Pozueta, L., Eguren, J.A.: Model/framework for addressing continuous improvement projects effectively and efficiently using Six Sigma Methodology. Case study of automotive auxiliary company. Manag. Prod. Eng. Rev. **3**, 35–46 (2012). https://doi.org/10.2478/v10270-012-0032-y
3. Klug, F.: Lean logistics. In: Logistikmanagement in der Automobilindustrie. VDI-Buch, pp. 287–326. Springer, Heidelberg (2018). https://doi.org/10.1007/978-3-662-55873-7_7
4. Wirth, S., Baumann, A.: Wertschöpfung durch vernetzte Kompetenz: schlanke Kompetenzkooperation: Überlebensstrategie für kleine Produktions-und Dienstleistungsunternehmen. Huss (2001)
5. Krafcik, J.F.: Triumph of the lean production system. Sloan Manage. Rev. **30**, 41 (1988)
6. Yin, R.K.: Case Study Research–Design and Methods. Sage Publ. Inc. (2003)
7. Coughlan, P., Coghlan, D.: Action research for operations management. Int. J. Oper. Prod. Manag. **22**, 220–240 (2002). https://doi.org/10.1108/01443570210417515
8. Arunagiri, P., Gnanavelbabu, A.: Identification of major lean production waste in automobile industries using weighted average method. Procedia Eng. **97**, 2167–2175 (2014). https://doi.org/10.1016/j.proeng.2014.12.460

9. Danese, P., Manfè, V., Romano, P.: A Systematic Literature Review on Recent Lean Research: State-of-the-art and Future Directions. Int. J. Manag. Rev. **20**, 579–605 (2018). https://doi.org/10.1111/ijmr.12156
10. Tortorella, G.L., Fettermann, D.: Implementation of industry 4.0 and lean production in Brazilian manufacturing companies. Int. J. Prod. Res. **56**, 2975–2987 (2018). https://doi.org/10.1080/00207543.2017.1391420
11. Negrão, L.L.L., Godinho Filho, M., Marodin, G.: Lean practices and their effect on performance: a literature review. Prod. Plan. Control. **28**, 33–56 (2017). https://doi.org/10.1080/09537287.2016.1231853
12. Rother, M., Shook, J., Womack, J., Jones, D.: Learning to see valuer stream mapping to create value and eliminate Muda (1999)
13. Andreadis, E., Garza-Reyes, J.A., Kumar, V.: Towards a conceptual framework for value stream mapping (VSM) implementation: an investigation of managerial factors. Int. J. Prod. Res. **55**, 7073–7095 (2017). https://doi.org/10.1080/00207543.2017.1347302
14. Bevilacqua, M., Ciarapica, F.E., De Sanctis, I.: Lean practices implementation and their relationships with operational responsiveness and company performance: an Italian study. Int. J. Prod. Res. **55**, 769–794 (2017). https://doi.org/10.1080/00207543.2016.1211346
15. Boppert, J., Schedlbauer, M., Günthner, W.A.: Neue Wege in der Automobillogistik, München (2007)
16. Klug, F.: Logistikmanagement in der automobilindustrie: Grundlagen der logistik im automobilbau. (2018)
17. Die Automobilindustrie als Vorbild - ingenieur.de. https://www.ingenieur.de/fachmedien/logistikfuerunternehmen/produktionslogistik/die-automobilindustrie-als-vorbild/. Accessed 19 May 2022
18. Bessant, J., Caffyn, S., Gallagher, M.: Evolutionary model of continuous improvement behaviour. Technovation **21**, 67–77 (2001). https://doi.org/10.1016/S0166-4972(00)00023-7
19. Hodge, G.L., Goforth Ross, K., Joines, J.A., Thoney, K.: Adapting lean manufacturing principles to the textile industry. Prod. Plan. Control. **22**, 237–247 (2011). https://doi.org/10.1080/09537287.2010.498577
20. Kurpjuweit, S., Reinerth, D., Schmidt, C.G., Wagner, S.M.: Implementing visual management for continuous improvement: barriers, success factors and best practices. Int. J. Prod. Res. **57**, 5574–5588 (2019). https://doi.org/10.1080/00207543.2018.1553315

Segmentation of Industrial Sectors Based on the Characteristics of Their Greenhouse Gases Emissions

J. Retegi[1,2(✉)], B. Kamp[2], and J. I. Igartua[1]

[1] Mechanical and Industrial Production Department, Mondragon University, Mondragon, Spain
{jretegi,jigartua}@mondragon.edu

[2] Orkestra-Basque Institute of Competitiveness, San Sebastian, Spain
bart.kamp@orkestra.deusto.es

Abstract. This paper analyses the characteristics of sectoral contributions to Greenhouse gases emissions based on economic data of industrial energy consumption in Spain and gives some insights about public programmes for emissions reduction. It departs from the total amount of Greenhouse gases emissions due to the energy mix deployed per industrial sector, the percentage of electrification of its activities and the indirect emissions due to generation mix behind electricity consumption. Separately, it examines the dispersion of emissions across firms (tCO2-eq/firm) per industrial sector. By segmenting the industrial sectors into quadrants, the authors identify in quadrant iv four industrial sectors with a low level of electrification, high level of emissions and a strong concentration of emissions at the level of individual firms. Due to their characteristics, it is suggested that specific public programmes for Greenhouse gases reduction should target these four industrial sectors.

Keywords: Circular economy · Green deal · Sustainability · Greenhouse gases

1 Introduction

The Green Deal [2] seeks to reduce the footprint caused by economic activities on the environment. In 2020, industrial direct Greenhouse gases (GHG) emissions accounted for 20% of total emissions in Spain [7]. In addition, part of the indirect emissions related to the electricity generation mix is due to electricity consumption in industrial processes.

European and state regulations associated with the promotion of sustainability affect industrial sectors differently. Some authors [1] state that climate-neutral energy infrastructure or the housing sector and materials used in its value chain, such as cement or metals (steel, copper, aluminium, nickel, zinc, manganese or lead), account for 9% and 7% of total emissions, respectively. Thirteen sectors [3], especially those involved in the Industrial Emissions Directive, are analysed, including Energy, Refineries, Iron and steel, Non-ferrous Metals, Chemicals, Food and drink, Cement, Lime and magnesium oxide, Surface treatment with solvents, Pulp and paper, Rendering, Ceramics, Glass, and textiles.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 19–24, 2023.
https://doi.org/10.1007/978-3-031-27915-7_4

To implement effective emissions reduction policies, it is necessary to understand the characteristics of the emitting sectors, such as the energy consumption mix, the percentage of electrification, the total amount and the direct or indirect nature of emissions and their concentration (amount of tCO2-eq/firm).

Considering that each one of the energy sources emits a different amount of GHG during its use, the energy consumption variables per energy source are necessary to obtain the estimation of the emissions and prioritise the most emitting sectors. The percentage of electrification is necessary to estimate the amount of indirect emissions and the degree to which the projects to reduce the GHG footprint are mainly related to a change in energy source or to a reduction in the consumption of electricity. The generation mix is necessary to account for the GHG emissions in electricity production companies' facilities due to the consumption of electricity in industrial companies.

2 Methodology

In this article, the analysis of data obtained has been made within the following framework: the total Tier I and Tier II [6] emissions (tCO2-eq) attributed to the industrial system of a country or region can be expressed as follows:

$$E = \sum\nolimits_{i=1}^{n} \sum\nolimits_{j=1}^{m} \left(1000.C_{ij}.K_j\right) \quad \text{and} \quad K_j = \left(EF_j/1000\right)/AP_j$$

where E is the total amount of CO2-eq (tCO2-eq) emitted due to the industrial activity of a country or region for the period of analysis, Cij is the consumption (m€) of energy source j on behalf of sector I, Kj is the emission factor (tCO2-eq/€) of energy source j, EFj is the emission factor of energy source j (tCO2-eq/MWh), and APj is the average price for the year of reference of energy source j (€/KWh). Average prices have been obtained mainly from the Eurostat Data Browser. The values for emission factors have been obtained from [4, 5], and [7]. Data related to the Survey of Energy Consumption and for the year 2019 was obtained from the National Institute of Statistics (INE) and have been used.

The activities of extractive industries corresponding to the statistical classification of economic activities in the European Community (NACE) codes 051 to 099 and '19. Manufacture of coke and refined petroleum products' are not considered, as they are not included in the official data obtained from INE.

3 Results

According to the results, the energy consumption of the manufacturing sectors amounted to EUR 10,117 million, of which EUR 5,948 million was in the form of electricity and EUR 2,887 million was in the form of gas. In addition, EUR 789 million were consumed in petroleum products (diesel, fuel oil, gasoline, butane, propane and others) and EUR 491 million in others (coal and coke, solid or liquid biofuels, heat and other products). Electricity (58%) and gas (28%) accounted for a high percentage of the energy consumption of companies in most manufacturing sectors.

The sectors that consume the most energy are the following: Manufacturers of food products, Manufacturing of basic metals, Manufacturing of chemicals and chemical products, and Manufacturers of other non-metallic mineral products. Together, they account for 64% of the total consumption of the entire manufacturing sector.

The two sectors in which petroleum products and others (coal and coke, solid or liquid biofuels, heat and other products) account for the highest percentage in their production are Repair and installation of machinery and equipment (49.4%) and Manufacturing of furniture (29.9%), although both sectors together account for only 1.14% of the total consumption of the manufacturing sector.

Based on estimations using economic data and the previously presented formula, the total emissions of industrial companies in Spain during 2019 accounted for 53.85 MTCO2-eq (NACE codes 10 to 33, excluding '19. Manufacturing of coke and refined petroleum products'). The CO2-eq emitted in industrial facilities (MTCO2-eq) were as follows: gas 34.46 Mt; gasoil 3.59 Mt; fuel oil 2.45 Mt; coal and coke 1.85 Mt; others 3.49 Mt. The indirect emissions linked to electricity consumption and generation mix and heat accounted for 10.51 MtCO2-eq. During 2020, 16% of electrical energy was produced from gas in combined-cycle plants, 2% from coal, 0.8% from non-renewable waste, and 1.9% from other renewables [8].

The industrial sectors emitting the biggest amount of CO2-eq are as follows: Manufacturing of other non-metallic mineral products, Manufacturing of chemicals and chemical products, Manufacturing of food products, and Manufacturing of basic metals. The level of consumption of electricity (€) over the total energy consumption of the three most emitting sectors is lower than 60%.

4 Discussion

In Fig. 1, the emissions per sector (size of the bubble) are represented with their concentration levels (emissions per firm in x axis) and the electrification percentage (y axis). Considering that the article aims to give some insights that could guide GHG emission reduction public programmes, the percentage of electrification was selected to assess whether the investments should be executed in the industrial company or in the electricity supplier company.

For the same reason, it was necessary to know if the emissions were concentrated in companies with a high amount of emissions or dispersed in many sites and locations with few emissions. Depending on the case, the size of the projects and financing needs can be a lot different.

Based on the figure, the sectors can be segmented depending on the quadrant where they are located. The industrial sectors have been segmented using the averages for the x and y axes, which are represented with dotted lines.

Quadrant i) Top-left. It includes 11 sectors (48%) that emit 7% of the total emissions. The emissions are widely dispersed in firms with a high level of electrification. On average, cost-oriented, energy efficiency projects with low emission reductions per firm can be addressed.

Quadrant ii) Bottom left. It includes six sectors (26%) that emit 26% of total emissions. The emissions are very dispersed in firms with a low level of electrification.

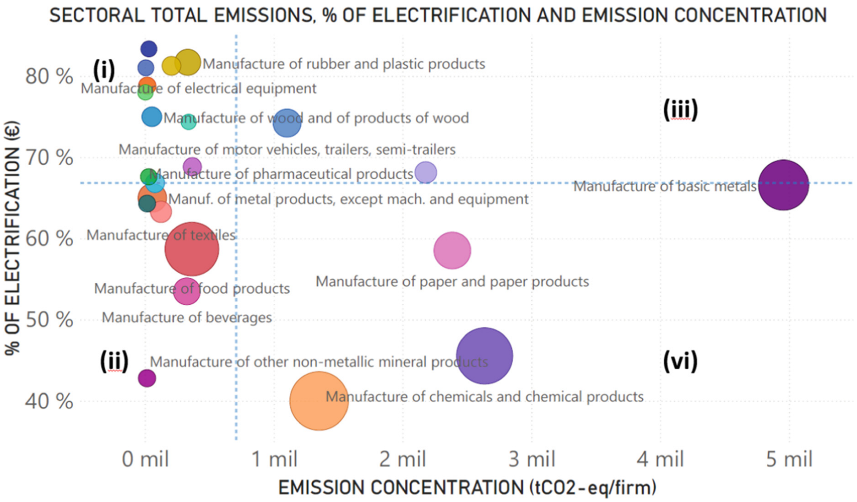


Fig. 1. Sectoral total emissions, % of electrification and emission concentration

'Manufacture of food products' is included in this quadrant and represents 65% of the emissions of this quadrant. Projects for energy efficiency, electrification or low emission alternative energy sources with relatively low levels of investment can be suitable for companies represented in this quadrant.

Quadrant iii) Top-right. It includes two sectors (9%) that emit 5% of the total emissions. The emissions are concentrated with a high level of electrification. Manufacture of pharmaceutical products and Manufacture of motor vehicles, trailers and semi-trailers are included in this quadrant. Cost-oriented energy efficiency projects with a relatively high level of investment per firm can be applied.

Quadrant iv) Bottom-right. It includes four sectors (17%) that emit 61% of the total emissions. The emissions are very concentrated in firms with a low level of electrification. The sectors that comprise this quadrant are as follows: manufacture of basic metals, manufacture of chemicals and chemical products, manufacture of paper and paper products and manufacture of other non-metallic mineral products. Alternative energy source projects (electricity or other non-GHG-emitting sources) can contribute strongly to the reduction of emissions.

5 Conclusions

In this paper, the energy-related emissions of industrial sectors have been analysed based on economic consumption data obtained from official sources. The estimates based on energy consumption in firms allow for estimates of GHG emissions up to a NACE 3-digit level using publicly available data.

The results confirm that the four sectors that emit the most GHG account for 71% of the total emissions. The electrification level of all sectors is 59% on average. Three of the four most emitting sectors have an equal or lower level of electrification than average.

Considering the concentration of emissions in firms, manufacturing of other non-metallic mineral products (1,351 tCO2-eq/firm), manufacturing of chemicals and chemical products (2,636 tCO2-eq/firm) and manufacturing of basic metals (4,956 tCO2-eq/firm) comprise a high level of emissions per firm. Manufacturing of paper and paper products has a lower level of emissions (3.92 MtCO2-eq), but they are heavily concentrated emissions (2,385 tCO2-eq/firm).

As mentioned in the introduction, this paper aims to give some insights into public programmes for GHG emission reduction. These programmes should be adapted to the characteristics of the emitting sectors as much as possible. In this research, we have segmented industrial sectors depending on their percentage of electrification and the emissions concentration.

The percentage of electrification allowed us to know if the projects to reduce the GHG footprint for industrial companies were mainly related to a change from a non-electricity energy source to electricity or other non-GHG-emitting sources or to a reduction of the consumption of electricity.

The concentration of emissions in the companies allowed us to know if the emissions were concentrated in companies with a high amount of emissions or dispersed in many sites and locations with few emissions. Depending on the case, the size of the projects and the financing needs could be completely different.

Considering this, a short description of the kind of GHG emissions reduction projects has been presented for the sector included in each quadrant.

The sectors located in the bottom-right quadrant in Fig. 1 should be prioritized to reduce the total amount of emissions. They require intense sources of heat for their processes, and electrification does not seem to be a solution.

The reduction of emissions for these sectors requires a major technological transformation and reconversion that could come from the use of alternative sources of energy, such as hydrogen, if the technology is available at suitable costs. The execution of these projects could include consideration of the industrial footprints of the companies.

The types of projects to be developed in these sectors (investment level, technology development, skills and experience) are distinctive from, for instance, energy efficiency projects in highly electrified and low-consumption companies; thus, the supporting public programmes to foster investment should be different as well.

References

1. Elkerbout, M., Egenhofer, C., Núñez Ferrer, J., Cătuţi, M., Kustova, I., Rizos, V.: The European Green Deal After Corona: Implications for EU Climate Policy. Policy Insights. Nº 2020–06, March 2020 (2020)
2. European Commission: The European Green Deal. Communication from the Commission to the European Parliament, The European Council, The Council, The European Economic and Social Committee and the Committee of the Regions. Brussels, 11.12.2019. COM (2019) 640 final (2019)
3. European Commission: Wider Environmental Impacts of Industry Decarbonisation Final Report. Wood E&IS GmbH – February 2021 (2021)

4. Krey, V., et al.: Annex II: Metrics & Methodology. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge and New York (2014)
5. López Martínez, J.M., Flores, N., Lumbreras, J., Villimar R., Pascual, C.: Análisis de las Emisiones de CO2 en la Producción de las Fuentes Energéticas Utilizadas en el Transporte por Carretera. Actas del IX Congreso de Ingeniería del Transporte, CIT 2010 (2010)
6. Pandey, D., Agrawal, M., Pandey, J.S.: carbon footprint: current methods of estimation. Environ. Monit. Assess. **178**, 135–160 (2010)
7. REE: Red Eléctrica Española.: Emisiones de CO2 Asociadas a la Generación de Electricidad en España (2021). https://www.ree.es/es/sala-de-prensa/
8. REE: Red Eléctrica Española. El Sistema Eléctrico Español 2020 (2021). https://www.ree.es/es/datos/publicaciones/

Design of a Learning Environment Based on Flip Teaching in Industrial Engineering Subjects

Carlos Andrés(✉), Manuel Cardós, Julien Maheut, and Lourdes Canós

Management Department, Universitat Politècnica de València, Cno de Vera s/n, 46022 Valencia, Spain
candres@omp.upv.es

Abstract. The introduction of the Flip Teaching (FT) based learning into higher education has accelerated in recent years but application examples in Industrial Engineering teaching are scarce. This paper describes some experiences in the the application of the FT methodology to some degree and master subjects (all of them related with industrial engineering) and examine the results associated with this teaching method.

Keywords: Flip teaching · Industrial engineering · Education

1 Introduction

Flip Teaching (FT) also known as Inverted Classroom or Blended Learning has become increasingly popular in higher education since the last 20 years [1]. The key of this method is to focus the learning in the effort of the students previously to the class. Unlike traditional methodology (TM) where concepts are explained by the teacher in class and later students work the taught content at home, in the FT model students must prepare the class before and the day of the class they work together and discuss matters as a group [2]. In the FT model, learning focus changes from the teacher to each student effort through participation in interactive activities while they can obtain teachers' feedback [3].

During the last twenty years, different experiences have been published in areas of both pre-university [2] and university education [4] regarding with the application of FT in education. Flipped learnign has been reported in various disciplines including mathematics [5], health education [6], business education [7] or engineering [8]. Despite the growing interest that has aroused FT in the last two decades, little or not much has been done in Industrial Engineering Field. This paper present three experiences in degree (second and third year of Grado de Ingenieria de Organización Industrial or GIOI) and master (second year of Master de Ingeniería Industrial or MUII).

The paper is organized as follows: Sect. 2 provides the general approach of FP and Sect. 3 discusses of results after two years of teaching using FT with their implications and limitations.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 25–30, 2023.
https://doi.org/10.1007/978-3-031-27915-7_5

2 Proposed Model of FT in Industrial Engineering Subjects

2.1 Background

In the Polytechnic University of Valencia (UPV) the so-called new teaching methodologies have been encouraged in the last 25 years. Recently there has been an interest in the application of FT due to two fundamental circumstances:

- The need to continue advancing in methodologies that allow students to develop skills in a continous way and changing from traditional master classes to lifelong learning. This trend began at the last decade of the 20th century with the development and implementation of the European Higher Education Area.
- However, after the pandemic situation in 2020 and the "new normality", it was seen the need to change the design of the subjects to allow students follow the rhythm of classes when face-to-face teaching is not possible. Thus, one of the objectives of flip teaching, which is that the student is the center of the process and has an active role in it, has been revealed as a valid approach that allows teaching when face-to-face assistance is not possible.

In the 2020–2021 academic year, the Vice-Rector for Digital Resources and Documentation of the Polytechnical University of Valencia, opened a call that encouraged the transformation of subjects taught in the traditional way to the new flip teaching approach and which was called "Projecte A+D - Docència Inversa de la UPV". Several subjects from production area of the Department of Business Organization participated in this program: Logistics and Supply Chain Processes, Operations Consulting taught by Professor Julien Maheut (from second year of MUII), Design of Productive Systems and Logistics taught by Professor Manuel Cardós (from second year of GIOI) and Programming and Control of Production and Operations taught by Professor Carlos Andrés (from third year of GIOI). In the following section FT approach in all the subjects is explained.

2.2 FT Implementation

The basis of the proposal is to divide the teaching activity of each class session into three phases:

- Preliminary phase. At home, prior to the face-to-face session, students are expected to autonomously achieve the simplest and most concrete learning outcomes with the help of videos and other materials selected by the teacher. This allows students to reach a "previous level" necessary to "advance" in class.
- Face-to-face phase. In the class, the previous results are consolidated and more complex aspects and higher cognitive levels are worked on that need to be worked on with the guidance of the teacher and the collaborative work of their classmates.
- Homewotk phase. After the face-to-face class session, the aim is to finish consolidating the contents taught as well as deepening some aspects that need more time to be assimilated.

In order to structure this process, an application called LESSONS has been used within the UPV teaching platform, which allows digital content to be created and inserted into the subject's website without difficulty.

Following the recommendations of the Institute of Educational Sciences (ICE) of the UPV, the interface of each subject in LESSONS has been structured in three main sections:

- Presentation of the methodology to the student. Since it is essential that students get involved and participate in the process it is neccesary to present the concept of flip teaching and how it will be applied to the subject (what the student is expected to do and what the teacher will do). The objective is to show to students how FT methodology contributes to their learning (acquisition of transversal skills, improve the transfer of learning, collaborative learning, etc…). And to banish the false belief that flip teaching is "a way for the teacher to work less".
- Work plan. A structured program by sessions has been followed (each session corresponds to a class of 1.5 h) plus the practical sessions. In each session (which becomes visible one week before the date on which it is to take place) the student is given a schematic specification of the learning outcomes to be achieved, the activities to be carried out and the monitoring and evaluation criteria. A color-based notation has been used to identify which activities and contents must be worked on prior to the session (red), will be worked on during the session (yellow), must be worked on after the session (green) and can be work optionally, even if they are not evaluated (blue).
- Other contents of the subject. Linked to the work plan, there are repositories with documents, case studies, tasks, tests and videos so students who prefer a more traditional approach to the subject can access directile to the contents without the work plan.

2.3 FT in Practice

A typical session begins one week before the date of the class. An email is send to the students to announce them that the session is ready to be visited. They receive a summary of the session and the objectives and competences to reach during the class. They get feeedback from the previous session because the results of tasks and test are published and explained in the email.

They have one week to work the materials of the session (specifically videos, documents, case studies and small questions) and ask professors about the content of the session. In some cases, some contents are not visible until the students have worked on or passed others, thus allowing a certain gamification of teaching and a stimulus to learning.

The day of the class (each class lasts 1, 5 h), the teacher explain the learning objectives of the session. Then the results of previous tests are shared and commented with all the students (emphazising and explaining the frequent mistakes). Then, the teacher links previous session contents with the present session and presents exercises or cases studies related with the matter. Sometimes, solutions are discussed or one student is required to explain all the class how he focused the cases study or the exercise. If there is a test related with the session, the teacher remind the students the obligation to do the test before the following session.

After the class, students have more exercises or cases to practice the contents of the finished session. Sometimes the exercises are small exams or case studies that will be worked in several sessions using different tools or approaches.

2.4 Datails About FT in Every Subject

Although all the subjects follow the general guidelines explained in the previous section, it is important to highlight some characteristics of each of them. For example, due to the fact that Design of Productive Systems and Logistics belongs to second year, much emphasis has been placed on carrying out exercises and weekly activities that force students to self-study almost continuously. Thus, in all the sessions reading documents or viewing videos and self-assessment exams are proposed to ensure understanding of the documents. In addition, a large number of tasks related to the content of the session are carried out, such as searching for news in the press, answering specific questions, doing a simple exercise or completing an activity started in class. This material is used during the session reviewing the results of the self-assessments and the contributions of the tasks are shared.

In the case of the subject Programming and Control of Production and Operations, it is a third-year subject where it is assumed that the students have already advanced in their autonomous learning abilities, so they must work on the necessary theoretical and practical content prior to each session. The session itself a set of application exercises are solved in groups. These exercises are discussed among all the students in the final part of the session. Subsequently, test-type exams are carried out to reinforce the assimilated contents.

Reverse teaching in master's courses is based on fully autonomous learning. In this case, all the material is made available to the students but in a less structured way than in undergraduate teaching (newspaper articles, repository of teaching videos, example cases, etc…). Students themselves must organize themselves to work on these materials that will be necessary for them to solve a series of open cases in face-to-face sessions that together constitute a complete project.

3 Results and Conclusions

3.1 Results

It should be noted that the assessment made by the students has been very positive. In the surveys that ICE has been carrying out in recent years, there is one of the sections where the use of methodologies and activities in the development of the subject that help motivate students is valued. In the 2017/18 academic year, an average score of 6.6 was obtained, while in the 2018/18 academic year the average score dropped to 5.8. In the following course (year of confinement) the average fell even further to 4.68. However, in the following course, where the teaching staff was the same, the same contents were taught and the same evaluation system was used, the average rose to 7.97.

Regarding about the effect over student learning, it must be noted that there are a strong correlation between the participation of the students in FT and their results. For example, as it can be seen in the following Table 1 (from Design of Productive Systems and Logistics) almost all the students who worked hard under FT approach passed the final exam, most of them with good results. However, for students who chose a traditional way to the FT (only preparing by themselves and presenting to final exams), only the 26% passed the subject.

Table 1. Percentage of approved according to the percentage of the tasks carried out.

Percentage of task carried aout	Percentage of approved students
Less than 33%	23%
Between 33% and 66%	68%
More than 66%	92%

3.2 Conclusions

The researchers conclude that the flipped classroom can be implemented for different groups of students related with Industrial Engineering (degree and master) and can be used as a means to improve the learning experience for students. Flip classroom provides a platform for the students to learn at their own pace and repeatedly to gain understanding of abstract organization concepts. Even though flipped classroom requires a great effort to prepare cases studies, tests, videos and other content, students appreciate this effort due to the impact it has on their own performance.

Acknowledgements. This work was supported by the Universitat Politècnica de València project PIME 21-23 “El Ambiente de Aprendizaje y la Formación de Estudiantes de Gestión, Tecnología e Ingeniería”.

References

1. Lage, M.J., Platt, G.J., Treglia, M.: Inverting the classroom: a gateway to creating an inclusive learning environment. J. Econ. Educ. **31**, 30–43 (2000)
2. Teo, T.W., Tan, K.C.D., Yan, Y.K., Teo, Y.C., Yeo, L.W.: How flip teaching supports undergraduate chemistry laboratory learning. Chem. Educ. Res. Pract. **15**, 550–567 (2014)
3. Thai, N.T.T., De Wever, B., Valcke, M.: The impact of a flipped classroom design on learning performance in higher education: looking for the best “blend” of lectures and guiding questions with feedback. Comput. Educ. **107**, 113–126 (2017)
4. Şengel, E.: To FLIP or not to FLIP: comparative case study in higher education in Turkey. Comput. Hum. Behav. **64**, 547–555 (2016)
5. Lo, C.K., Hew, K.F.: Developing a flipped learning approach to support student engagement: a design-based research of secondary school mathematics teaching. J. Comput. Assist. Learn. **37**(1), 142–157 (2021)
6. Sullivan, J.M.: Flipping the classroom: an innovative approach to graduate nursing education. J. Prof. Nurs. **38**, 40–44 (2022)

7. Fang, J., Vong, J., Fang, J.: Exploring student engagement in fully flipped classroom pedagogy: case of an Australian business undergraduate degree. J. Educ. Bus. 1–10 (2021)
8. Awuor, N.O., Weng, C., Militar, R.: Teamwork competency and satisfaction in online group project-based engineering course: the cross-level moderating effect of collective efficacy and flipped instruction. Comput. Educ. **176**, 1–12 (2022)

Reconfiguration of Multi-business Chains Through Vertical Synergies

Manuel Mateo[1](✉) and Nicolas Anich[2]

[1] Department of Management/IOC, Universitat Politècnica de Catalunya, Av. Diagonal 647, 7th., 08028 Barcelona, Spain
manel.mateo@upc.edu

[2] Department of Management, Universitat Politècnica de Catalunya, Av. Diagonal, 647, 7th., 08028 Barcelona, Spain
nicolas.anich@upc.edu

Abstract. Synergy between supply chains implies complementarities of activities at different levels (operational, tactical and strategic). The chain contains different types of drivers of integration, called synergistic factors. Within the framework of a supply chain reconfiguration methodology, this paper reviews the global and particular elements of multi-business chains and synergies. The tool evaluates the synergies (horizontal and vertical) at different levels and stages, given the different channels, and determine the degree of complementarity and integration in a multi-business network.

Keywords: Supply chain · Reconfiguration · Design · Synergy · Multi-business

1 Introduction

In the context of multi-business chains (for example, more than one sales channel or type of customer), it is necessary to evaluate, measure and formulate solutions based on horizontal and vertical synergies. Synergistic strategies introduce the cooperation when companies share part of their resources and capabilities. Horizontal or static integration consists of two or more companies that carry out the same work or produce the same good and are integrated into a single organization [1]. In that case, the complexity of the supply chain and the operational risks in the supply chain are reduced [2]. Vertical integration aims to coordinate the processes of more than one actor throughout the supply chain. In this sense, such integration can be physical or virtual; simultaneously a better service quality is achieved and risk is reduced [3].

These synergies can be integrated into the three decision levels (Operational, Tactical and Strategic). Thanks to synergistic sources, fully complementary or mixed chains can be achieved instead of individual ones, depending on the degree of fusion and integration between the different businesses.

For the design or redesign of supply chains, the REDNURS (REDesign Under Risk and Synergy) methodology encompassed by a set of steps has been definied [4]. EHAVS (Evaluation Horizontal And Vertical Synergies), as part of this methodology, is a tool

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 31–36, 2023.
https://doi.org/10.1007/978-3-031-27915-7_6

for evaluating horizontal and vertical synergies. The purpose is to evaluate and propose a priori solution for a network based on the complementarities and integration of synergistic sources. Therefore, this research is based on the following questions: Which are the dimensions in vertical synergies? How can the vertical synergies be measured? What are the implications of these synergies within a multi-business chain?

This document is configured as follows. Section 2 explains synergistic networks. Section 3 presents the evaluation tool. Section 4 discusses its application on a distribution network. Finally, Sect. 5 gives some conclusions.

2 Supply Chain and Synergistic Networks

The multi-business company is the result of the search for growth of a business from the creation or acquisition of others, which are managed under the structure of strategic units. For a multi-business network reconfiguration, the REDNURS (REDesign Under Risk and Synergy) methodology is defined [4] following the guidelines in [5]. In stage 6, an integrative effect between the different partial solutions needs to be evaluated in order to arrive at a priori synergistic solution. These synergies can occur in the horizontal and vertical aspects.

In the configuration of vertical synergies in multi-channel chains, there must be at least one horizontal solution as a precondition. This allows having a configuration with synergies respect to a pivot chain [6].

3 EHAVS Tool to Determine Vertical and Total Synergies

The EHAVS (Evaluation of Horizontal And Vertical Synergies) allows evaluate the synergistic capacity of the supply chain, and then configure it. The supply chain may be better managed selecting synergistic sources and then improving the performance of the KPIs.

The developed tool starts from the schematic representation of the different stages in a synergistic supply chain. This development occupies a Botton-Up logic [7]. The vertical synergy dimensions are structured in levels and based on the SCOR model. First, they are classified as a result of the integration of processes at the Operational level: Purchase-inbound logistics, Inbound logistics-Outbound logistics, Outbound logistics-Transportation and Transport-Customer. Also at the tactical level, it is made up of the planning stage. Finally, the strategic level concerns the businesses of the multichannel network [8].

The procedure consists in 4 steps, in which the second one is to evaluate Horizontal Synergies and the fourth is for Vertical Synergies:

1. Apply REDNURS methodology up to step 5 to define and obtain synergistic sources.
2. Evaluate Horizontal Synergies.
3. Definition of the a priori network proposed (arcs and vertical mergers in the horizontal solution of the network).
4. Evaluate Vertical Synergies.

The evaluation in step 4 for the Operational Level is done in this way: for Source-Inbound processes, reliability of the suppliers and delivery efficiency; for Inbound-Outbound processes, robustness of the replenishment process in picking; for the Outbound-Transportation processes, total time for outbound and robustness in the delivery to transport; for Transport-Client, total time outbound and reliability of the transport. For the tactical level, interaction of inventory with projected demand is measured. And for the strategic level, inbound time efficiency, outbound time efficiency and network fill rate are measured.

A synergistic network (sum of chains that have synergies with each other) must be the starting solution (after applying steps 1 and 2). Through the procedure described in Anich and Mateo [6], the pivot chain is the referent.

Once the result from step 2 is adapted for step 3, for each pair of processes at the operational level OVS_j stands for Operational Vertical Synergy of the pair j ($j = 1, \ldots, 4$). The vertical synergistic factors are evaluated, with an index between 0 and 1. Moreover, a weight of 4 is given for each of the remaining two levels (Tactical and Strategic, repectively): $0 \leq TVS \leq 4$ and $0 \leq SVS \leq 4$. The degree of integration of the chain is VSF (Vertical Synergy Factor). At the chain level, the maximum value for is 12: $VSF = OVS_1 + OVS_2 + OVS_3 + OVS_4 + TVS + SVS$.

For $VSF \leq 9.84$, the network is considered without attributes of vertical integration (a chain with little resilience and high risk). For $9.84 < VSF \leq 10.56$, the chain has an important capability for vertical synergy, which leads to increase resilience and/or reduce the risks. Finally, if $10.56 < VSF \leq 12$, the chain has very important attributes for a vertical synergy.

4 Case in a Distribution of Pharmacy Products

In a distribution of pharmaceutical products there are three types of business: public health (b1), Pharmacies (b2) and Private Institutions (b3). The main differentiating characteristics for *b1* are costs; for *b2*, it is service quality, and for *b3*, it is the response time. Figure 1 represents each supply chain. More than 1000 active ingredients are sold, supplied by more than 65 domestic and foreign suppliers. More than 1000 clients are distributed throughout the country. Each business list has a mix of different products, depending on their formats and values.

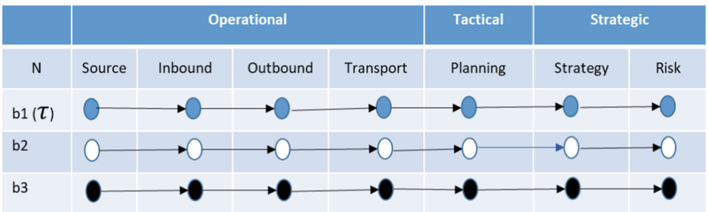


Fig. 1. Horizontal configuration of the supply chains of the different businesses

Next step searches to find which links and processes can improve the efficiency via the horizontal synergy between the different businesses. An evaluation of the synergistic sources is necessary. The expected result is some merging processes between the different channels. Data to evalute the synergistic sources are obtained from a company, simulations and interviews with other companies in the sector.

In the horizontal evaluation, the public business *b1* is the pivot chain (τ).

The Horizontal Synergy Factor (HSF) is obtained from the synergy values corresponding to each stage. For the case of the chains *b1* + *b2*, the factor of the operational level is 2.96; the factor for the tactical level is 3.02 and the one for the strategic level is 3.03. The sum of these three values means that the horizontal synergistic factor for the network as sum of the chains *b1* + *b2* is 9.01.

Additionally, for the chains *b1* + *b3* the factor for the operational level obtained is 2.87; the one for the tactical level is 3.15 and the one for the strategic level is 2.8. Given the sum of these levels, it represents an horizontal synergistic factor of the chains *b1* + *b3* of 8.87.

All processes with synergistic factor value greater than 0.70 are merged into a single one. As a result, the multi-business network *b1* + *b2* + *b3* has a high degree of synergy in most of the stages (Source, Inbound, Ourbound, Planning and Risk). On the other hand, Transport ans Strategy cannot be mixed in single operative decisions. Figure 2 shows these conclusions, as result of the step 2 of the procedure in Sect. 3 (EHAVS).

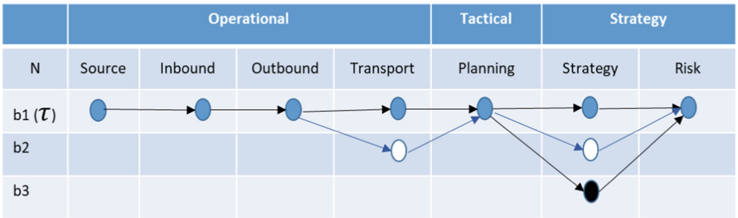


Fig. 2. Result of the network after the evaluation of horizontal synergies

Once the horizontal synergies have been determined, possible vertical synergies are proposed. In this case, the Inbound-Outbound can be concentrated in a single process and in the strategic level, the Business and Risk decisions also can be considered together (Fig. 3).

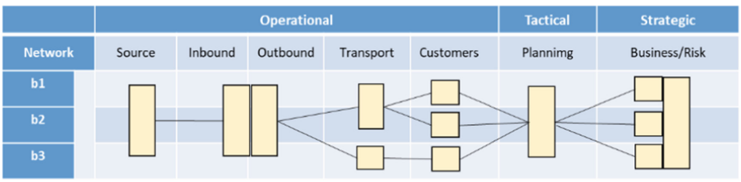


Fig. 3. Meso configuration of the multibusiness network to evaluate vertical synergies

Finally, in step 4, the evaluation of Vertical Synergies is done.

- For the Operational Level in Source-Inbound processes, the degree of reliability (robustness) related to the suppliers is 0.8039 based on the data. The delivery efficiency (62.5% of the volume) was measured based on the national supplies. The factor 0.78 is obtained by averaging these two sources.
- For the Inbound-Outbound processes, the robustness of the replenishment process in the picking areas is evaluated. The result is 100% compliance.
- Synergistic sources in the Outbound-Transportation processes are the total time outbound and the robustness in the delivery to the transport. For the robustness, the reliability is 0.99. To measure the delivery flow, the difference between the real and the best configuration obtained with simulation is calculated given a value of 0.83. Therefore, the average value of the different sources is 0.91.
- Finally, synergistic sources in the interaction of the transport with the client correspond to the total time outbound and the reliability of the transport. In the case of transport quality, a value of 0.94 is obtained based on measurements. Together with the outbound time, it gives a weighted value of 0.88.
- At the tactical level, the interaction of inventory with projected demand is measured: the network is simulated and an inventory policy satisfies 97% of the requested products.
- The strategic level synergistic sources are made up of inbound time efficiency (this value is 0.76), outbound time efficiency (this value is 0.83) and network fill rate (this value is 0.94), all of them obtained from a simulation model. The weighted synergistic factor of this level is 0.84.

The synergistic factor of the first stage are below 0.9, which causes effects on the inventory level. Also, this configuration considers the assignment of transports in the last mile. Although it is not critical, for instance the synergistic factor 0.88 could be improve through optimization models to seek better efficiency. In Fig. 4, all values of 0.88 or higher are shown as thicker in the grapical representation.

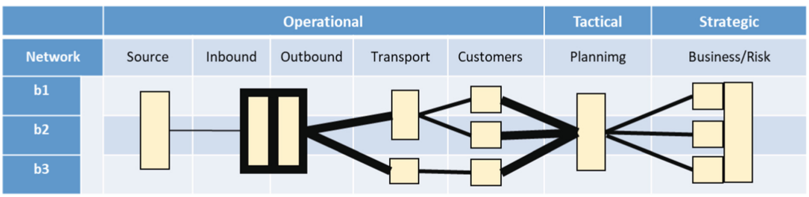


Fig. 4. Meso configuration final of the multibusiness network to vertical synergies

5 Conclusions

This study develops a tool called EHAVS, whose objective is to evaluate the synergistic capacity in a multi-business supply chain from an horizontal and vertical points of view.

Once represented in a graph, the arcs show the connection of the different stages in the chains, together with the measurement of the synergistic sources. The dimensions are the integration of processes at the Operational level (Purchase-inbound logistics, Inbound logistics-Outbound logistics, Outbound logistics-Transportation and Transport-Customer), the tactical level and the strategic level. The tool can support the redesign methodologies, since it incorporates the definition of all the kinds of decisions in the business.

In dynamic terms, the complexity in a network depends on the sum of links. According to the values of the factors obtained from the evaluation of synergies, the management of the supply chain in the different stages can be improved.

One of the first benefits of evaluating the total synergies in EHAVS is the development of an a priori configuation based on the sources of horizontal or static synergies and vertical or dynamic ones. However, the total synergies are made up of the dynamic component. This is related to the flows in the network from one edge to the other, taking into account time and risk. Therefore, in the search of a priori network, the links and mergers that allow greater resilience are defined (as it can be seen in the graph in Fig. 4 with thicker links).

Although the EHAVS tool can consider Reverse logistics, this deserves full consideration early in the Supply Chain Design process. Therefore, it is one of the topics to develop deeply in the future, specially related to the complexity.

Another path is the optimal decisions once considered all together (horizontal and vertical) synergies. This involves the selection of the most appropriate configuration, based on the testing of different scenarios.

References

1. Lan, Y., Yan, H., Ren, D., Guo, R.: Merger strategies in a supply chain with asymmetric capital-constrained retailers upon market power dependent trade credit. Omega **83**, 299–318 (2019)
2. Durowoju, O.A., Chan, H.K., Wang, X., Akenroye, T.: Supply chain redesign implications to information disruption impact. Int. J. Prod. Econ. **232**, 107939 (2021)
3. Andreou, P.C., Louca, C., Panayides, P.M.: Valuation effects of mergers and acquisitions in freight transportation. Transp. Res. Part E Logist. Transp. Rev. **48**(6), 1221–1234 (2012)
4. Anich, N., Mateo, M.: Application of a methodology for the management of risk in a pharmaceutical supply chain. In: De la Fuente, D., Pino, R., Ponte, B., Rosillo, R. (eds.) ICIEOM 2018. LNMIE, pp. 127–136. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-67708-4_14
5. Calleja, G., Corominas, A., Martínez-Costa, C., de la Torre, R.: Methodological approaches to supply chain design. Int. J. Prod. Res. **56**, 4467–4489 (2017)
6. Anich, N., Mateo, M.: Analysis of synergies in the supply chain with distribution to multiple types of clients. In: 14th International Conference on Industrial Engineering and Industrial Management, Adingor, Madrid (2020)
7. Chopra, S., Meindl, P.: Supply Chain Management: Strategy, Planning, and Operation. Pearson, Boston (2016)
8. Chandra, C., Grabis, J.: Supply Chain Configuration: Concepts, Solutions, and applications, 2nd edn. Springer, New York (2016). https://doi.org/10.1007/978-1-4939-3557-4

Impact of Optimizing Vegetable Freshness on Agri-Food Supply Chain Design

Ana Esteso[1(✉)], M. M. E. Alemany[1], Angel Ortiz[1], and Rina Iannacone[2]

[1] Research Centre on Production Management and Engineering (CIGIP), Universitat Politècnica de València, Camino de Vera s/n, 46022 Valencia, Spain
{aesteso,aortiz}@cigip.upv.es, mareva@omp.upv.es
[2] ALSIA-Metapontum Agrobios Research Center, S.S. Jonica 106, Km 448,2, 75012 Metaponto, MT, Italy
rina.iannacone@alsia.it

Abstract. Some characteristics of vegetables such as freshness have a great impact on their management and on the supply chain performance. However, this characteristic is not usually considered in strategic decision support models. To fill this gap, this paper proposes a multi-objective mixed integer linear programming model for supply chain design that includes tactical decisions related to the production and distribution of vegetables and simultaneously optimize supply chain profits and the average freshness of sold vegetables. The purpose of this paper is to determine whether maximizing the average freshness of the vegetables sold impacts on the supply chain design. To this end, the model is solved for eleven scenarios in which different weights are assigned to the objectives. The results obtained show how different supply chain configurations are generated depending on the weight assigned to each objective, proving the impact of maximizing the freshness of vegetables in the supply chain design.

Keywords: Agri-food supply chain design · Freshness · Optimization

1 Introduction

The freshness of vegetables is one of the most valuable characteristics for end consumers. As a result, companies in the agri-food sector are making an increasing effort to get vegetables to market as fresh as possible. However, most companies do not consider the freshness of the vegetables as a key factor when making decisions such as those related to supply chain (SC) design. Similarly, this characteristic is not usually considered in decision support models for the design and management of agri-food SCs.

To include characteristics such as freshness of vegetables in the design of the SC, it is necessary to take into account not only strategic decisions such as the location of nodes but also tactical decisions that will determine the management of the products such as the planning of their planting, harvesting or distribution.

Among the existing mathematical programming models for agri-food SC design in literature, most of them focus on strategic decisions related to the SC design, such as

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 37–41, 2023.
https://doi.org/10.1007/978-3-031-27915-7_7

facility location and supply, facility, and market allocation, and neglect tactical decisions related to product management (see [1] for an updated state of the art on agri-food SC design optimization models).

Few papers model tactical decisions such as the planning of planting or harvesting of vegetables [2–5] in conjunction with agri-food SC design. Even fewer agri-food SC design models also consider characteristics of fresh agri-food products such as their perishability [4, 5]. In this sense, Esteso et al. [5] showed that considering the perishable aspect of the products during the design of the SC has a great impact on the configuration obtained, with the economically optimal configuration being different for chains commercializing products with short or long shelf lives.

Similarly, this paper aims to determine whether maximising the average freshness of vegetables sold would have an impact on the configuration of the SC to be designed. The main novelties of this paper are the modelling of product freshness in a model for SC design, and the joint optimization of the average freshness of vegetables sold and the SC profits in SC design.

2 Multi-objective Model for Agri-Food SC Design

This paper proposes a multi-objective mixed integer linear programming model to support agri-food SC design for fresh vegetables that aims to simultaneously optimize SC profits and the average freshness of the vegetables sold, the inclusion of the latter objective in a SC design model being novel in the literature.

In order to model the freshness of vegetables, it is necessary to include in the model not only decisions related to the selection of the nodes that will be part of the designed SC, but also other tactical decisions related to the planning of planting, harvesting, packing and distribution of vegetables that will determine the freshness with which these vegetables reach the market, and therefore can be sold.

Thus, in this paper, agri-food SCs for fresh vegetables are considered to be composed of farms, packing plants (PPs), warehouses, distribution centres (DCs) and markets that are connected as shown in Fig. 1.

The decisions considered in the model are the selection of SC nodes, as well as the area to be planted and harvested by farmers in each time period, the quantity of vegetables to be harvested by farmers in each time period, the quantity of vegetables to be packed in PPs in each time period, the quantity of vegetables to be stored in PPs, warehouses and DCs in each time period, the quantity of vegetables wasted in PPs, warehouses and DCs in each time period, the quantity of vegetables transported between farms and PPs, between PPs and warehouses, between PPs and DCs, and between DCs and markets in each time period as well as the number of trucks needed for this, the quantity of vegetables sold in each market per time period, and the quantity of unsatisfied demand.

The main assumptions considered by the model are: the planting of vegetables is limited both by a minimum area to be planted due to technical reasons (in case it is decided to do so) and the area of the farm; the area planted with all vegetables on a farm cannot exceed its available area; the plants are harvested in the periods defined according to the planting and harvesting calendar for each vegetable; the amount of vegetable harvested on each plant is dependent on the planting and harvesting period;

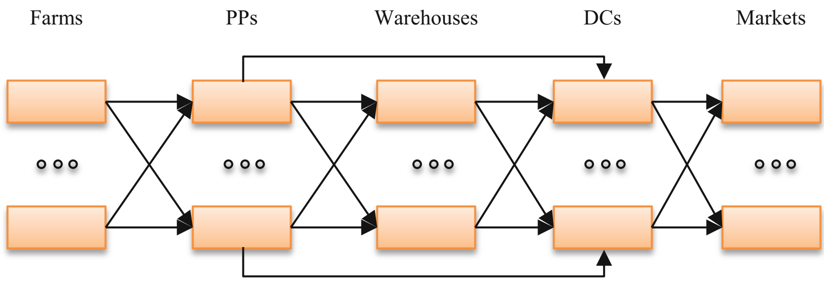


Fig. 1. Agri-food SC configuration

all mature vegetables on the plant must be harvested; vegetables are transported from the farm to the PP during the same period of harvesting; on arrival at the PP vegetables can be stored, packed or wasted; the quantity of vegetables to be packed is limited by the packing capacity of each PP; once packed vegetables can be transported to warehouses or DCs; in warehouses the vegetables can be stored, wasted or transported to DCs; in DCs vegetables can be stored, wasted or transported to markets; storage capacity in warehouses and DCs is limited; the number of trucks to be used between two nodes of the SC per time period depends on the amount of vegetables to be transported and the capacity of the trucks; vegetables have a limited shelf-life after harvesting that decreases over time; markets require vegetables to have a minimum freshness for sale, where the freshness of vegetables is defined by their remaining shelf-life; vegetables with less freshness than required by markets must be wasted; if the quantity of vegetables sold is less than demand, unsatisfied demand occurs; both unsatisfied demand and vegetable wastage are economically penalized; the costs related to planting, cultivating, packing, transporting, and storing vegetables are known; the transport time between nodes in the SC are known.

3 Experimentation

The proposed model is validated by solving it for a realistic case study on the design of an agri-food SC in the region of La Plata in Argentina [5]. In this case study, ten farms, eight PPs, four warehouses, and eight DCs are eligible to be part of the SC. The members chosen to be part of the SC must supply vegetables to four markets.

It is also considered that three types of vegetables are commercialized whose shelf-life is limited to three weeks. The freshness of vegetables is measured as the remaining shelf-life of the vegetable so that, at the time of harvesting the freshness would be equal to three and this would decrease by one unit with each period. The minimum freshness required by customers at the time of purchase of vegetables is one week.

Additionally, the nodes of the SC are located in different areas, so that the freshness of the vegetables not only decreases when they are stored at a particular node of the chain, but also decreases during transport between the nodes according to their distance and, consequently, their transport time.

The objective of the experimentation is to determine whether considering the maximization of the average freshness of the sold vegetables when designing the agri-food

SC influences the configurations obtained. To test this, the proposed model is run for eleven scenarios in which different weights are assigned to the objectives of maximizing SC profits and maximizing the freshness of vegetables sold. In the two extreme scenarios, full weight is assigned to one of the objectives (100%) and zero weight to the other objective (0%), these scenarios corresponding to the optimization of a single objective. The rest of the scenarios are constructed by distributing the total weight (100%) between the two objectives in such a way that one of them receives a weight of 10, 20, 30, 40, 50, 60, 70, 80 or 90% and the other objective receives the remaining weight.

The experiment was implemented in the optimization program MPL® 5.0 and solved with the solver Gurobi 9.1.2. For data import and export of results, databases created in Microsoft Access Database were used.

The results obtained for the eleven proposed scenarios are analysed in terms of the SC configuration obtained, as well as for the values of the optimized objectives: SC profit and average freshness of vegetables sold.

4 Conclusions

The results show how the configuration of the SC varies according to the relative importance assigned to the objectives. Thus, when full weight is assigned to maximizing the average freshness of vegetables sold, all available nodes are selected to configure the new SC (ten farms, eight PPs, four warehouses, and eight DCs). In contrast, assigning full weight to maximizing SC profits designs a SC with only six farms, three PPs, one warehouse, and one DC.

In the scenarios where weight is assigned to both objectives, SCs are designed with six to ten farms, three to eight PPs, one to four warehouses, and one to eight DCs, with the configuration being different for most scenarios. Therefore, it is proven that taking into account the optimization of the average freshness of vegetables sold has an impact on the SC design process, thus meeting the objective of this paper.

Regarding the values obtained for both objectives, it can be seen how improving the value of one of the objectives implies worsening the value of the other. In other words, increasing profits for the SC implies reducing the average freshness of vegetables sold and vice versa. However, due to the short shelf-life of the vegetable, large variations in SC profit (up to 53,250,000 € when no weight is assigned to profit objective and up to 6,000,000 € when weight is assigned to profit objective) lead to a small variation in the average freshness of the vegetables sold (up to 0.58 weeks).

It would therefore be interesting to determine the impact of optimizing the freshness of vegetables sold on the design of the SC for vegetables with a longer shelf-life. It would be appropriate to conduct the study for at least two scenarios: one in which the shelf-life of the vegetables is shorter than the time required to travel the longest route between farms and markets, and one in which the shelf-life of the vegetables is longer than the time required to travel the longest route between farms and markets.

Acknowledgements. The authors acknowledge the support of the Project 691249, "RUC-APS: Enhancing and implementing Knowledge based ICT solutions within high Risk and Uncertain Conditions for Agriculture Production Systems", funded by the EU under its funding scheme H2020-MCSA-RISE-2015.

References

1. Esteso, A., Alemany, M.M.E., Ortiz, A.: Conceptual framework for designing agri-food supply chains under uncertainty by mathematical programming models. Int. J. Prod. Res. (2018). https://doi.org/10.1080/00207543.2018.1447706
2. Zhao, X., Lv, Q.: Optimal design of agri-food chain network: an improved particle swarm optimization approach. In: 2011 International Conference on Management and Service Science, pp. 1–5 (2011). https://doi.org/10.1109/ICMSS.2011.5998308
3. Bortolini, M., Galizia, F.G., Mora, C., et al.: Bi-objective design of fresh food supply chain networks with reusable and disposable packaging containers. J. Clean. Prod. **184**, 375–388 (2018). https://doi.org/10.1016/j.jclepro.2018.02.231
4. Jonkman, J., Barbosa-Póvoa, A.P., Bloemhof, J.M.: Integrating harvesting decisions in the design of agro-food supply chains. Eur. J. Oper. Res. **276**, 247–258 (2019). https://doi.org/10.1016/j.ejor.2018.12.024
5. Esteso, A., Alemany, M.M.E., Ortiz, Á.: Impact of product perishability on agri-food supply chains design. Appl. Math. Model. **96**, 20–38 (2021). https://doi.org/10.1016/j.apm.2021.02.027

A Matlab-Based Educational Tool for Quantitative Risk Analysis

F. Acebes(✉), J. De Antón, F. Villafáñez, and D. Poza

INSISOC – Universidad de Valladolid, C/Dr. Mergelina s/n, 47011 Valladolid, Spain
fernando.acebes@uva.es

Abstract. Risk Management is a core discipline within Project Management. The successful achievement of project objectives depends enormously on the proper implementation of project risk management, which includes the identification, qualitative analysis, quantitative analysis, planning and implementation of risk response and control. In this article, we focus on quantitative risk analysis. To assist project management students in dealing with project risks, we have developed an application in Matlab® (MCSimulRisk) that allows students to perform Monte Carlo Simulation applied to any project type simply and intuitively. Consequently, a valuable amount of time that would otherwise be wasted in project configuration can be devoted to interpreting the results. In addition, the presented tool allows modeling any type of project uncertainty and is not restricted to the aleatory uncertainty associated with the duration of the activities, which is the only type of uncertainty considered by other analysis tools available to date.

Keywords: MCSimulRisk · Monte Carlo simulation · Risk management · Uncertainty · Quantitative analysis

1 Introduction

Practical activities are an essential complement to theoretical lectures. These activities allow students to apply the theoretical knowledge acquired to solve problems or case studies, which constitutes an efficient feedback factor. Their adequate inclusion within the course syllabus allows reinforcing and applying the concepts exposed in theoretical lectures and encouraging the student's capacity for analysis and synthesis. Likewise, professors can obtain valuable information from these classes since they allow them to detect difficulties in the understanding and in the application of the theoretical concepts.

The Risk Management course, which runs throughout the first quarter of the Master's Degree in Project Management at the University of Valladolid, provides specifically theoretical knowledge on quantitative risk analysis. This theoretical knowledge is supported by practical exercises where students must solve, interpret and discuss the results obtained. There exist specific commercial software applications for Monte Carlo simulation, such as Crystal Ball [1] or @Risk [2]. These applications run as extensions of a well-known spreadsheet application. However, the experience in this subject has made us see that students spend too much time configuring the project proposed as a problem,

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 42–46, 2023.
https://doi.org/10.1007/978-3-031-27915-7_8

a time that turns out to be unproductive, taking away time dedicated to the observation and commentary on the results obtained.

This paper aims to present a tool implemented in Matlab® [3], specifically designed to facilitate the project configuration with which Monte Carlo simulation is to be performed. The application has been developed by the teachers who teach this subject. The implementation of this application as a teaching tool in class is planned for the next academic year. The results obtained from the tool provides the data that students need to solve the exercises. These results are provided in an attractive and visual fashion, including the possibility of exporting the simulation data as external files for processing in auxiliary applications. This tool eliminates unproductive time for students, allowing them to dedicate it to solving the problem and finding an explanation for the results.

The rest of the paper is organized as follows. The following section introduces the context where Monte Carlo simulation is used to perform quantitative risk analysis. Next, we show the educational tool developed, including the explanation of the results it offers. Finally, we present the conclusions of our work.

2 Risk Management

Project risk management is the practice of identifying, analyzing and proactively responding to different types of potential project risks. We understand project risk as any uncertainty type that may affect project objectives [4]. The vast majority of standards and methodologies dealing with risk management (PMBoK [5, 6], PM2 [7], Prince2 [8], ISO [9] …) include a specific process for risk assessment.

The risk assessment process can be divided into two parts. The first consists of performing a qualitative analysis to prioritize individual project risks. The second consists of performing a quantitative analysis to quantify the combined effect of the individual project risks and other sources of uncertainty on the overall project objectives [5, 6]. In this context Monte Carlo Simulation is a widespread quantitative technique that allows analyzing the impact of this uncertainty. Applying Monte Carlo Simulation allows obtaining, for example, the probability of meeting project deadlines or budget (among other possible outcomes) in the project under study [10].

The education tool presented in this paper focuses on quantitative risk analysis and uses Monte Carlo simulation as a technique for data processing.

3 'MCSimulRisk' for Quantitative Risk Analysis

'MCSimulRisk' is the name of the application developed under the Matlab® environment for the quantitative project risk analysis, using Monte Carlo simulation. The application consists of a group of functions that allow the user to obtain graphical and tabular data of the problem to be solved, interacting through menus with different options (Fig. 1).

The first part of the process consists of reading the data of the project under study. We have defined all the data characterizing the project in an external file, including the number of activities, their duration, cost (fixed and variable), the precedence relationship of each of the activities, and each of the uncertainties affecting the project objectives.

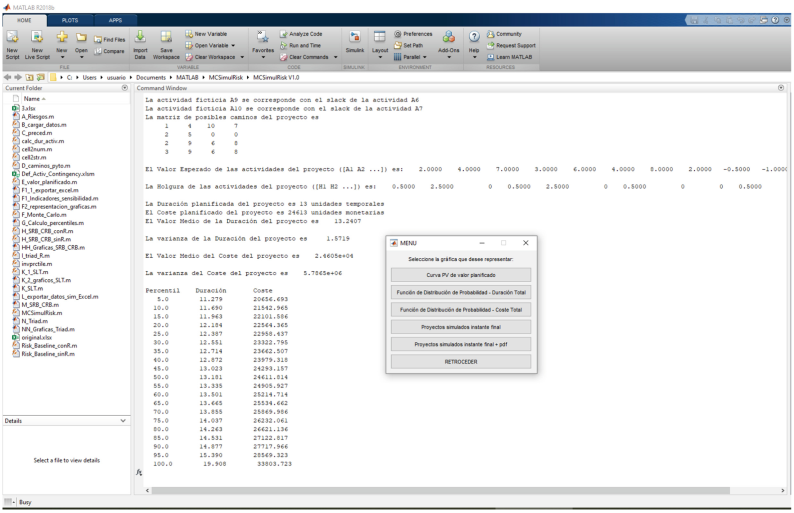


Fig. 1. MCSimulRisk working environment.

These uncertainties can be aleatory, stochastic, or epistemic, depending on how they have been assessed in the previous risk identification phase. Stochastic uncertainty - also called "event risk" - is defined as a "possible future event"; aleatory uncertainty is described by variability, meaning that there is a wide range of possible outcomes; finally, epistemic uncertainty is related to lack of knowledge [11]. This means that it could be modelled by obtaining information about the system and the environment.

For each of the risks identified, the probability of occurrence and the possible impact on the project's objectives is estimated, differentiating whether it affects the time or cost goals. Also, the activity that may be affected by the potential impact is identified.

The first result provided by 'MCSimulRisk', once the project data is loaded into the application, is to report all the possible paths deriving from the precedence relationships of the project activities. In a first step, the application calculates and represents the deterministic information of the project without considering the risks. This deterministic project information is used to represent the project Planned Value (PV) curve and to calculate the planned duration and cost of the project. Next, the application performs Monte Carlo simulation, integrating all the risks identified in the problem, to obtain the project duration and cost statistics.

'MCSimulRisk' provides the numerical data and the plots representing the probability density curves of the duration and cost output functions (Fig. 2). In addition, it provides all the data necessary for the resolution of the exercises proposed by the instructor. Moreover, the application allows extracting the activity sensitivity metrics, percentile curves for the monitoring and control of projects under uncertainty, or project duration and cost contingency values for a given probability percentile.

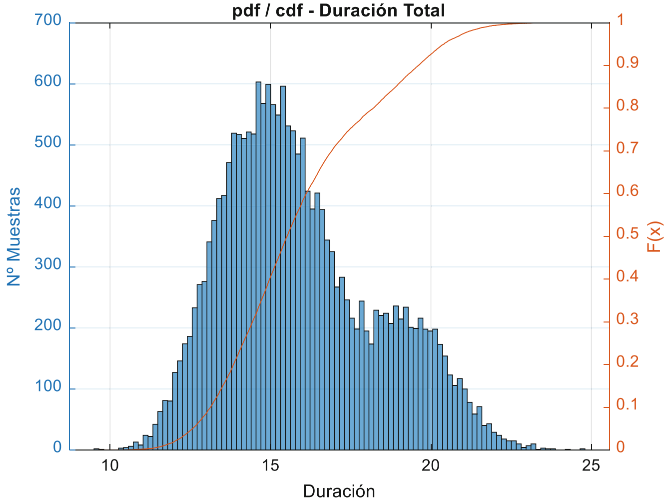


Fig. 2. Probability density curve and cumulative probability curve.

4 Conclusions

Although there are commercial tools specifically designed to perform Monte Carlo simulation for project quantitative risk analysis, our experience has shown that their use requires students to devote a great deal of time in the project setup which reduces the available time for the interpretation and the discussion of the simulation results. The application 'MCSimulRisk' bridges this gap. It fulfils a dual purpose. On the one hand, it is a tool that allows the configuration of any project type, with complex structures, even with a high number of activities, without taking up excessive configuration time for students (definition of activities, sequencing, definition of risks, and others). In this way, students can use this time to reason about the configuration parameters of the problem project and the results obtained according to the programmed parameters.

On the other hand, 'MCSimulRisk' allows the integration of any type of uncertainty beyond aleatory uncertainty, which is the only type of uncertainty considered by commercial software. Therefore, this tool allows performing a comprehensive quantitative risk analysis that integrates not only aleatory uncertainties but also stochastic and epistemic uncertainties. The results offered by the application are very varied, as we can determine the duration and cost contingency margins (depending on the chosen percentile), prioritise activities according to different sensitivity indexes, or monitor and control the project by incorporating uncertainty in the project activities, among other applications.

The software application has been used during the present course as a test version, although we intend to incorporate it in the following academic years as an educational tool for solving the risk management exercises proposed in the course.

As future lines of research, we plan to expand the application's functionalities, focused on quantitative risk assessment. The medium-term objective is also to change the programming environment, developing the same application with the Python programming language. Under this new programming environment, the possibilities for development and dissemination of the software application would be greater than under the Matlab environment.

Acknowledgments. This research has been partially financed by the Regional Government of Castile and Leon (Spain) and the European Regional Development Fund (ERDF, FEDER) with grant VA180P20.

References

1. Oracle. Crystal Ball (2022). https://www.oracle.com/es/applications/crystalball/
2. Palisade. @RISK (2022). https://www.palisade.com/risk/
3. MathWorks. MATLAB® (2022). https://es.mathworks.com/products/matlab.html
4. Hillson, D.: Managing Risk in Projects. Gower Publishing Ltd., Aldershot (2009)
5. Project Management Institute. A Guide to the Project Management Body of Knowledge: PMBoK(R) Guide, 6th edn. Project Management Institute Inc. (2017)
6. Project Management Institute, A Guide to the Project Management Body of Knowledge: PMBoK(R) Guide, 7th edn. Project Management Institute Inc. (2021)
7. European Commission. Project Management Methodology. Guide 3.0. Publications Office of the European Union (2018)
8. AXELOS. Managing Successful Projects with PRINCE2®. TSO (The Stationery Office) (2017)
9. International Organization for Standardization. ISO 31000: 2018 Risk management – Guidelines, vol. 2 (2018)
10. Rezaie, K., Amalnik, M.S., Gereie, A., Ostadi, B., Shakhseniaee, M.: Using extended Monte Carlo simulation method for the improvement of risk management: consideration of relationships between uncertainties. Appl. Math. Comput. **190**, 1492–1501 (2007). https://doi.org/10.1016/j.amc.2007.02.038
11. Hillson, D.: How risky is your project – and what are you doing about it ? PMI Global Congress Proceedings - Phoenix, Arizona, USA, pp. 1–10 (2014).

Combining Quality Indexes in the Retail Location Problem Using Generalized Linear Models

Virginia Ahedo, José Ignacio Santos, and José Manuel Galán(✉)

Departamento de Ingeniería de Organización, Escuela Politécnica Superior, Universidad de Burgos, Ed. A1, Avda. Cantabria s/n, 09006 Burgos, Spain
{vahedo,jisantos,jmgalan}@ubu.es

Abstract. The most important strategic decision in retailing is location. The process of selecting a proper place is a complex and multidimensional problem. A relevant factor that must be taken into account in the decision is the existence of an appropriate commercial ecosystem for the type of business to be located. There are different network-based quality indices to quantify the fitness of each location. In this paper, we show that the combined use of all the primary quality indices through generalized linear models and the aggregation of the information through consensus techniques allow improving the assessment of the different locations.

Keywords: Complex networks · Retail location problem · Prediction · Knowledge transfer · Classification · Pattern recognition · Generalized linear models

1 Introduction

Location is probably the most relevant strategic decision in retailing. The difficulty of completely imitating this aspect can be a critical competitive advantage [1].

The retail location problem is complex and multidimensional. Therefore, it is common practice to assess the different and varied factors that influence the decision and then to evaluate the available choices using multi-criteria decision techniques [2, 3].

An important dimension in the decision is the adequacy of the commercial ecosystem of the neighborhood for the type of activity to be located. Different network-based techniques analyze the location patterns of business categories (bakeries, bars, restaurants, etc.) to identify the level of attraction and repulsion between them [4, 5]. A set of primary quality indexes has been proposed to condense this information, each based on various assumptions about the structure of the commercial network and/or quantification of business patterns. Previous work suggests that the combination of all available metrics, given their complementary perspectives, may be the most interesting approach [6].

In this paper, we analyze the effect of using all the primary quality indices as features of Generalized Linear Models (GLM) to obtain a classifier capable of predicting the

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 47–52, 2023.
https://doi.org/10.1007/978-3-031-27915-7_9

commercial category at each location. Classifiers with high performance and predictive capacity can be used as tools to comparatively assess the suitability of each location alternative and to enhance existing location recommender systems.

2 Generalized Linear Models

Generalized Linear Models are a family of classification and regression techniques that generalize traditional linear regression models in two ways: (i) for target variables that follow some exponential distribution and (ii) by allowing the variance to be dependent on the estimated value [7]. Given the nature of the location problem, the response variable has been modeled as a multinomial distribution.

The two most important hyperparameters of this family of models are *alpha* and *lambda*. Alpha is a regularization parameter that determines the type of regularization applied to the model and varies within the range [0,1]. When it is 0, the model is known as Ridge regression (L2-regularization), while when it is 1, the model is known as Lasso (L1-regularization); for intermediate values, where both types of regularization are combined, models are known as elastic nets [8, 9]. The particular regularization value set by the model with respect to each family is given by the lambda parameter and is obtained by cross-validation. L2-regularization allows dealing with problems of high correlation between variables, while L1-regularization allows obtaining a more parsimonious and sparser model through the selection of variables.

3 Computational Experiments and Results

The computational experiments have been conducted on data from the nine provincial capitals of Castile and Leon (Spain). The dataset used is publicly available as open data [10]. The commercial information in such dataset includes the business typology of the stores listed in the Yellow Pages, their geo-location extracted from MapQuest, Open Street Map, and Google Maps, and the proximity networks (for a radius of 100 m).

The business categories are classified according to the North American Industry Classification for Small business (NAICS) [11]. This type of classification has been used in previous research on retailing [4–6, 12, 13]. The NAICS establishes 68 different business categories.

The performance metric used to compare the different algorithms is the Mean Reciprocal Rank (MRR) (see Eq. (1)) [14].

$$\mathrm{MRR} = \frac{1}{|Q|}\sum\nolimits_{i=1}^{|Q|}\frac{1}{\mathrm{rank}_i} \tag{1}$$

The MRR is a statistical metric to evaluate the quality of the response based on the position in which the correct response is placed. Typical performance measures for classification such as accuracy and/or other metrics based on the confusion matrix are not adequate for the problem. The reason is that, although the empirical assignment of a category to a certain location is evidence of the suitability of the location for the category, this does not mean that the location is not suitable for alternative categories. Given this, a high-performing algorithm is one that scores the actual empirical category high in the ranking of possible categories for the location under scrutiny, but not necessarily in the first position.

The training and evaluation process has been performed using data from eight cities as the training set and the data from the remaining city as the test set. This process has been rotated to obtain nine evaluations of each algorithm (the results for each city are shown in Fig. 1, where the color of the dots represents the MRR obtained with each algorithm for the same city). To aggregate the information of the eight cities in the training datasets, the consensus networks of relationships methodology [4] was used without applying any threshold. The lambda and alpha hyperparameters of the GLMs have been optimized by conducting 5-fold cross-validation on the training data. The results have been compared with those obtained using the six primary quality indices based on networks proposed in the scientific literature [4–6, 12, 13]. These are Quality Jensen (QJ), Quality Permutation (QP), Quality Rewiring (QR), Quality Jensen Raw (QJR), Quality Permutation Raw (QPR), and Quality Rewiring Raw (QRR).

The six quality measures are based on Eqs. (2) and (3), where X represents Jensen, Permutation or Rewiring, the three alternative ways to obtain the interaction matrices a_{ij} between the different business typologies. N represents the total number of different categories, $nei_{ij}(x, y)$ denotes the number of neighbor stores from category j around the geographical point (x, y) (assuming that (x, y) belongs to category i given a considered interaction radius), $\overline{nei_{ij}}$ indicates the average number of neighbors of category j that the stores of type i empirically have. Equation (2) states how the candidate location fits the empirical proportion, while Eq. (3) aggregates—duly weighted—the attraction and repulsion relations in the vicinity of the considered point.

$$Q_{X_i}(x, y) \equiv \sum_{j=1}^{N} a_{ij}\left(nei_{ij}(x, y) - \overline{nei_{ij}}\right) \tag{2}$$

$$Q_{X-RAW_i}(x, y) \equiv \sum_{j=1}^{N} a_{ij}\left(nei_{ij}(x, y)\right) \tag{3}$$

The results of the analyses are shown graphically in Fig. 1. The GLMs successfully combine the metrics and improve the results of any of the primary quality indices used in isolation. These results support the notion of complementarity of the different metrics and the possibility of aggregating them effectively. Better predictors allow for improved assessment of the quality of commercial ecosystems and more successful evaluation of the suitability of different locations.

However, although the results seem straightforward, it is relevant to establish the degree of confidence in the conclusions, especially given that the number of cities is limited since the data collection and analysis process is computationally expensive. For this purpose, we have used the Bayesian Signed-Ranked test [15, 16]. This test allows to establish the probability, given the available evidence, that one algorithm is better than the other or—by setting limits that determine a region of practical equivalence (rope)—that both algorithms can be considered equivalent. The results of this analysis comparing the best quality index found empirically in our data (QJR) with GLMs are shown in Fig. 2. For 10000 Monte Carlo samples, we found that the probability that GLMs are better than the best of the primary quality indices used in isolation (QJR) is close to 0.75.

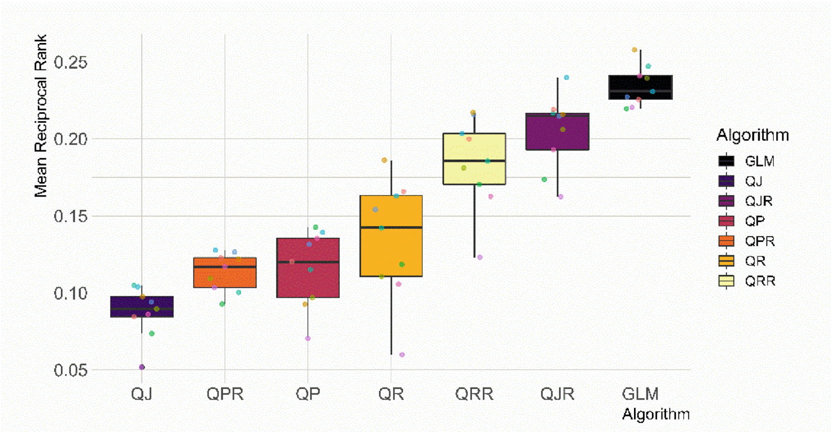


Fig. 1. Comparison of the predictive performance of the primary quality indices in isolation and that of the generalized linear models. The color of the dots represents the MRR results for each city.

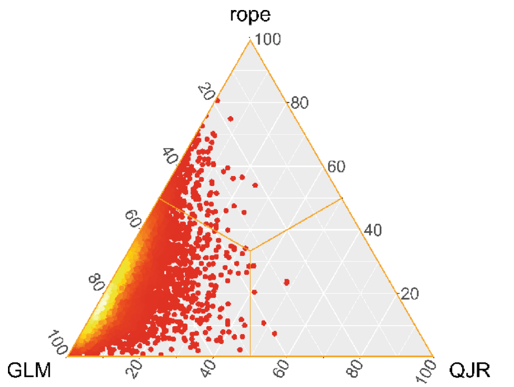


Fig. 2. Results of the Bayesian signed-rank test for comparison between algorithms. The results compare the GLMs with the best of the empirically found quality indices, the QJR. Given the evidence from the data, the probability that the GLM is better is 0.734, the probability that the QJR is better is 0.033, while the region of practical equivalence (rope) for a range [−0.01, 0.01] is 0.233.

4 Conclusions

The location problem in retailing is a very relevant problem in strategical terms, but at the same time, it is complex and multidimensional. An influential dimension in the decision is the suitability of the commercial ecosystem in the candidate neighborhood. Different quality indices based on network theory attempt to quantify this adequacy based on various assumptions. In this work, we have shown that using several sources of information from different cities, aggregated through consensus techniques, and the combination of all quality indices using generalized linear models improve the predictive performance and, consequently, the assessment of potential locations. These results suggest that the combined use of the primary quality indices aggregated by means of supervised learning techniques is a better performing approach than using them in isolation.

Acknowledgements. The authors acknowledge financial support from the Spanish Ministry of Science, Innovation and Universities (Excellence Network RED2018-102518-T), the Spanish State Research Agency (PID2020-118906GB-I00/AEI/10.13039/501100011033) and the Fundación Bancaria Caixa D. Estalvis I Pensions de Barcelona, La Caixa (2020/00062/001). In addition, we acknowledge support from the Santander Supercomputación group (University of Cantabria), that provided access to the Altamira Supercomputer—located at the Institute of Physics of Cantabria (IFCA-CSIC) and member of the Spanish Supercomputing Network—to perform the different simulations/analyses.

References

1. Zentes, J., Morschett, D., Schramm-Klein, H.: Strategic Retail Management. Gabler Verlag, Wiesbaden (2012). https://doi.org/10.1007/978-3-8349-6740-4
2. Shaikh, S.A., Memon, M.A., Prokop, M., Kim, K.S.: An AHP/TOPSIS-based approach for an optimal site selection of a commercial opening utilizing geospatial data. In: Proceedings - 2020 IEEE International Conference on Big Data and Smart Computing, BigComp 2020, pp. 295–302 (2020). https://doi.org/10.1109/BigComp48618.2020.00-58
3. Çoban, V.: Solar energy plant project selection with AHP decision-making method based on hesitant fuzzy linguistic evaluation. Complex Intell. Syst. **6**(3), 507–529 (2020). https://doi.org/10.1007/s40747-020-00152-5
4. Sánchez-Saiz, R.M., Ahedo, V., Santos, J.I., Gómez, S., Galán, J.M.: Identification of robust retailing location patterns with complex network approaches. Complex Intell. Syst. **8**(1), 83–106 (2021). https://doi.org/10.1007/s40747-021-00335-8
5. Jensen, P.: Network-based predictions of retail store commercial categories and optimal locations. Phys. Rev. E **74**, 035101 (2006). https://doi.org/10.1103/PhysRevE.74.035101
6. Ahedo, V., Santos, J.I., Galan, J.M.: Knowledge transfer in commercial feature extraction for the retail store location problem. IEEE Access **9**, 132967–132979 (2021). https://doi.org/10.1109/ACCESS.2021.3115712
7. Hastie, T., Tibshirani, R., Friedman, J.: The Elements of Statistical Learning. Springer, New York (2009). https://doi.org/10.1007/b94608
8. Tibshirani, R.: Regression selection and shrinkage via the lasso. J. Roy. Stat. Soc. Ser. B (Stat. Methodol.) **58**, 267–288 (1996). https://doi.org/10.2307/2346178
9. Zou, H., Hastie, T.: Regularization and variable selection via the elastic net. J. Roy. Stat. Soc. Ser. B (Stat. Methodol.) **67**, 301–320 (2005). https://doi.org/10.1111/j.1467-9868.2005.00503.x
10. Sánchez-Saiz, R.M., Ahedo, V., Santos, J.I., Gómez, S., Galán, J.M.: Dataset of the retailing location networks in the cities of Castile-Leon, Madrid and Barcelona (2021). http://hdl.handle.net/10259/5585. https://doi.org/10.36443/10259/5585
11. Statistics Canada Government of Canada: NAICS 2012 – 44-45 - Retail trade (2011). http://www23.statcan.gc.ca/imdb/p3VD.pl?Function=getVD&TVD=118464&CVD=118465&CPV=44-45&CST=01012012&CLV=1&MLV=5
12. Gómez, S., Jensen, P., Arenas, A.: Analysis of community structure in networks of correlated data. Phys. Rev. E Stat. Nonlinear Soft Matter Phys. **80**, 16114 (2009). https://doi.org/10.1103/PhysRevE.80.016114

13. Jensen, P.: Analyzing the localization of retail stores with complex systems tools. In: Adams, N.M., Robardet, C., Siebes, A., Boulicaut, J.-F. (eds.) IDA 2009. LNCS, vol. 5772, pp. 10–20. Springer, Heidelberg (2009). https://doi.org/10.1007/978-3-642-03915-7_2
14. Craswell, N.: Mean reciprocal rank. In: Liu, L., Özsu, M.T. (eds.) Encyclopedia of Database Systems, pp. 1703–1703. Springer, Boston (2009). https://doi.org/10.1007/978-0-387-39940-9_488
15. Carrasco, J., García, S., Rueda, M.M., Das, S., Herrera, F.: Recent trends in the use of statistical tests for comparing swarm and evolutionary computing algorithms: practical guidelines and a critical review. Swarm Evol. Comput. **54**, 100665 (2020). https://doi.org/10.1016/j.swevo.2020.100665
16. Benavoli, A., Corani, G., Demšar, J., Zaffalon, M.: Time for a change: a tutorial for comparing multiple classifiers through Bayesian analysis. J. Mach. Learn. Res. **18**, 1–36 (2017)

Identification and Prioritisation of Professional Transitions in Manufacturing Operations in the New Context of Industry 4.0

José Alberto Eguren[1], Unai Ziarsolo[2], Iñigo Mugica[2], Iñigo Larrea[3], and Imanol Olaizola[1](✉)

[1] Faculty of Engineering, Mechanics and Industrial Production, Mondragon Unibertsitatea, Loramendi 4, 20500 Mondragon, Gipuzkoa, Spain
iolaizolaa@mondragon.edu

[2] CIFP Miguel Altuna, Aumategi Bidea, 2, 20570 Bergara, Gipuzkoa, Spain

[3] MONDRAGON Corporacion, Pº Jose Mª Arizmendiarrieta nº 5, 20500 Mondragón, Gipuzkoa, Spain

Abstract. This paper examines the results from the identification and prioritisation phase of professional transitions towards the requalification of digital job operators. It was developed as part of the 'Learning Solutions for Employability' project, which seeks to develop and test learning solutions to improve, accelerate and make lifelong learning processes more sustainable, as well as to support people with low employability in their professional transitions within the MONDRAGON Corporation. The analytical process was applied to seven companies from different industrial divisions of the MONDRAGON Corporation. The competencies identified mainly correspond to the acquisition of basic digital skills to use new tools. These mainly affect approximately 1,800 people integrated into the groups with the highest impact of digitalisation, such as assembly and production line operators.

Keywords: Digitalisation · Manufacturing · Industry 4.0 · Employment · New skills

1 Introduction

The fourth industrial revolution, also called Industry 4.0, has undergone a transformation in industrial processes to make more efficient and productive. This transformation requires a major shift in workforce skills, organisational structures, leadership mechanisms and corporate culture [1]. However, it has resulted in a decreasing demand for low-skill jobs, and presents greater potential for automation, as well as operations that rely on pre-specified, routine physical activities, data collection and processing [2, 3]. In this context, job automation is increasing, and new jobs are simultaneously emerging that require new digital skills. For all these reasons, to prepare for these imminent changes and to ensure their productivity and competitiveness within the Industry 4.0 era, industrial companies' staffs must develop and adapt to new skills. Developing these

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 53–58, 2023.
https://doi.org/10.1007/978-3-031-27915-7_10

new competencies involves not only attracting, recruiting and developing the workforce of the future, but also retraining current employees through training programmes and redesigning work processes to reduce job mismatches and reduce incongruence between jobs, skills and employees [4]. Numerous studies have been conducted in an attempt to address the issue of the number of jobs that could be displaced by substituting human work with machines. [1, 2]. These studies forecast that around 30–40% of jobs in advanced economies will be at risk within the next 15–20 years, and that the need for manual and physical skills, as well as basic cognitive skills, will decrease, but that the demand for technological, social and emotional skills will increase [6]. There are numerous studies on how these new competencies may be developed for the new Industry 4.0 context. It is noteworthy that the McKinsey study identified 56 skills grouped into 4 general groups: cognitive, interpersonal, self-leadership and digital competencies [6].

Table 1. Categories of new skills used in the study (Adapted [6, 7])

Categories	Skills groups	Foundational skills
General digital skills	Digital fluency and citizenship	1. Digital literacy 2. Digital collaboration 3. Digital learning 4. Digital ethics
	Software use and development	1. Programming literacy 2. Computational and algorithmic thinking 3. Data analysis and statistics
	Understanding digital systems	1. Data literacy 2. Cybersecurity literacy 3. Smart systems 4. Tech translation and enablement
Specific digital skills	Industry 4.0 technologies	1. Big data-driven quality control 2. Robot-assisted production 3. Self-driving logistics vehicles 4. Production line simulation 5. Smart supply networks 6. Predictive maintenance 7. Machines as a service 8. Self-organised production 9. Additive manufacturing 10. Augmented work

In the case of this study, as shown in Table 1, the focus is placed on the development of general digital skills that are related to general behaviours towards the aforementioned systems and the specific digital skills that are related to the knowledge and use of Industry 4.0 technologies [7]. Given the context of growing business complexity and digital transformation, it is anticipated that the MONDRAGON Corporation companies will need to requalify their staffs with a higher risk of digital exclusion to adapt to digital transformation requirements of their productive processes. This paper demonstrates the results from the identification and prioritisation phase for professional transitions towards the requalification of digital job operators. It was developed as part of the 'Learning Solutions for Employability' project, which seeks to develop and test learning solutions to improve, accelerate and make lifelong learning processes more sustainable, as well as to support people with low employability in their professional transitions within the MONDRAGON Corporation.

2 Methodology

The methodology followed is based on the one developed by Behrendt [6], which states that to address the integration of digitalisation skills and competencies throughout the organisation, it is necessary to have a holistic vision in which businesses, organisations and technologies are integrated. To this end, the research team has organised work sessions within the companies analysed in which those responsible for human resources, IT, production and industrial directors have participated.

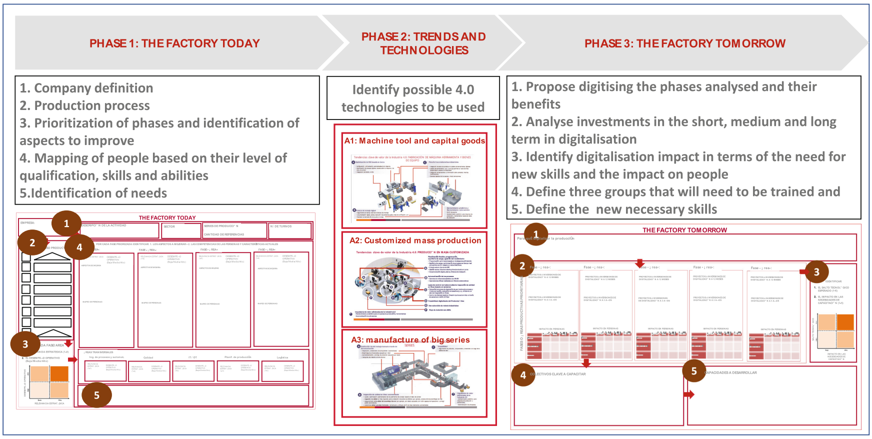


Fig. 1. Methodology applied in field work

As can be seen in Fig. 1, the methodology used is structured into three phases for which specific templates have been developed to collect information based on the questions to be answered.

Phase 1: The factory today: The objective of this phase is to identify the characteristics of the company today. To do this, first, the type of product manufactured was identified, as well as the sector to which the company belongs. Subsequently, the critical phases of the production process were identified through a multicriteria analysis based on the strategic level of the phase analysed and its capacity for improvement. Afterwards, workers were mapped for each phase identified above based on their level of training and their competencies and skills. Finally, the opportunities for improvement or the needs of the process analysed were identified.

Phase 2: Trends and technologies: In this phase, the possible Industry 4.0 technologies to be used are identified and analysed. To this end, the three production archetypes and the application of Industry 4.0 technologies proposed by the company have been taken as a basis in which Industry 4.0 technologies are identified for the three most common archetypes in industrial processes: A1: machine tool and capital goods, A2: customised mass production and A3: manufacture of big series [9].

Phase 3: The factory tomorrow: In this phase, the new profiles and skills to be developed are identified. First, a reflection is made concerning why it is necessary to digitalise the process based on the information previously collected. Then, an analysis of the investments in digitalisation in the short, medium and long terms is conducted. Next, a multi-criteria matrix is used to analyse the impact of digitalisation on people. Finally, the groups that need to acquire new skills, as well as the new skills to be developed, are identified.

3 Results and Discussion

The analytical process was applied to seven companies (C) from different industrial divisions of the MONDRAGON Corporation, and it was conducted in November and December 2021. Below is a summary of the companies' most important characteristics, digitalisation strategies, digital skills identified and the profile of affected personnel:

C1. Medical devices sector: The company must meet strict quality standards and approval processes, as well as ensure products' traceability to protect their monitoring throughout their life cycle. The main digitalisation strategy to be addressed is the development of digital supports to facilitate tasks and monitor management and operational processes. The digital competencies identified for development correspond to the acquisition of basic digital skills and the development of tools and techniques to speed up training processes. Future retraining needs now affect the people integrated into the warehouse and production operator groups.

C2. Electrical appliance auxiliary components: The company has two lines of business with a wide variety of machines, with maintenance of installations being a key variable when measuring the efficiency of the business. The main digitalisation strategy is the development and implementation of a preventive and corrective maintenance management system for the company's facilities. The digital competencies identified for development correspond to the acquisition of skills in data understanding and management for technicians and managers with the aim of speeding up and improving their use. Future retraining needs have affected the people integrated into maintenance technician and process manager groups.

C3. Automotive auxiliary components: The company focuses on manufacturing varied and large series of components, and it faces increasing market demands in terms of quality, delivery time and service. The company has a constant need to increase its productivity and flexibility and overcome its products' strict homologation processes. The main digitalisation strategy should be aimed at developing digital jobs in the manufacturing sector to facilitate tasks and monitor processes. The digital competencies identified for development correspond to the acquisition of competencies in the development of digital skills and abilities, as well as to the acquisition of basic knowledge and habits in the use of digitalisation technologies, which allow operators to efficiently manage manufacturing areas. Future retraining needs affect the workers integrated into the groups of assembly and production operators.

C4. Automated capital goods: The company's products and markets create the need for very flexible production planning. Product customisation, lack of foresight and short delivery times make planning a complex task. Principal digitalisation strategies should be aimed at developing digital support to facilitate tasks and monitor management and operational processes. The digital skills identified for development correspond to line operators' acquisition of basic digital skills. Future requalification needs affect the people integrated into the groups of assembly line workers.

C5. Cold equipment manufacturing company: The company in question has two business lines: one corresponding to the manufacturing of standard products and the other to the manufacturing of customised products. The typology of products and markets makes for very flexible production planning necessities. The main digitalisation strategy should be aimed at implementing and deploying an enterprise resource planning (ERP) system as a basis for applying solutions to improve operational efficiency. Digital competencies are those related to the acquisition of digital skills for the implementation and deployment of the ERP system and basic digital skills for using new tools. Future requalification needs affect the workers integrated into groups of planning technicians and assembly line workers.

C6. Machinery manufacturing company: This company manufactures customised machinery with a high level of standardisation and small series production. As for the main digitalisation strategies, they should be aimed at the development of digital support to facilitate tasks and monitor the management and assembly operating processes. The digital skills identified for development correspond to the development of basic and general digital skills. Future requalification needs affect the people integrated into groups of assembly operators.

C7. Special automatic machinery: This company manufactures special machinery adapted to the manufacture and assembly of products for different sectors. Each project is usually different; thus, workers constantly adapt to market requirements. The great challenge facing this company is the need to increase the manufacturing efficiency of its special, custom-made machines'. For this purpose, special attention is paid to project management and decision-making among the project team. The main digitalisation strategy should be aimed at creating digital jobs in which it would be possible to track assembly times and data in real time for subsequent data analysis. The digital skills identified for development correspond mainly to the development of specialist profiles for the use of digital tools and support for project management and the assembly process. Future requalification needs affect the people integrated into groups of assembly workers and project managers.

4 Conclusions

A simple method was designed and applied that to allow for the identification and prioritisation of professional transitions for the requalification of operators of jobs affected by digitalisation processes. The skills to be developed and the groups to be requalified have also been identified. The competencies identified mainly correspond to the acquisition of basic digital fluency skills for using new tools. These mainly affect approximately 1,800 people integrated into groups with the highest impact of digitalisation, such as assembly and production line operators. Furthermore, the work has allowed for the identification of the typology of courses and training programmes to be developed during the project's second phase.

Acknowledgements. The authors would like to thank the Spanish Confederation of Social Economy (CEPES), the European Social Fund of the European Union and Lagun Aro EPSV for funding received for the 'Learning Solutions for Employability' project.

References

1. van Laar, E., van Deursen, A., van Dijk, J., de Haan, J.: Measuring the levels of 21st-century digital skills among professionals working within the creative industries: a performance based approach. Poetics **81**, 101434 (2020). https://doi.org/10.1016/j.poetic.2020.101434
2. Benedikt Frey, C., et al.: The future of employment: how susceptible are jobs tu computerisation? Oxford Martin Programme on Technology and Employment (2013)
3. Manyika, J., et al.: MGI A future that works. McKinsey Global Institute (2017)
4. Ustundag, A., Cevikcan, E.: Springer Series in Advanced Manufacturing Industry 4.0: Managing the Digital Transformation (2018). https://doi.org/10.1007/978-3-319-57870-5
5. Freddi, D.: Digitalisation and employment in manufacturing. AI Soc. **33**(3), 393–403 (2017). https://doi.org/10.1007/s00146-017-0740-5
6. Dondi, M., Klier, J., Panier, F., Schuert, J.: Defining the skills citizens will need in the future world of work. Mc Kinsey & Company (2021)
7. Lorenz, M., Russmann, M., Strack, R., Lasse Lueth, K., Bolle, M.: Man and Machine in Industry 4.0: How Will Technology Transform the Industrial Workforce Through 2025? The Boston Consulting Group (2015)
8. Behrendt, A., de Boer, E., Kasah, T., Koerber, B., Mohr, N., Richter, G.: Leveraging Industrial IoT and advanced technologies for digital transformation. McKinsey & Company (2021)
9. Schmitz, C., Tschiesner, A., Jansen, C., Hallerstede, S., Garms, F.: Industry 4.0. Capturing value at scale in discrete manufacturing. Mckinsey & Company (2019)

An Iterated Prisoner's Dilemma Tool to Play and Learn Inside and Outside the Class

Pablo José Lorente[1] and María Pereda[1,2(✉)]

[1] Grupo de Investigación Ingeniería de Organización y Logística (IOL), Departamento Ingeniería de Organización, Administración de empresas y Estadística, Escuela Técnica Superior de Ingenieros Industriales, Universidad Politécnica de Madrid., C/ José Gutiérrez Abascal, 2., 28006 Madrid, Spain

maria.pereda@upm.es

[2] Grupo Interdisciplinar de Sistemas Complejos, Madrid, Spain

Keywords: Prisoner's Dilemma game · Game theory · Education · NetLogo · Simulator

1 Introduction

The information age in which we live presents us with a dynamic and overstimulated environment that inevitably affects the way we learn and impart knowledge. Teaching and studying human cooperation is no exception. It is a field that continues to intrigue and amaze scientists from many disciplines and is also facing the challenge of adapting its teaching to the new times. It is common to find game theory and decision theory (operations research) subjects in the curricula of engineering degrees. In this line we find new tools such as games or simulators, which allow us to energize classes and learn by doing/playing. In this paper we present a tool to complement the study of the Iterated Prisoner's Dilemma game, which can be used in the classroom and outside the classroom. The tool that accompanies this article is available for download at the link that accompanies this paper.

2 Theoretical Background

In Game Theory and the study of human cooperation is a well-known practise to study the strategic interactions using simplified representations of reality, which are called *games*. One of those is the Prisoner's Dilemma game, widely used to study cooperation under the selfish interest of non-cooperative individuals, the *free riders*, that benefit from the cooperative actions of others. Designed in the 50's by Flood and Dresher and provided with a narrative with prisoners by Tucker [1], the game is a classical in the study of human cooperation to study many real-life situations involving strategic interactions, such as pollution and the climate catastrophe, the payment of taxes, the use of masks during a pandemic, doping in sports, etc. In the game, the best social outcome is obtained

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 59–63, 2023.
https://doi.org/10.1007/978-3-031-27915-7_11

when all individuals cooperate, but each individual is tempted to not cooperate (*defect*) and benefit from others. The payoff matrix of the game in its normal form is shown at Table 1. The game has to meet the condition $T > R > P > S$ to be a Prisoner's Dilemma game.

The game is called the n-people Iterated Prisoner's Dilemma game (IPD) if it is played more than once among several individuals, so they interact several times and can learn from the past. In the iterated version, the condition $2R > T + S$ also applies, to avoid cycles of alternating cooperation and defection that rewards mutual cooperation.

Table 1. Payoff matrix of the Prisoner's Dilemma Game. Row player payoffs shown.

		Column player	
		C	D
Row player	C	R	S
	D	T	P

The iterated version of the game is particularly interesting because of the dynamics that emerge as individuals gain experience from previous interactions. Empirical studies have shown that individuals are influenced by their previous bad experiences, so that they cooperate less frequently. The first study on strategies in the Iterated Prisoner's Dilemma was carried out by scientist Robert Axelrod in 1979 [2]. Axelrod organized a IPD tournament and invited scientists from several academic disciplines to send their strategies for the game and published the results in his seminar book book *The evolution of cooperation* [4]. From the book was learnt that, although the optimal strategy for the IPD is not fixed, nicer strategies do better. And so does the winning strategy *tit-for-tat* from Anastol Rapoport. This strategy can be studied by using our tool (see next section).

Although there are other software proposals to study the IPD [3–7], our tool present the following advantages and characteristics: the strategies for each individual in a population of several sizes can be defined; there are two different game modes to use the tool, "experimental mode" that mimics a real experiment of human cooperation with virtual people, and "strategy mode" that allows the user to play one classical predefined strategy during the whole game (as taking part of Axelrod's tournament); the tool provides visualization of the evolution of the payoffs and a representation of the population that make the results of the game easier to understand and more visual appealing (see also experimental research on feedback [8]); the tool is programmed in an widely-used open-source programming language, Netlogo [9]; the simulator is distributed under an open-source license and can be easily extended to define personalized strategies for the game (as if you were taking place in the famous Axelrod's tournament); and it is created by a student for other students.

3 Description of the Tool

In this section we present the *iterated Prisoner's Dilemma tool* and how to use it. The tool is available to download at GitHub (https://github.com/pablolorente/IPD-Simulator) (both in Spanish and English) and can be directly open and used in NetLogo [9].

The design of the game in the tool is structured as a well-mixed population, i.e., all individuals have the same probability of playing with each other since the game is played in randomly formed pairs. The game is played repeatedly with newly formed pairs each round (iteration).

As mentioned before, the user can play in two ways or modes:

- Experimental mode: the user makes a decision each round after receiving the last round feedback (the decision of your opponent in the last round, your payoff in the last round, your cumulative payoff). This mode mimics a real behavioural economics experiment
- Strategy mode: use the same strategy during the whole game. The user can choose among a set of six classical IPD strategies from the literature:
  - *Always cooperate*: this strategy cooperates in any interaction, thus representing the so-called full cooperator.
  - *Always defect*: opposed to the full cooperator, this strategy impersonate the full defector o free rider, who never cooperates.
  - *Random*: each round a randomly chosen decision is taken: cooperate or defect.
  - *Friedman*: in this strategy the individual starts cooperating in every round, but as soon as its opponent defects, it takes revenge and never cooperates with that opponent again.
  - *Tit-for-Tat*: cooperate on the first iteration and in the subsequent rounds copy what her opponent did on the previous interaction with this opponent (ref. [4]).
  - *Pavlov*: cooperate if the previous interaction with that opponent was beneficial to her, that is, if both the opponent and she did the same thing (both cooperated or defected). Otherwise, she defects. Initially cooperate. This strategy is also called *win-stay, lose-switch.*

Figure 1 shows the interface of the tool, with four different sections which are marked with numbers surrounded by circles in the figure to support the explanation: setup (number 1), configuration (numbers 2 to 4), participant decisions (number 5), and game evolution (numbers 6 and 7).

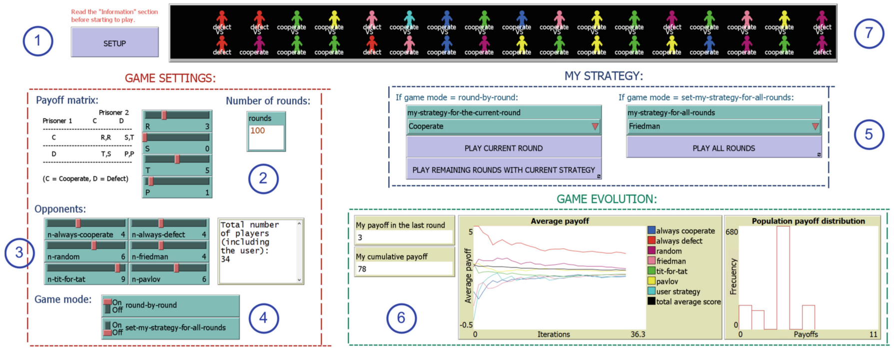


Fig. 1. Interface of the tool. Numbers represents different sections mentioned in the text.

4 How to Use It

The first thing to do to set up a game is defining the population. Since the game is played in pairs, an even population (including the user) need to be configured. To do so, section (3) in the interface (see Fig. 1) provides the user with six sliders to define the number of opponents in the game playing each of the six strategies in the game (the same ones that those for the "strategy mode"). The tool will show an alert in the population is not an even number.

Then, the payoffs of the game need to be defined. The tool has some predefined values that can be tunned using sliders (section 2). The tool will also ensure that the condition $T > R > P > S$ is met through a warning. The number of rounds for the game is also configured in section (2).

The game mode is selected in section (4) using selectors (see Fig. 1). And lastly, the user has to play the "setup" button at (1) to apply all the configurations.

Once the game has started, in the first round the player will have to decide their strategy for the whole game using the drop-down menu "my-strategy-for-all-rounds" (if playing under "strategy mode") or to take her first decision using the drop-down menu "my-strategy-for-the-current-round". This is done in section (5). Then, she will click the "play current round" or "play remaining rounds with current strategy" in "experimental mode", or "play all rounds" for the "strategy mode", which will advance the game until the last round will showing feedback round by round (the speed of the visualization can also be tuned in NetLogo by means of a slider on top of the interface).

Round by round, the feedback for the game is shown at the monitors in section (6) and (7). Firstly, in (6) the user can see her payoff in the last round and her cumulative payoff. She can complement this information with the central monitor in (6) that shows the evolution of her average payoff (in cyan), the average payoff of the population (in black) and the average payoffs of the other players grouped by strategy types (in other colours). The payoff distribution of the population each round can also be seen at (6) right side. At each round, the *n/2* pairs playing each PD are represented in section (7) with colours according to their strategy, same colours as in section (6), and their current decision (cooperate/defect) is shown in text.

5 Conclusions

In this work, we have presented a simulation tool to be used in the class and also outside the class, for example, as an experimentation tool for students. It can be used in two modes: "experimental mode", to experience a semi-experimental session with other virtual opponents; and "strategy modes" to learn from well-known strategies.

The feedback of the tool after each game round includes the distribution of payoffs. This novel information can be used to complement traditional explanations of the IPD with the latest research on feedback and framing of games [8] showing that cooperation in increased when providing people with information about the distribution of decisions in the last round.

The code of the tool is available online both in Spanish and English.

References

1. Tucker, A.W.: The mathematics of tucker: a sampler. Two-Year Coll. Math. J. **14**(3), 228–232 (1983)
2. Axelrod, R.M., Hamilton, W.D.: The Evolution of Cooperation. Basic Books, New York (1984)
3. Repeated Prisoner's Dilemma Applet. https://www.mikeshor.com/gametheory/Mike/applets/PDilemma/. Accessed 25 Jan 2022
4. Game Theory 101: The Prisoner's Dilemma & Iterated Prisoner's Dilemma Game Simulation. https://webupon.com/blog/iterated-prisoners-dilemma-game/. Accessed 25 Jan 2022
5. Wilensky, U.: NetLogo PD N-Person Iterated model. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL (2002). https://ccl.northwestern.edu/netlogo/models/PDN-PersonIterated
6. Bodo, P.: In-class simulations of the iterated prisoner's dilemma game. J. Econ. Educ. **33**(3), 207–216 (2002)
7. Axelrod Python library. https://axelrod.readthedocs.io/en/stable/index.html. Accessed 25 Jan 2022
8. Pereda, M., Tamarit, I., Antonioni, A., et al.: Large scale and information effects on cooperation in public good games. Sci. Rep. **9**, 15023 (2019)
9. Wilensky, U: NetLogo. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL (1999). http://ccl.northwestern.edu/netlogo/

Requirements for the Development of a Collaboration Platform for Competency-Based Collaboration in Industrial Data Science Projects

Marius Syberg[1(✉)], Nikolai West[1], Jörn Schwenken[1], Rebekka Adams[3], and Jochen Deuse[1,2]

[1] Institute of Production Systems, Technical University Dortmund, Leonhard-Euler-Str. 5, 44227 Dortmund, Germany
marius.syberg@ips.tu-dortmund.de
[2] Centre for Advanced Manufacturing, University of Technology Sydney, 11 Broadway, Ultimo, NSW 2007, Australia
[3] NEOCOSMO GmbH, Science Park 2, 66123 Saarbrücken, Germany

Abstract. The ongoing digitization of online learning resources has led to a proliferation of collaboration platforms for specific areas of application and disciplines. Simultaneously, the need for collaboration in the field of data analysis and knowledge management increases, especially for manufacturing companies. In this paper, collaborative and competency-based requirements for applying industrial data analytics are derived into tangible specifications for implementing a collaboration platform. The currently absent requirements of Industrial Data Science (IDS) projects are determined and then translated into platform-specific functions. Using the practical implementation of an ongoing research project, the defined requirements are transformed into features and applied in an online platform. The validation in a system of dynamic value networks serves to confirm the practical suitability of the specified requirements. The innovation of the platform is its clear focus on IDS project practitioners, who are typically comprised of several different domains. They often use a variety of analytics tools and aim for long-term use of deployed solutions. A pilot implementation of the developed platform is available online and additionally serves to validate the platform suitability.

1 Fundamentals

The extensive digitization of industrial production is placing Data Science at the center for all companies that are aligning themselves in a modern and productive way. A data science project usually follows the same schematic process and has a reoccurring character in its structure [9]. Caused by this iterative character the roles of such projects are often very similar. To accomplish different tasks with respect to the common goals in IDS, Mazarov et al. [8] define roles for those tasks. In order to use these roles efficiently in the projects, it also seems appropriate to fragment the analysis activities themselves into analysis modules, since many processes are recurring. These can be built up and

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 64–69, 2023.
https://doi.org/10.1007/978-3-031-27915-7_12

divided using the Process Chain of IDS [3]. The different modules need to be developed in the phases of *access, analysis* and *application.*

Another way of enhancing the implementation of IDS projects in SMEs is working with other enterprises, which we refer to as *collaboration.* In contrast to the term *cooperation*, especially collaborating partners achieve results that cannot be directly attributed to any of them [2, 7]. Collaborative work initially supports the joint development of knowledge. Here, for example, collaboration helps to overcome the challenges of heterogeneous system landscapes [7]. It also reduces the risks and barriers of high investments for an SME [13]. Only sufficient collaboration between said roles and between industrial SMEs as users as well as system providers leads to an appropriate knowledge management and short development cycles. Coordination, communication and organization are mandatory prerequisites to ensure effective collaboration at these levels.

In addition to collaboration, *competence development* is a key factor for SME when using IDS. Collaboration helps to develop knowledge in a subject area. At the same time, however, an individual, targeted design of the *competence development* process is important [1]. Digitization as such is on the one hand the reason why competencies must be developed, but at the same time it is also a tool that can be used for this competence development process [1]. Due to the major changes in the context of digitization, the competence profiles of employees need to be further developed at various levels. In the context of IDS, the recognition, encouraging and securing of technology- and data-oriented competencies as well as process-, customer- and organization-oriented competencies should be highlighted as essential areas [4]. The use of digital technologies is effective for promoting competencies if they follow the principles of situated learning [10]. To additionally support knowledge transfer, user-activating elements are another crucial factor of success by increasing the effectiveness of learning activities, individual participation and overall motivation [6].

2 Requirements for a Collaboration Platform for IDS

The fulfillment of these requirements makes a platform an enabler for successful data science projects in SME. However, no requirements models can be found in the literature for a collaboration platform specifically in the field of IDS. Therefore, additional models were referred to that have been developed for learning or collaboration platforms from other areas or with different focuses. The requirements in the following chapter were developed out of four directions.

General Requirements. Broken down, it must be possible on the corresponding platform solution to carry out data analyses, to develop competencies in a targeted manner and to collaborate with one another. First of all, the *technical infrastructure* for the Data Analysis itself, but also for learning and collaborating on the platform has to be implemented. This also relates to the requirement for *individualization.* Although data analysis projects have an iterative and always similar procedure, it is crucial for the success of the projects in SMEs that the individual problems are actually solved. Additionally, *accessibility* and *security* must be guaranteed as a basis. A*ccessibility* means that the platform must be usable by as many SMEs as possible. It must be able to integrate it in a systemically simple way, download data and results as well as store data. *Security* includes the safety of personal and company-specific data before, during and after the analysis and learning processes in relation to up-/download and storage (see Table 1).

Table 1. General requirements for a competency-based collaboration plattform.

Requirement	Description
Individualization	User individual choice of contents; Company individual choice of contents; Individual assistance systems
Technical infrastructure	Powerful backend; Intuitive user interface; Execution of analysis directly in the system
Accessability	Access for many users with different technical prerequisites; general possibility to integrate in IT infrastructure or use as open cloud service, Upload, download and store data
Security	Safety of personal and company specific data; Following international legal requirements

IDS Specific Requirements. The requirements for a collaboration platform for Industrial Data Science are based on the FURPS Model and extended by additional aspects [5]. The *functionality* requirement initially includes the fragmentation of the analysis process into modules that must be reusable, be configurable and representable in different ways. For *usability*, modules have to be developed for all phases of an IDS project, which have to be related to the cases users face in industrial production. In this approach, *Reliability* means that a certain amount of pre-processing of the data as well as preparation of the analysis process is handled technically so that the necessary data quality is achieved. *Performance* is technically achieved through a high-performance server environment as part of a cloud solution and content-wise by linking the analysis area with competence development in a proficient manner. *Supportability* is ensured by the collaborative approach of the platform, appropriate administration and technical infrastructure (see Table 2).

Table 2. IDS specific requirements, based on the FURPS Model [5].

Requirement	Description
Functionality	Fragmentation of analysis process; Configurability; Use of results in other environments
Usability	Creating modules for all phases of an IDS Project; Selection and creation of modules by users; Documentation
Reliability	Preprocessing data and Preparation of analysis to ensure Data Quality [12]
Performance	High performance analytic environment (cloud-based); Linkage to competence development
Supportability	Secured by platform approach itself; Structured database, up- and download of data and results; technical problem support

Collaboration Requirements. The collaboration-specific requirements result directly from the fundamentals [2, 7, 13]. Thus, the platform gains value if you make your individually created and customized modules available to other users again. To reinforce their use, the platform needs to enable intuitive *communication*. The platform must contain features in the form of forums, comment options, and chat functions to encourage an exchange between users. In addition, *information* is an important requirement. In order to keep users up to date on such a current and changing topic as data science, feed functionalities or the implementation of a Wiki are helpful that present general news and changes to modules or learning content that are of interest to users in a transparent and up-to-date manner (see Table 3).

Table 3. Collaboration specific requirements [2, 7, 13]

Requirement	Description
Communication	Features to encourage an exchange between users (Forum, comment options, chat)
Information	Keep users on current state of Data Science and their projects/learning (e.g. information feed, wiki)

Competence Development Specific Requirements. For the success of the concept, there are specific requirements in the area of multidisciplinary competence development for Industrial Data Science. *Content efficiency* is ensured by a close link to the existing role concepts for IDS projects. Content-related learning modules must be developed or integrated externally that teach data science as such in an industry-oriented form. In the process, an understanding of the methods themselves must be taught, but also the procedure based on the procedure models (CRISP-DM, Process Chain of IDS). In addition, the functionality of the platform and its modules must be taught in order to use the features efficiently. The second requirement here is *learning support*. According to the literature, different concepts are helpful to support the learning success. Different approaches in the area of gamification, the use of different media (text, video) as well as progress reports, tests and certificates should ensure learning results. Focused on the intended role and based on the user's initial level, the user's learning path, which consists of targeted learning modules, is to be recommended (see Table 4).

Table 4. Requirements for competence development of IDS projects [1, 4, 10]

Requirement	Description
Content efficiency	Develop knowledge in Data Science Methods and Algorithms, Data Science Procedure Models and Using the Platform properly
Learning support	Ensure targeted learning by determining users initial level, using Gamification, different media, awarding and certification

3 Validation of the AKKORD Work & Learn Platform

In the AKKORD project, the so-called 'Work & Learn Platform' is being developed in the style of a digital workplace based on the NEOCOSMO platform PIIPE in accordance with these requirements. It is described in detail on the projects homepage [11]. The collaborative analyses are capsuled on the basis of the RapidMiner software. The backend is designed modularly and is created and managed by the project partners VPE, PDtec, CONTACT and ARENDAR. Within the AKKORD project, the data science software RapidMiner is used to create numerous modules corresponding to the phases of the Process Chain of IDS available for all platform users. The developed platform in AKKORD fulfills a wide range of said requirements. The basic requirements for making the platform *accessible* and *secure* are met. The ongoing validation of the platform will show to what extent adaptations and extensions in the form of interfaces are still necessary. However, the browser-based approach is initially promising for *accessibility*. The technical infrastructure is based on a preexisting system (PIIPE), and at the same time functions are available for administration in general as well as for competence development. Whether the *administration* and *infrastructure* also enable the successful use of the analysis modules cannot be evaluated at the current time, but the requirements are structurally met. IDS *specific* requirements are met by the modular structure of the analyses based on RapidMiner as well as the implementation in the collaboration platform. The communication functions, the profile management, and also the functionalities enable targeted *collaboration* on the platform. With regard to *competence development*, the requirements of content efficiency and learning support are also satisfied by the high diversity of the delivered content and the implemented user-activating elements in the course area of the platform, mainly developed by project partner BtF. In the final phase of platform development, it appears to make sense to add project management functionalities in the area of collaborative data analysis, as these already function in the learning area.

4 Conclusion

Competence development and collaboration are two key factors for SME to solve problems with IDS. Digitization requires this effort, at the same time it enables the design of a digital solution. There are various requirements for such a platform that supports companies in managing IDS projects. These requirements are met by the Work & Learn platform developed in the AKKORD research project. In the last phase of the project, the final part of the integration and validation with additional users will take place, resulting in final adjustments. The achieved results are already promising that the platform will provide support to all companies, especially SME, in IDS projects. Through it, user companies are able to create a network, build up competencies and carry out targeted data analyses with a low threshold. There is even potential in the development of new business models through the selected approach from the area of the platform economy, if network effects are used accordingly.

References

1. Bauer, W., Dworschak, B., Zaiser, H.: Weiterbildung und Kompetenzentwicklung für die Industrie 4.0. In: Vogel-Heuser, B., Bauernhansl, T., ten Hompel, M. (eds.) Handbuch Industrie 4.0 Bd.1, pp. 125–138. Springer, Heidelberg (2017). https://doi.org/10.1007/978-3-662-45279-0_36
2. Briggs, R., de Vreede, G.-J., Nunamaker Jr, J.F.: Collaboration engineering with ThinkLets to pursue sustained success with group support systems. J. Manag. Inf. Syst. **19**, 31–64 (2003)
3. Deuse, J., West, N., Syberg, M.: Rediscovering scientific management. The evolution from industrial engineering to industrial data science. Int. J. Prod. Manag. Eng. **10**(1), 1–12 (2022). https://doi.org/10.4995/ijpme.2022.16617
4. Deutsche Akademie der Technikwissenschaften; Herbert Utz Verlag: Kompetenzen für Industrie 4.0. Qualifizierungsbedarfe und Lösungsansätze (Competencies for Industry 4.0. Requirements for Qualitifcations and Solutions). acatech Position. Herbert Utz Verlag GmbH, München (2016)
5. Grady, R.B., Caswell, D.L.: Software metrics. Establishing a company-wide program. Prentice-Hall, Englewood Cliffs (1987)
6. Hamari, J., Koivisto, J.: Why do people use gamification services? Int. J. Inf. Manag. **35**(4), 419–431 (2015). https://doi.org/10.1016/j.ijinfomgt.2015.04.006
7. Henke, M., Kuhn, A. (eds.): Kollaboration als Schlüssel zum erfolgreichen Transfer von Innovationen. Analyse von Treibern und Hemmnissen in der Automobillogistik (Collaboration as to the Successful Transfer of Innovations. Analyses of Drivers and Barriers in automotive logistics). acatech STUDIE. Herbert Utz Verlag GmbH, München (2017)
8. Mazarov, J., Schmitt, J., Deuse, J., Richter, R., Kühnast-Benedikt, R., Biedermann, H.: Visualisierung in Industrial Data-Science-Projekten (Visualisation in Industrial Data Science projects). In: Industrie 4.0 Management, vol. 36, pp. 63–66 (2020)
9. Schulz, M., et al.: Introducing DASC-PM: a data science process model. In: ACIS 2020 Proceedings, vol. 45 (2020)
10. Stegmann, K., Wecker, C., Mandl, H., Fischer, F.: Lehren und Lernen mit digitalen Medien. In: Tippelt, R., Schmidt-Hertha, B. (eds.) Handbuch Bildungsforschung, pp. 1–22. Springer Fachmedien Wiesbaden, Wiesbaden (2016). https://doi.org/10.1007/978-3-531-20002-6_42-1
11. Weidemann, J.: First Work report for the Use Case 5 "Directed and SME-friendly competence development" (2021). https://akkord-projekt.de/en/report-directed-and-sme-friendly-competence-development-1. Accessed 21 Feb 2022
12. West, N., Gries, J., Brockmeier, C., Göbel, J.C., Deuse, J.: Towards integrated data analysis quality: criteria for the application of industrial data science. In: 2021 IEEE 22nd International Conference on Information Reuse and Integration for Data Science (IRI), pp. 131–138 (2021). https://doi.org/10.1109/IRI51335.2021.00024
13. Zahoor, N., Al-Tabbaa, O., Khan, Z., Wood, G.: Collaboration and internationalization of SMEs: insights and recommendations from a systematic review. Int. J. Manag. Rev. **22**(4), 427–456 (2020). https://doi.org/10.1111/ijmr.12238

Sustainable Last Mile in E-commerce: A Literature Review

Iria González-Romero(✉) and J. Carlos Prado-Prado

Business Administration and Marketing, School of Industrial Engineering, University of Vigo, 36310 Vigo, Spain
{iria.gonzalez.romero,jcprado}@uvigo.es

Abstract. The interest in last mile, considered the most important factor in e-commerce, has grown as online sales have increased. This interest has been reflected in the literature. However, there is not an overview of this whole research field. The purpose of this article is to provide a complete view of the topics in the field of sustainable last mile in e-commerce. To achieve this, a literature review was carried out in which 58 articles were identified. Afterwards, these papers were classified according to their topic and research method, providing a complete vision of the field of analysis. As a result, 11 topics were identified, the most studied being the *Quantification of the effect on sustainability of the last mile in e-commerce*. In addition, four future lines for research were established.

Keywords: Last mile · Sustainability · e-Commerce · Literature review

1 Objectives and Methodology

E-commerce is undergoing exponential growth, which means the last mile (transporting online orders from the last point of contact with the retailers to the point where they are consumed) has become the most important factor in online sales [1]. This importance stems from it being the only point of contact between the e-retailer and the final customer. However, it is also important because of its disproportionate impact on online logistics costs and the environmental and social damage caused by transportation [2].

This importance has been reflected in the literature, where research into sustainable design in this operation has started to proliferate, including the appearance of literature reviews on this subject. However, these works have focused on analyzing a specific problem (e.g., electric vehicles), without differentiating the methodologies employed to tackle it, or they have compiled the issues dealt within the last mile from a specific perspective (e.g., stakeholders). There is not, therefore, an overview of this whole research field.

Thus, this paper aims to provide a literature review on the sustainable last mile in e-commerce. By classifying publications according to the research method adopted, it will in turn provide a clear view of the topics dealt with in the articles published to date and the research lines for the future.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 70–76, 2023.
https://doi.org/10.1007/978-3-031-27915-7_14

In order to carry out this study, the authors opted, due to its capacity to identify the topics covered in the articles, for a systematic review of the literature based on three stages (planning, implementation, and presentation of results), a method followed by Mangiaracina et al. [3]. In the first stage, the scope of the research was defined as being sustainable management of the last mile in e-commerce. On the basis of this scope, Scopus and Web of Science were searched using the following concepts: “last-mile”, “e-commerce” and “sustainability”. A total of 576 papers were identified. After examining their titles and abstracts, a refined list of 58 articles was generated. The full list is available on request from the authors[1]. Once the articles were selected, they were analyzed and the results presented. To do so, the general characteristics of the collected articles were identified and the publications were classified according to their content and the research method used.

2 Results

Regarding the general characteristics of the papers under review, it is important to point out that the first article on the sustainable last mile in e-commerce was published in 2014 although no further papers were published on the topic until 2017. Four publications were identified between 2017 and 2018 (7% of the total). However, interest in the subject grew from 2019, by which time a total of 11 studies had appeared (pushing the total thus far to 19%). A total of 42 papers were published between 2020 and 2022—72% of the total—with 2021 having the greatest tally at 26 articles, or 45% of the total.

The 58 papers considered in this literature review were published in 29 journals. Over half of the papers studied came from just six publications (i.e., *Sustainability*, *International Journal of Logistics Research and Applications*, *Sustainable Cities and Society*, *Transportation Research Part D: Transport and Environment*, *Journal of Cleaner Production*, and *International Journal of Sustainable Transportation*).

The selected articles were classified based on their decision-making and sustainability approach. First, 23 papers belong to the strategic level, 18 publications analyze the sustainable last mile from a tactical level, and the remaining 17 articles used an operational focus. Second, 30 publications analyzed the environmental pillar of sustainability, 18 papers focused on the economic pillar, 3 articles on the social pillar, and 7 publications jointly analyzed the three pillars of sustainability.

For the study of the topics, the papers were classified according to their research method. The methods were grouped into the following: quantitative models (analytical models and simulations), conceptual models (frameworks and general classifications), and empirical models (case studies, interviews, and surveys) [3].

Twenty-five papers were identified that were based on quantitative models. In this sense, 13 articles focused on quantifying the effect on sustainability of the last mile in e-commerce and the different design alternatives. Thus, de Mello Bandeira et al. [4] created a model that allowed calculation of the effect on the three pillars of sustainability (economic, environmental, and social) of three different delivery strategies (traditional intermodal distribution, alternative intermodal distributions, and distribution by electric

[1] Due to page limits, it is not possible to include the full list in this paper.

tricycle). Another example is by Wang et al. [5], whose study analyzed the sustainable deployment of different last-mile strategies in e-commerce on the basis of different criteria. The work determined that the criteria with the most impact are delivery time, order fulfillment, decarbonization, convenience of payment, and real-time tracking systems. Finally, Siragusa et al. [6] compared the effect on the economic and environmental pillars of sustainability's of electric vans and traditionally fueled vans, concluding the superiority of the former both economically (after the eighth year) and environmentally.

At the same time, ten of the papers in this study are based on the analysis of models or simulations for alternatives aimed at improving last-mile sustainability. Thus, Leyerer et al. [7] developed a model to optimize a network of refrigerated lockers, where packages are deposited to be collected by customers or delivered to homes by electric bicycles. Another example is the paper by Simoni et al. [8], in which a delivery service based on crowdsourcing is simulated, identifying the crucial operational aspects for the sustainability of this strategy (length of detours, parking behavior, and daily traffic variations).

The final two articles analyzed the response of customers to price changes in sustainable deliveries and explored specific factors that influence the sustainability of last-mile deliveries in rural areas. In the latter, Jiang et al. [9] highlighted four basic factors (convenience of returning goods, integrity of goods, advance reservation of goods pickup, and delivery costs).

A total of 14 articles were selected on the basis of conceptual models. Several papers are worthy of note. First Olsson et al. [10], with a study that provided a classifying framework for the last mile, comprising five components (logistics, distribution, fulfillment, transport, and delivery). At the same time, Guo et al. [11] analyzed the effectiveness of crowdsourced delivery when mitigating last-mile sustainability issues. To do this they created a framework based on five basic principles (small-scale pilot, community-based approach, low added network complexity, low additional investment level, and co-functionality). Another example is by Halldorsson and Wehner [12]. Their study created a framework that establishes the basic parameters (distribution structure, transportation execution, and household logistics capability) that should be taken into account when it comes to creating energy-efficient last-mile strategies in e-commerce.

Nineteen articles with empirical models were identified. First, research that focuses on determining how the sustainable last mile ought to be structured should be highlighted. In this regard, Mkansi and Nsakanda [13] opted to study the benefits of using an offline logistics strategy (mainly stores) as the starting point for the creation of sustainable last-mile strategies for e-commerce.

Ten of the papers analyzed consumer behavior towards different sustainable last-mile strategies. In this regard, Rai et al. [2] analyzed changes in consumer behavior in choosing delivery type, according to the information on sustainability received. By offering free deliveries and returns, consumers were willing to collect their orders themselves or wait longer for them to arrive. For their part, Caspersen and Navrud [14] analyzed the consumer response to five sustainable design factors for the last mile (delivery time, delays, information, CO2 emissions, and particulate matter).

At the same time, four of the articles under study analyzed the benefits for last-mile sustainability of the use of different novel strategies (electric vehicles, drones, cargo bikes, mobile depot, or crowd logistics). An example is the study by Serrano-Hernandez et al. [15], which analyzed the state of the last mile in cities, highlighting the preference for the use of drones or bicycles for city-center deliveries in order to reduce social and environmental problems.

Finally, two of the selected articles focus on analyzing the role of two main stakeholders: delivery drivers and institutions. In this regard, de Kervenoael et al. [16] studied the importance of the delivery drivers as a key factor in attaining a sustainable last mile, concluding that collaboration with independent workers can increase the sustainability of this operation.

Table 1 gives a summary of the topics identified in the articles published within the scope of the sustainable last mile in e-commerce.

Table 1. Summary of topics covered within the scope of the sustainable last mile in e-commerce.

Research method	Topic	Articles mentioned	Total number of articles	%
Quantitative model	1. Quantification of the effect on sustainability of the last mile in e-commerce	[4, 5, 6]	13	22
	2. Modeling or simulation of different sustainable alternatives for the last mile in e-commerce	[7, 8]	10	17
	3. Customer response to price changes in sustainable deliveries		1	2
	4. Study of the relationship of factors influencing the sustainability of last-mile deliveries in rural areas	[9]	1	2
Conceptual model	5. Classification framework for the sustainable last mile in e-commerce	[10]	6	10
	6. Framework allowing analysis of the effectiveness of different strategies to mitigate sustainability problems in the last mile	[11]	3	5
	7. Framework that serves as a design tool for sustainable last-mile strategies	[12]	5	9
Empirical model	8. Determination of how the sustainable last mile should be structured	[13]	3	5
	9. Analysis of consumer behavior in the face of different sustainable strategies for e-commerce deliveries	[2, 14, 17]	10	17
	10. Study of the benefits to last-mile sustainability of using different novel strategies	[15]	4	7
	11. Analysis of the role of stakeholders in the sustainable last mile	[16]	2	3

3 Conclusions and Future Lines for Research

This systematic literature review on sustainable management of the last mile in e-commerce reveals an area of research that is limited but in which there has been growing interest over recent years. After analysis of the contents of the 58 articles, 11 predominating topics have been identified (see Table 1).

An increased concern for the high impact of last mile on sustainability [2] prompted research on three specific topics (from Table 1, number 1, followed by number 6 and 4). Researchers began the study of these topics by analyzing the total cost of deliveries, as well as the emissions of pollutant gases (e.g., [6]). Over the years, other implications have begun to be analyzed, such as level of service, congestion, fuel consumption or safety and accidents (e.g., [4]). However, the analysis of cost and emissions continues to be the predominant approach in this research, with the analysis of the rest of the impacts being minimal in comparison. In this sense, there is a lack of a global vision of the impact of the last mile in e-commerce on the three pillars of sustainability, mainly from the social point of view.

When defining and structuring the last mile (topics number 5 and 8), research has focused on determining which elements must be taken into account, in addition to defining possible structures to be used when designing a sustainable last mile in e-commerce (e.g., [10, 13]). However, this research again lacks the integration of the three pillars of sustainability in last-mile strategies.

Regarding the topics that study new sustainable alternatives (number 2, 7 and 10), articles discussed crowdsourcing, collection and delivery points, drones, city hubs, cargo bikes or AGVs, among others, studying their applicability and benefits, mostly through geographically limited case studies (e.g., [8, 15]). The lack of analysis on the possibility of large-scale implementation (different geographical circumstances and characteristics) of some of these alternatives (for example, AGVs, drones and crowdsourcing), as well as their implications on security and legislation, is preventing their mass implementation in last-mile deliveries.

Finally, the role of stakeholders in sustainable last mile (topics number 3, 9 and 11) is unevenly analyzed. On the one hand, multiple authors have extensively studied the role of customers, determining, among others, the willingness of consumers to use sustainable alternatives such as AGVs (e.g., [17]). However, there is a lack of analysis on the factors that can change this behavior towards these alternatives (e.g., [2]). On the other hand, regarding the rest of stakeholders (local governments, residents, transport companies) only two articles have addressed this issue, analyzing the need for collaboration between them (e.g., [16]). Thus, this limitation is reflected in the lack of research on the challenges and benefits of establishing collaborative relationships between all stakeholders.

In relation to the above and with regard to future lines for research, although many topics have been studied concerning the sustainable last mile in e-commerce, there are still some aspects that should be examined in more detail, particularly from the empirical and conceptual standpoint. Primarily, the three pillars of sustainability should be included in order to investigate any effects on them and to take any necessary steps. On the basis of the findings, there is also a need to offer a holistic view on sustainable last-mile design and structure all the design factors taken into account when it comes to creating sustainable strategies. There is also a need, through the creation of a system of metrics, to evaluate the current level of sustainability of last-mile strategies employed by e-retailers, taking into account the three pillars of sustainability. Finally, future studies should focus on establishing which sustainable last-mile design is the most suitable, depending on the features of each online retailer, the preferences of its customers and the relationship with its stakeholders.

References

1. Rai, H.B.: Environmental sustainability of the last mile in omnichannel retail (2019)
2. Rai, H.B., Verlinde, S., Macharis, C.: The "next day, free delivery" myth unravelled: possibilities for sustainable last mile transport in an omnichannel environment. Int. J. Retail Distrib. Manag. **47**(1), 39–54 (2019)
3. Mangiaracina, R., Song, G., Perego, A.: Distribution network design: a literature review and a research agenda. Int. J. Phys. Distrib. Logist. Manag. **45**(5), 506–531 (2015)
4. de Mello Bandeira, R.A., Goes, G.V., Gonçalves, D.N.S., Márcio de Almeida, D.A., de Oliveira, C.M.: Electric vehicles in the last mile of urban freight transportation: a sustainability assessment of postal deliveries in Rio de Janeiro-Brazil. Transp. Res. Part D: Transp. Environ. **67**, 491–502 (2019)
5. Wang, C.N., Dang, T.T., Hsu, H.P.: Evaluating sustainable last-mile delivery (LMD) in B2C E-commerce using two-stage fuzzy MCDM approach: a case study from Vietnam. IEEE Access **9**, 146050–146067 (2021)
6. Siragusa, C., Tumino, A., Mangiaracina, R., Perego, A.: Electric vehicles performing last-mile delivery in B2C e-commerce: an economic and environmental assessment. Int. J. Sustain. Transp. **16**(1), 22–33 (2022)
7. Leyerer, M., Sonneberg, M.O., Heumann, M., Breitner, M.H.: Shortening the last mile in urban areas: optimizing a smart logistics concept for e-grocery operations. Smart Cities **3**(3), 585–603 (2020)
8. Simoni, M.D., Marcucci, E., Gatta, V., et al.: Potential last-mile impacts of crowdshipping services: a simulation-based evaluation. Transportation **47**, 1933–1954 (2020). https://doi.org/10.1007/s11116-019-10028-4
9. Jiang, X., Wang, H., Guo, X., Gong, X.: Using the FAHP, ISM, and MICMAC approaches to study the sustainability influencing factors of the last mile delivery of rural E-commerce logistics. Sustainability **11**(14), 3937 (2019)
10. Olsson, J., Hellström, D., Pålsson, H.: Framework of last mile logistics research: a systematic review of the literature. Sustainability **11**(24), 7131 (2019)
11. Guo, X., Jaramillo, Y.J.L., Bloemhof-Ruwaard, J., Claassen, G.D.H.: On integrating crowdsourced delivery in last-mile logistics: a simulation study to quantify its feasibility. J. Clean. Prod. **241**, 118365 (2019)
12. Halldorsson, A., Wehner, J.: Last-mile logistics fulfilment: a framework for energy efficiency. Res. Transp. Bus. Manag. **37**, 100481 (2020)
13. Mkansi, M., Nsakanda, A.L.: Leveraging the physical network of stores in e-grocery order fulfilment for sustainable competitive advantage. Res. Transp. Econ. **87**, 100786 (2021)
14. Caspersen, E., Navrud, S.: The sharing economy and consumer preferences for environmentally sustainable last mile deliveries. Transp. Res. Part D: Transp. Environ. **95**, 102863 (2021)
15. Serrano-Hernandez, A., Ballano, A., Faulin, J.: Selecting freight transportation modes in last-mile urban distribution in Pamplona (Spain): an option for drone delivery in smart cities. Energies **14**(16), 4748 (2021)

16. de Kervenoael, R., Schwob, A., Chandra, C.: E-retailers and the engagement of delivery workers in urban last-mile delivery for sustainable logistics value creation: leveraging legitimate concerns under time-based marketing promise. J. Retail. Consum. Serv. **54**, 102016 (2020)
17. Rai, H.B., Verlinde, S., Macharis, C.: Who is interested in a crowdsourced last mile? A segmentation of attitudinal profiles. Travel Behav. Soc. **22**, 22–31 (2021)

Identifying the Critical Success Factors of the Digital Transformation

Ángel Hernández-García(✉), Carlos Cuenca-Enrique, Pablo Jarabo-Valdivieso, and Julián Chaparro-Peláez

Departamento de Ingeniería de Organización, Administración de Empresas y Estadística, ETSI de Telecomunicación, Universidad Politécnica de Madrid, Av. Complutense 30, 28040 Madrid, Spain

{angel.hernandez,carlos.cuenca,julian.chaparro}@upm.es, p.jarabo@alumnos.upm.es

Abstract. Many companies struggle when facing their digital transformation, generally lacking guidance on what changes they need to undergo to adapt to the digital environment. This research aims to help them implement their digital transformation successfully. The study identifies the critical success factors of digital transformation and prioritizes them to provide guidelines and recommendations on the steps that companies must take to succeed in their digital transformation. The study covers a review of 52 case studies of companies that achieved successful digital transformation and identifies 25 critical success factors, grouped in five areas. The results of the analysis emphasize the relevance of the enabling digital technologies and the orientation of the company to the customer, leveraged by data collection and backed by partnerships. The strategic planning of digital transformation must support this approach, which can require additional changes in organizational culture and capabilities.

Keywords: Digital transformation · Critical success factors · Case study review

1 Introduction and Background

While the concept of digital transformation is widely used nowadays, there does not seem to be a consensus on its definition [1], even though it encompasses the idea of the changes that organizations must undergo to adapt to the digital world by smartly combining current knowledge and processes with technology to be more efficient, competitive and profitable [2]. Digital transformation involves the integration of digital technologies in all areas of a company. It changes the way the company operates to optimize processes, improve competitiveness, and offer new added value to its customers.

Although 66% of Spanish CEOs consider digital transformation a key factor in their strategy or business plan and consider their companies actively disruptive (up from 36% in 2018) [3], embracing digital technologies does not equate to a successful digital transformation. Digital transformation goes beyond the mere application of technologies and entails cultural change in the organization (and a shift in the mindset of managers and

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 77–81, 2023.
https://doi.org/10.1007/978-3-031-27915-7_15

employees), process redesign across all functional areas of the organization, and even structural changes and a complete rethinking of the strategy. It is essential to investigate to which of these elements should companies pay more attention, which of them are critical in ensuring success in their digital transformation, and how they should be prioritized. The notion of critical success factors (CSFs) refers to the limited number of areas of the business in which results, if satisfactory, will ensure successful competitive performance for the organization [4]. In the context of this study, CSFs embody the factors that should be considered when implementing a digital transformation project.

The main motivation of this research is not only to identify the CSFs in successful implementations of the digital transformation process, but also to be able to prioritize them and provide guidelines and recommendations to companies willing to face the challenge of undergoing the digitalization process. We seek to investigate whether it is possible to determine what specific areas a company must focus on to achieve a successful digital transformation.

Despite the growing body of knowledge on the topic of digital transformation, academic research has focused primarily on four areas: enabling technologies of digital transformation (e.g., [5]), barriers and drivers of digital transformation (e.g., [6]), impact of digital transformation (e.g., [7, 8]), and organizational views on digital transformation: organizational capabilities, strategic planning, business model redesign, or organizational structure (e.g., [9–11]).

So far, there is a paucity of comprehensive views on successful digital transformation with a focus on CSFs. Some examples of this approach are found in [12–16]. Although some of the studies mentioned address some elements of the objectives of this research, none of them provide a comprehensive and complete account of CSFs of the digital transformation, or they fail to identify and prioritize them.

Therefore, the following section describes the methods used in this study (namely, a systematic review of case studies) to achieve the proposed research goals. Once the research method is explained, Sect. 3 covers the analysis and main findings of the review, and Sect. 4 provides some concluding remarks.

2 Materials and Methods

The research explores case studies to generate robust conclusions and provide a wide diversity of real implementation cases of digital transformation. Data collection covered the period between August and September 2021. While we first aimed to conduct a systematic literature review, the initial set of results (14) was considered too small. Therefore, we decided to extend the search to other sources using search engines such as Google and Google Scholar. We then selected case studies found on websites of consulting firms and technology providers, business magazines, company reports, and thesis, including a diversity of companies and sectors. The inclusion of grey literature helps reducing publication bias and facilitates a more balanced view of the evidence [17]. The analysis protocol was as follows.

- Identification: literature searches were conducted on academic databases (e.g., Web of Science, Scopus, Springer, IEEE). Additionally, searches on Google Scholar and Google returned results from the additional sources mentioned earlier.

- Keywords: “digital transformation” and “success factor*” and “case stud*” and related variants, to ensure consistency of results and completion.
- Inclusion criteria: literature written in English, Spanish, or French that addressed the analysis of real and successful digital transformation projects and identified success factors.
- Screening: a first selection was made from the search results by reading the title, abstract and keywords where available, or by searching for terms in the text.

The final analysis comprises 52 reports and articles, and was followed by data charting, where we identified key items of information from the documents, which were then sifted, sorted and charted according to key issues and themes [18]. To do so, two independent reviewers identified the most common topics and success factors (54 CSFs). Then, some CSFs were removed based on similarity or inclusion under a different broader CSF (32 CSFs). After a repeated independent analysis of the 52 reports, the set was then reduced by including only CSFs that were present in more than 5% of the reports (that is, in at least 3 reports). Therefore, the final set included 25 CSFs, which were grouped into broader topics that covered five different business areas: technology, strategy, internal and external analysis, digital culture, and customers. We prioritized CSFs according to the number of occurrences and assigned them a criticality index (I_c) ranging from 3 to 52.

3 Data Analysis and Discussion

We found three relevant CSFs for successful digital transformation: digitalization of processes and operations, digitalization of products, and transforming the customer relationship model, followed by other factors related to strategy (e.g., investment, partnerships, organizational redesign, organizational capabilities, the definition of a digital roadmap) and aspects relative to data collection. The results suggest that the digitalization of products and internal processes is at the core of digital transformation. From the results, the digitalization of a company must be driven by a customer-centric approach, whereby the company must leverage the digital technologies to get closer to the customer to improve their shopping experience. This customer-centric approach must be supported by data collection, both internal and external, that provides deeper understanding of the company’s customers and their markets, helping companies anticipate the customer needs and provide the right product offering at the right time. The results also support that the use of digital technologies to support customer-centric approaches must be done strategically, often involving a redesign of the structure and culture of the organization and the need to establish partnerships (with technology providers, retailers, or consulting firms that help guide the digital transformation) and being willing to invest in the digital technologies necessary to complete the transformation.

For managers and practitioners, the analysis provides the following recommendations and guidelines for successful implementation of digital transformation processes in organizations in different areas:

- Introduce technologies that enable digital transformation in the company's product offering, processes and operations, and choose them based on the specific needs of the company.
- Place the customer at the center of the company's activity: always seek customer satisfaction through excellent and personalized service, tailored products and advertising, and improved shopping experience.
- Focus on data collection and storage, and place data at the center of the transformation strategy; use it to make decisions and anticipate future changes through in-depth data analysis using information systems.
- Establish relationships and agreements with solid technology providers when implementing new technologies and information systems; consider using the services of specialized consulting companies to carry out the transformation process.
- Establish a digital transformation strategy and set a high priority for the strategy among the main company goals; considerable investment in research, new technologies, and the acquisition of small innovative companies may be necessary.
- Perform a deep analysis of the current state of the technology in the company, as well as in competitors and the industry, and perform continuous monitoring of the transformation process, while looking at what other companies have done and are doing.
- Create a new digital business subdivision (directed by a Chief Digital Officer and/or Chief Information Officer) to oversee the transformation process, implement the digital culture in all layers of the company's organizational structure (from top management to lower levels); train the company's current staff, hire digital professionals if needed, and implement agile methodologies.

4 Conclusion

This study confirms the results of previous research and contributes to knowledge by offering further insight about the role played by the different CSFs. It is now widely accepted that digital technologies are necessary but not sufficient conditions for a successful digital transformation. However, while the focus of successful digital transformations has shifted in recent years to aspects related to strategic planning and dynamic capabilities of organizations, the analysis shows that digitalization of processes and products enabled by digital technologies at the service of customer-centric approaches is the primary key to success.

References

1. Vial, G.: Understanding digital transformation: a review and a research agenda. J. Strat. Inf. Syst. **28**(2), 118–144 (2019). https://doi.org/10.1016/j.jsis.2019.01.003
2. De la Peña, J.M., Cabezas, M.: La gran oportunidad: Claves para liderar la transformación digital. Gestión 2000 (2015)
3. KPMG: Ágil o irrelevante. Redefiniendo la resiliencia. Technical report, KPMG (2019)
4. Rockart, J.F.: Chief executives define their own data needs. Harv. Bus. Rev. **57**(2), 81–93 (1979)

5. Frank, A.G., Dalenogare, L.S., Ayala, N.F.: Industry 4.0 technologies: implementation patterns in manufacturing companies. Int. J. Prod. Econ. **210**, 15–26 (2019). https://doi.org/10.1016/j.ijpe.2019.01.004
6. Horváth, D., Szabó, R.Z.: Driving forces and barriers of Industry 4.0: do multinational and small and medium-sized companies have equal opportunities? Technol. Forecast. Soc. Chang. **146**, 119–132 (2019). https://doi.org/10.1016/j.techfore.2019.05.021
7. Jafari-Sadeghi, V., Garcia-Perez, A., Candelo, E., Couturier, J.: Exploring the impact of digital transformation on technology entrepreneurship and technological market expansion: the role of technology readiness, exploration and exploitation. J. Bus. Res. **124**, 100–111 (2021). https://doi.org/10.1016/j.jbusres.2020.11.020
8. Llopis-Albert, C., Rubio, F., Valero, F.: Impact of digital transformation on the automotive industry. Technol. Forecast. Soc. Chang. **162**(120343), 1–9 (2021). https://doi.org/10.1016/j.techfore.2020.120343
9. Hess, T., Matt, C., Benlian, A., Wiesbock, F.: Options for formulating a digital transformation strategy. MIS Q. Exec. **15**(2), 103–119 (2016)
10. Warner, K.S., Wäger, M.: Building dynamic capabilities for digital transformation: an ongoing process of strategic renewal. Long Range Plan. **52**(3), 326–349 (2019). https://doi.org/10.1016/j.lrp.2018.12.001
11. Li, L., Su, F., Zhang, W., Mao, J.Y.: Digital transformation by SME entrepreneurs: a capability perspective. Inf. Syst. J. **28**(6), 1129–1157 (2018). https://doi.org/10.1111/isj.12153
12. Petrova, N., Fustik, V.: Digital industry transformation - complex analysis of technologies, benefits, success factors and barriers. In: Proceedings of the 35th International Conference on Information Technologies (InfoTech-2021), pp. 41–50 (2021)
13. Holotiuk, F., Beimborn, D.: Critical success factors of digital business strategy. In: Wirtschaftsinformatik (WI 2017), pp. 991–1005 (2017). https://aisel.aisnet.org/wi2017/track09/paper/5/
14. Furjan, M.T., Tomičić-Pupek, K., Pihir, I.: Understanding digital transformation initiatives: case studies analysis. Bus. Syst. Res. **11**(1), 125–141 (2020). https://doi.org/10.2478/bsrj-2020-0009
15. Loonam, J., Eaves, S., Kumar, V., Parry, G.: Towards digital transformation: lessons learned from traditional organizations. Strateg. Chang. **27**(2), 101–109 (2018). https://doi.org/10.1002/jsc.2185
16. Vukšić, V.B., Ivančić, L., Vugec, D.S.: A-preliminary-literature-review-of-digital-transformation-case-studies. Int. J. Comput. Inf. Eng. **12**(9), 737–742 (2018)
17. Paez, A.: Gray literature: an important resource in systematic reviews. J. Evid. Based Med. **10**(3), 233–240 (2017). https://doi.org/10.1111/jebm.12266
18. Arksey, H., O'Malley, L.: Scoping studies: towards a methodological framework. Int. J. Soc. Res. Methodol. Theory Pract. **8**(1), 19–32 (2005). https://doi.org/10.1080/1364557032000119616

Understanding Strategic Response to Covid-19 Crisis in Manufacturing SMEs: A Cluster Analysis

J. I. Igartua[1](✉), A. M. Valenciano[2], and D. Ibarra[1]

[1] Mechanical and Industrial Production Department, Mondragon University, Mondragon, Spain
{jigartua,dibarra}@mondragon.edu

[2] Arantzazulab – Social Innovation Lab, Oñati, Spain
amvalenciano@arantzazulab.eus

Abstract. Manufacturing small- and medium- sized enterprises (SMEs), which play a decisive role in the Spanish and European economy, have been particularly affected by the disruption generated by the COVID-19 crisis, being their strategic decisions key to maintain their competitiveness. This article explores the strategic priorities defined by managers of manufacturing SMEs to face COVID-19 related challenges. Data were collected from 167 manufacturing companies through an online questionnaire and exploited with factorial and cluster analysis. The results highlight the strategic importance of developing more advanced business models, boosting customer responsiveness and developing the innovative value propositions in developing a proactive response to the Covid-19 crisis. The value of this ongoing study lies in its contribution to quantitative research on the impact of the Covid-19 crisis on the strategic management of manufacturing SMEs.

Keywords: Cluster analysis · Business model innovation · Managerial practices · Manufacturing companies · SMEs · Covid-19

1 Introduction

Small- and medium- sized enterprises (SMEs) play a key role in the European and Spanish economy. Moreover, in the case of companies in the Basque Country, many of these SMEs are manufacturing companies that respond to an economy related to the automotive, aeronautical and machine tool sectors, through the manufacture of components, assemblies, products and systems, and industrial services.

These companies were already experiencing a number of major changes in their competitiveness and challenges, arising from market and industry changes, digital transformation and Industry 4.0, when they were affected by the Covid-19 pandemic crisis. In this context, it is important to understand the strategies of manufacturing SMEs, as well as the role of business model innovation in this context. As underlined by research, strategic decisions condition the organizational performance [1] and competitiveness of firms [2]. The research explores these strategic decisions from a managerial perspective [3].

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 82–87, 2023.
https://doi.org/10.1007/978-3-031-27915-7_16

The paper first presents the theoretical approach, as well as the research objectives and methodology. This is followed by the results and a final discussion, including conclusions, limitations and future research approaches.

2 Strategic Response in SMEs

The theoretical underpinnings of this research are based on resource and capability theory [4], supported by research that emphasises the role of context in strategy setting [5].

This research takes as a reference different sets of capabilities that make up different strategic dimensions [6], with an impact on the competitiveness of companies. These capability sets are: Organisational culture [7]; Strategy formalization [8]; Customer orientation [9]; Value proposition development [10]; Value chain improvement and development [11]; People and talent management [12]; Resource efficiency and flexibility [13]; Open innovation practices [14]; Product and service innovation [15]; Business Model Innovation [16]; and Management maturity [17].

For some authors, the interaction of this set of capabilities can predict firm performance [18]. The prioritisation of these practices can also suggest patterns of strategy maturity, especially under conditions of major change [19].

3 Objectives and Methodology

The aim of this study is twofold: (1) to distinguish groups of SMEs according to the elements of strategic orientation and (2) to analyse the characteristics of the different groups. This exploratory study uses data collected through a structured questionnaire completed by the managers of SMEs participating in a Covid-19 crisis response initiative launched by the Department for Economic Promotion of the Provincial Council of Gipuzkoa in 2020. The sample comprises 167 industrial SMEs.

Data were collected through an online survey based on a 36-item questionnaire (measuring the strategic relevance of practices on a 5-point Likert scale), and explored through cluster analysis. Before performing the cluster analysis, an exploratory factor analysis (EFA) was carried out using the maximum likelihood method. Calculations of different statistics were previously carried out in order to determine whether the application of the factor analysis was justified. For the clustering, the log-likelihood distance measure and the Schwarz clustering criterion (BIC) were used. For each case, a clustering variable was created in order to develop the analyses shown in the following section. All these analyses were developed using SPSS statistical software, version 28.0.

4 Results

We used the two-steps cluster analysis [3], with a prior descriptive statistical analysis to check the necessary conditions. Before proceeding to the cluster analysis, we checked for multicollinearity by analysing the correlation between cluster variables. The rotation converged in 12 iterations, which allowed us to maintain the independence between the rotated factors to obtain a final structure of nine factors with eigenvalues > 1, which together explain 62.76% of the variance.

To investigate the heterogeneity among firms in identifying the strategic response, a two-stage cluster analysis was conducted based on the nine extracted factors:

- Advanced business models (Advanced BM): Digital offer, revenue generation through new sources and channels, development of new business logics (pay-per-use, subscription, etc.), reinvention of business logic (customers, activities, suppliers, resources, revenue model).
- Customer responsiveness (CUSTOMER): Risk assessment and management, adaptation to new environments and challenges, customer segmentation, understanding customer needs, transformation of customer relationships, agile validation of value propositions, rapid adaptation to new environments and challenges, customer engagement.
- Value proposition innovation (Value INNO): Development of new value propositions, and ideation of new products or services.
- Value chain efficiency (EFFICIENCY): internal and external value chain transformation, new logistic approaches, changes in the value chain, cost efficiency.
- Roadmap (ROADMAP): Development of a roadmap for continuity, for transformation, to face future challenges, to have the resources, capabilities and key competences for the future.
- New channels (CHANNEL): Development of distribution channels that respond to the needs of each of our customer segments, and new integrated distribution channels.
- Innovation culture (CULTURE): Encourage experimentation, to seek out new opportunities and exploit them, to exchange knowledge and approaches among people, and to participate actively in the company.
- People (PEOPLE): People´s skills development and training, polyvalence of people, retaining and attracting talent, promoting and facilitate a co-responsible work-life conciliation.
- Own products (Own PRODUCTS): Development of own products (good, services) and to market them directly.

The analysis suggests the creation of two different clusters (Cluster 1 with 95 firms - 56,9%, and Cluster 2 with 72 firms - 43,1%) with fair quality (Silhouette measure of cohesion and separation = 0,3), a value above 0.0, suggesting validity of the within and between cluster distances. T-test analysis confirmed the significance of the differences in the means of the nine factors between the two groups, with significantly higher values for all factors in the second group (Table 1).

The Advanced BM, followed by CUSTOMER and Value INNO factors, led the importance of the predictors for cluster creation (Fig. 1).

Table 1. Mean differences for variables between clusters

Measures	Cluster 1	Cluster 2
	Means ± SD	Means ± SD
Advanced BM	2,00 ± 0,86	3,34 ± 0,74
CUSTOMER	3,76 ± 0,60	4,55 ± 0,29
Value INNO	3,47 ± 1,02	4,61 ± 0,47
EFFICIENCY	2,94 ± 0,88	4,03 ± 0,76
ROADMAP	3,45 ± 0,90	4,26 ± 0,48
CHANNELS	1,76 ± 1,20	3,24 ± 1,64
CULTURE	3,68 ± 0,84	4,44 ± 0,55
PEOPLE	3,85 ± 1,05	4,55 ± 0,48
Own PRODUCTS	1,69 ± 1,43	4,44 ± 0,55

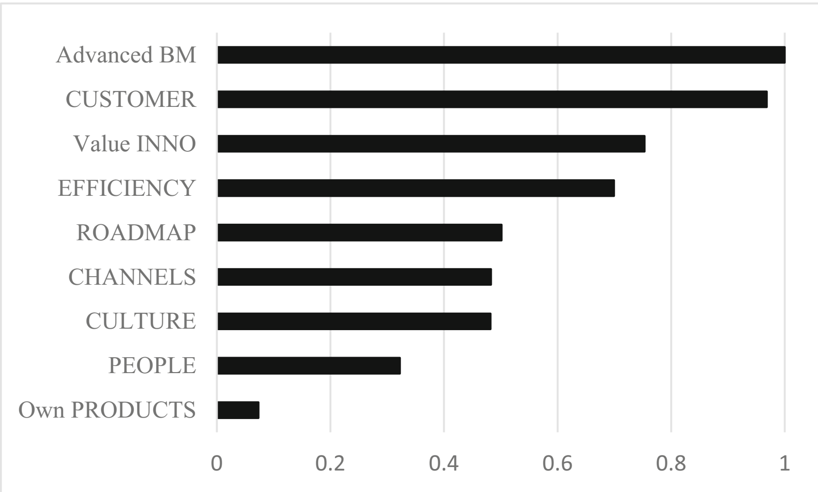


Fig. 1. Cluster formation predictor importance

Analysing the level of management in which the companies consider themselves to be situated (Management maturity). Table 2 shows the percentage distribution of all the companies according to this variable in the two clusters. Thus, companies that consider themselves "driver" or "advanced" are mainly located in cluster 2, while companies that consider themselves "reactive", "initial" or "managed" are located in cluster 1.

Table 2. Distributions of companies by management maturity in each cluster

Management maturity	Cluster 1	Cluster 2	Total
Driver	33,33%	66,67%	100,00%
Advanced	25,00%	75,00%	100,00%
Managed	69,41%	30,59%	100,00%
Reactive	94,44%	5,56%	100,00%
Initial	80,00%	20,00%	100,00%
Total	56,89%	43,11%	100,00%

5 Discussion, Conclusions and Further Research

The research results obtained through the two-stage cluster analysis suggest the existence of two strategic response configurations for the Covid-19 crisis among the manufacturing SMEs analysed. Specifically, those that are strongly committed to a proactive and agile response in relation to their customers, the development of advanced business models and value proposition innovations; and those that adopt a more reactive stance in relation to these three strategic practices.

Moreover, in the light of this research, the group of companies that are more proactive in strategic transformations towards the response to the Covid-19 crisis are those that are more mature in their management, as opposed to those that are more reactive or have weakly initiated their transformational reflections. Despite the limitations of this research, the results obtained provide important input for managers and policy makers.

Some limitations arise in this study due to the nature of the work. One of them refers to the size of the sample, and the other to the lack of a control group of similar companies that did not participate in the initiative.

We believe that this research contributes to the generation of knowledge on strategy in manufacturing companies in crisis. Future research could increase the sample size, develop a research based on control groups integrating similar companies that did not participate in this initiative, and develop comparisons in relation to other business sectors and regions.

References

1. George, B., Walker, R.M., Monster, J.: Does strategic planning improve organizational performance? A meta-analysis. Public Adm. Rev. **79**, 810–819 (2019). https://doi.org/10.1111/puar.13104
2. Mueller, G.C., Mone, M.A., Barker, V.L., III.: Formal strategic analyses and organizational performance: decomposing the rational model. Organ. Stud. **28**, 853–883 (2007). https://doi.org/10.1177/0170840607075262
3. Lorentz, H., Hilmola, O.-P., Malmsten, J., Srai, J.S.: Cluster analysis application for understanding SME manufacturing strategies. Expert Syst. Appl. **66**, 176–188 (2016). https://doi.org/10.1016/j.eswa.2016.09.016

4. Gebauer, C.J.H.S.: Business model innovation in the water sector in developing countries. Sci. Total Environ. **488–489**, 512–520 (2014). https://doi.org/10.1016/j.scitotenv.2014.02.046
5. Barney, J.B.: Is the resource-based "view" a useful perspective for strategic management research? Yes. Acad. Manag. Rev. **26**, 41–56 (2001). https://doi.org/10.5465/AMR.2001.4011938
6. Anand, G., Ward, P.T.: Fit, flexibility and performance in manufacturing: coping with dynamic environments. Prod. Oper. Manag. **13**, 369–385 (2004). https://doi.org/10.1111/j.1937-5956.2004.tb00224.x
7. Jardioui, M., Garengo, P., El Alami, S.: How organizational culture influences performance measurement systems in SMEs. Int. J. Product. Perform. Manag. **69**, 217–235 (2020). https://doi.org/10.1108/IJPPM-10-2018-0363
8. Fréchet, M., Goy, H.: Does strategy formalization foster innovation? Evidence from a French sample of small to medium-sized enterprises. M@n@gement **20**, 266–286 (2017). https://doi.org/10.3917/mana.203.0266
9. Peillon, S., Dubruc, N., Mansour, M.: Service and customer orientation of corporate culture in a French manufacturing SME. Procedia CIRP **73**, 91–95 (2018)
10. Neuhüttler, J., Woyke, I.C., Ganz, W.: Applying value proposition design for developing smart service business models in manufacturing firms. In: Freund, L., Cellary, W. (eds.) Advances in The Human Side of Service Engineering, pp. 103–114. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-60486-2_10
11. Noke, H., Hughes, M.: Climbing the value chain: strategies to create a new product development capability in mature SMEs. Int. J. Oper. Prod. Manag. **30**, 132–154 (2010). https://doi.org/10.1108/01443571011018680
12. Shipton, H., West, M.A., Dawson, J., et al.: HRM as a predictor of innovation. Hum. Resour. Manag. J. **16**, 3–27 (2006). https://doi.org/10.1111/j.1748-8583.2006.00002.x
13. Leitner, K.-H., Güldenberg, S.: Generic strategies and firm performance in SMEs: a longitudinal study of Austrian SMEs. Small Bus. Econ. **35**, 169–189 (2010). https://doi.org/10.1007/s11187-009-9239-x
14. Hossain, M., Kauranen, I.: Open innovation in SMEs: a systematic literature review. J. Strateg. Manag. **9**, 58–73 (2016). https://doi.org/10.1108/JSMA-08-2014-0072
15. Visnjic, I., Wiengarten, F., Neely, A.: Only the brave: product innovation, service business model innovation, and their impact on performance. J. Prod. Innov. Manag. **33**, 36–52 (2016). https://doi.org/10.1111/jpim.12254
16. Foss, N.J., Saebi, T.: Fifteen years of research on business model innovation: how far have we come, and where should we go? J. Manag. **43**, 200–227 (2017). https://doi.org/10.1177/0149206316675927
17. Ongena, G., Ravesteyn, P.: Business process management maturity and performance: a multi group analysis of sectors and organization sizes. Bus. Process Manag. J. **26**, 132–149 (2020). https://doi.org/10.1108/BPMJ-08-2018-0224
18. Christiansen, T., Berry, W.L., Bruun, P., Ward, P.: A mapping of competitive priorities, manufacturing practices, and operational performance in groups of Danish manufacturing companies. Int. J. Oper. Prod. Manag. **23**, 1163–1183 (2003). https://doi.org/10.1108/01443570310496616
19. Ibarra, D., Ganzarain, J., Igartua, J.I.: Business model innovation through Industry 4.0: a review. Procedia Manuf. **22**, 4–10 (2018)

Weaknesses Supply Chain Response Frameworks

Raúl A. Díaz Pacheco[1](✉) and Ernest Benedito[2]

[1] Department of Social Sciences, Universidad Nacional de Colombia, Cra. 32 # 12 - 00, Palmira, Valle del Cauca, Colombia
radiazpa@unal.edu.co
[2] Department of Management, Institute of Industrial and Control Engineering, Universidad Politécnica de Catalunya, Avinguda Diagonal, 647, Barcelona, Spain
ernest.benedito@upc.edu

Abstract. Managers are challenged to make decisions that facilitate the supply chain's response to the stimuli it faces daily. The response affects both the supply chain and the beneficiaries of the response. Several frameworks have been proposed by the scientific community to help supply chain managers improve decision-making in response. In this work, a qualitative analysis of existing supply chain response frameworks was conducted to identify the characteristics and weaknesses among them. Weaknesses are clues to be considered in the design, construction, and validation of a general framework for supply chain response. The general framework is applicable in any field in which the supply chain has to respond.

Keywords: Supply chain response · Supply chain response framework · Framework

1 Introduction

According to [1] an unexpected occurrence like natural calamity and abrupt changes in customer demand is the most challenging issue even for the efficient global supply chain management. [2] asserted that the supply chain (SC) copes with any kind of event like a fire at a manufacturing plant or delay in the arrival of goods. For all stimuli commented previously the SC must respond. The concept of Supply Chain Response (SCR) is defined in [3] as "the response of the supply chain is the adaptation of the supply chain activity to the stimuli it receives, to simultaneously meet certain objectives and those of the supply chain assessing the adaptation for the time elapsed between the occurrence of the stimulus and the fulfillment of the determined objective".

According to [4] an SC concept that is being designed or built must have a structure for its implementation. The structure is called a framework. Several frameworks dealing with SCR are found in the literature. [5] and [6] proposed 2 frameworks for assessing SCR. [7] and [1] proposed conceptual frameworks for investigating SCR. However, in the literature, the absence of an analysis of the characteristics of the frameworks that treat SCR was identified.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 88–92, 2023.
https://doi.org/10.1007/978-3-031-27915-7_17

The research carried out aims at analyzing the characteristics of the frameworks dealing with SCR. Feature analysis is done to identify weaknesses in frameworks of the SCR. The weaknesses are clues to consider to propose general SCR frameworks applicable in any field of SC and for any research purpose. A literature review was conducted to identify frameworks that address SCR. The characteristics of frameworks dealing with SCR were analyzed qualitatively. This article is composed of the following sections: number 2 details the methodology applied for the development of this research, Sect. 3, deals with the features of supply chain response frameworks; Sect. 4 comprises the results and discussion, and finishes with Sect. 5 conclusion and future research.

2 Methodology

A literature review on supply chain response was made up from 1996–2020 on the databases Scopus and Web of Science. The keywords applied to select the base documents for this research were "responsiveness, response, responsive". The total number of articles found was 983. The selection of the articles was carried out by applying three steps. The first step consisted of reviewing the title, abstract, and body of the article to determine if it shows a frame of reference. The total number of articles discarded was 756. The second step consisted of reviewing the remaining 227 papers to confirm that the framework addresses the SCR; in this step, a total of 160 papers were discarded. The last step was to confirm that 67 documents in which SCR frameworks are proposed meet the following conditions proposed by [4].

- A framework must depict the complete structure of relationships between elements of the system under study and not just suggest elements comprising the system.
- A framework must describe steps/stages/sequence of activities that are required to be used for the designated purpose.
- A framework must describe the activities involved, which connect various elements of the framework.

The 16 articles that meet the three criteria mentioned above were fully read to identify aspects such as SC topic in which the framework was proposed, novelty, and verification mode of the framework dealing with SCR.

3 Features of Supply Chain Response Frameworks

Of the 16 articles mentioned in the previous section, only 6 were selected since they broadly explained each detail of the criteria mentioned above. The rest of the articles contain partial explanations of one or two of the criteria, but not of the 3; moreover, these explanations are also contained in the 6 selected frameworks.

The characteristics analyzed in the 6 selected frames were the topic in which the SCR was investigated, the novelty of the framework, and the validation mode of the framework. Table 1 shows the characteristics of the frameworks dealing with SCR that were analyzed in this research.

The frameworks analyzed were proposed to respond to the increase in demand. The increase in demand is an external stimulus that affects the supply chain.

Frameworks have been proposed to improve SCR. For this, several aspects that influence the management of the SC have been analyzed and improved such as the order fulfillment process, the competitive strategy of the SC, the response to the customer, and the evaluation of the SCR.

Table 1. Characteristics of SCR frameworks.

Author	Year	Topic	Novelty of framework	Mode validation
Kritchanchai and MacCarthy [5]	1999	Order fulfillment process	New	Interview Case study
Wong *et al.* [6]	2006	Assessing responsiveness	New	Case study
Reichart and Holweg [7]	2007	Customer responsiveness	New	Not verified
Gunasekaran, Lai and Edwin Cheng [8]	2008	Competitive strategy	New	Case study
Sinha, Swati and Anand [1]	2015	Supply chain responsiveness	Adapted	Not verified
Yu *et al.* [9]	2018	Supply chain	New	Survey Interview

Columns 1 – 2 show the author and the year respectively. Column 3 shows the topic of the framework of the SCR. Column 4 shows which frameworks are new or adapted. Column 5 shows the mode of verification used to validate the framework. Each row contains an analyzed SCR framework

Five frameworks dealing with SCR are new and one is adapted. The adapted framework is based on the combination of other SCR frameworks. Column 4 of Table 1 shows the new frames and the adapted frame.

The modes used to validate the framework were a survey, interview, and case study. Column 5 of Table 1 shows the frames that deal with the SCR that was validated and the validation mode. Validation facilitates improvement and applicability of the framework.

4 Results and Discussion

The frameworks analyzed in Sect. 3 have been proposed for supply chains that respond to external stimuli and are circumscribed to the manufacturing function. In addition, the frameworks deal with particular situations in the supply chain. Also, it has been observed that the research is focused on the management of the response and not so much on the evaluation of the result of the response.

The analysis of the characteristics of the frameworks that deal with SCR facilitated the identification of the weaknesses that the frameworks have, in the sense that those frameworks do not meet one of the requirements demanded. Namely, that it should be of general application and not only in some activity of the chain or for some stimuli received. To determine if a framework is of general application, various aspects of the framework were analyzed, such as the stimulus to which the supply chain responds, the SC activities that are part of the framework if the framework is proposed and used by academics, professional or consultants, objectives that the SC achieves with the response to the stimulus and the validation of the framework. The weaknesses identified in the frameworks that deal with SCR are detailed below:

- The proposed SCR frameworks do not take into account the response to external stimuli such as natural disasters or internal stimuli such as a machine breakdown.
- Activities that SC adapts to respond to a stimulus are not included in all frameworks dealing with SCR.
- No SCR frameworks have been proposed for other SC functions such as storage or distribution. Neither did we find frameworks that covered several SC functions such as supply, production, and distribution.
- There is a lack of frameworks dealing with SCR proposed by SC professionals and consultants.
- The frameworks dealing with SCR do not include objectives that are imposed on SC such as compliance with environmental regulations and social responsibility objectives.
- Frameworks dealing with SCR that have not been validated have no improvement option.

In summary, there is a lack of a general SCR framework that can be applied to any type of stimulus that affects SC, that involves any SC process, that takes into account SC objectives other than financial, performance and service level objectives, that includes various SCR outputs.

5 Conclusion and Future Research

Various authors have proposed frameworks that address SCR. However, no research was known to address the identification of weaknesses in these frameworks. In this work, the existing frameworks that deal with SCR in the scientific literature have been reviewed and the 6 most representative were selected to be analyzed in detail. Characteristics such as the supply chain process in which it was proposed, the novelty and validation of each framework were analyzed. In addition, framework weaknesses were identified. Continuing to investigate SCR based on frameworks with the aforementioned weaknesses may have some consequences for supply chain academics, practitioners, and consultants, such as fragmented development of the SCR concept, making it difficult to compare and evaluate the responses provided by distinct supply chains to the same stimulus or delay in the development of the general theory of SCR.

The main limitation of this research is the way in which the frameworks that were analyzed were selected. This selection was made at the discretion of the authors, which could result in the exclusion of papers that could help better identify the weaknesses in frameworks dealing with SCR. In this sense, a future line of research is to apply various selection criteria for frameworks dealing with SCR to improve the identification of weaknesses. Additionally, supply chain stakeholders could determine the standard components of a SCR applying statistical techniques. Also, it is a research topic to define the relationships between the components of a general SCR framework. Likewise, it could be explored in a general framework of SCR, how to evaluate the response to a stimulus. Finally, determining the criteria that facilitate the comparison of the response given by the distinct supply chains to a stimulus using a general framework of SCR is a gap that must be filled by future research.

References

1. Sinha, A., Swati, P., Anand, A.: Responsive supply chain: modeling and simulation. Manag. Sci. Lett. **5**(6), 639–650 (2015). https://doi.org/10.5267/j.msl.2015.4.001
2. Mandal, S., Sarathy, R., Mishra, V., Bhattacharya, S., Dastidar, S.G.: Supply chain responsiveness: a relational capability perspective. Int. J. Appl. Manag. Sci. **7**(3), 244–268 (2015)
3. Díaz, R.A., Benedito, E.: Supply chain response: proposal for a general definition. In: Avilés-Palacios, C., Gutierrez, M. (eds.) Ensuring Sustainability New Challenges for Organizational Engineering, 1st edn., vol. 1, pp. 71–83. Springer (2022). https://doi.org/10.1007/978-3-030-95967-8_6
4. Soni, G., Kodali, R.: A critical review of supply chain management frameworks: proposed framework. Benchmarking Int. J. **20**(2), 263–298 (2013). https://doi.org/10.1108/14635771311307713
5. Kritchanchai, D., MacCarthy, B.L.: Responsiveness of the order fulfillment process. Int. J. Oper. Prod. Manag. **19**(8), 812–833 (1999). https://doi.org/10.1108/01443579910274419
6. Wong, C.Y., Stentoft Arlbjørn, J., Hvolby, H.H., Johansen, J.: Assessing responsiveness of a volatile and seasonal supply chain: a case study. Int. J. Prod. Econ. **104**(2), 709–721 (2006). https://doi.org/10.1016/j.ijpe.2004.12.021
7. Reichart, A., Holweg, M.: Creating the customer-responsive supply chain: a reconciliation of concepts. Int. J. Oper. Prod. Manag. **27**(7), 1144–1172 (2007). https://doi.org/10.1108/01443570710830575
8. Gunasekaran, A., Hung Lai, K., Edwin Cheng, T.C.: Responsive supply chain: a competitive strategy in a networked economy. Omega **36**(4), 549–564 (2008). https://doi.org/10.1016/j.omega.2006.12.002
9. Yu, W., Chavez, R., Jacobs, M.A., Feng, M.: Data-driven supply chain capabilities and performance: a resource-based view. Transp. Res. Part E Logist. Transp. Rev. **114**, 371–385 (2018). https://doi.org/10.1016/j.tre.2017.04.002

Deep Reinforcement Learning for the Job Shop Scheduling Problem: Reference Axes for Modelling, Implementation and Validation

Julio C. Serrano-Ruiz(✉), Josefa Mula, and Raúl Poler

Centro de Investigación en Gestión e Ingeniería de la Producción (CIGIP), Universitat Politècnica de València, 03801 Alcoy, Spain
{jserrano,fmula,rpoler}@cigip.upv.es

Abstract. The purpose of this paper is to indicate how the association of deep learning with reinforcement learning, known as deep reinforcement learning (DRL), influences recent research on one of the most representative problems in the production planning and control (PPC) area, the job shop scheduling problem (JSSP), by identifying both the main approaches and tools applied in its modelling, implementation and validation, and the direction in which future research moves.

Keywords: Job shop · Scheduling · Deep reinforcement learning

1 Introduction

The relatively recent arrival of some machine-learning methods, such as deep reinforcement learning (DRL), allows the challenge posed by the dynamic and stochastic job shop scheduling problem (JSSP) to be addressed from a novel and promising perspective that is very rapidly evolving. The use of neural networks has enabled DRL to significantly reduce computational times and increase efficiency in relation to conventional reinforcement learning methods. In some specific JSSP scenarios described in the literature, moreover, it has already managed to match, or even surpass, other resolution methods such as the heuristic rules [1], exact solvers [2] or some metaheuristics [3]. This evolution is further supported by the proliferation of specialised software libraries published with open-source licences [4] that facilitate access to DRL by increasing its application potential. This article shows how this evolution of DRL methods helps to address the challenges posed by JSSP by identifying the main reference models currently present in the literature and classifying them according to the approaches and tools applied for their modelling, implementation and validation. In addition, future research lines are established.

2 Literature Review

The application of the DRL methodology to solve JSSP has evolved rapidly. The first significant research to model this type of problem dates back to 2018. Query number

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 93–100, 2023.
https://doi.org/10.1007/978-3-031-27915-7_18

one performed in the Scopus database (Table 1) provided 42 results, while query number two in Web of Science (Table 1) provided 20 results, the majority of which, 15, were already included among the 42 found in Scopus. Each of these first 47 results was dated in 2018 or later. The task of refining these first results consisted mainly of eliminating those whose object was not the job scheduling on machines in an industrial job shop. Results whose approach was merely conceptual or descriptive, partial or poorly defined modelling, or literature reviews were also excluded. After this filtering, a total of 14 results were selected.

Table 1. Search query data

Query/Database		Query	Results
1	Scopus	TITLE-ABS-KEY ((“job shop” OR “job-shop” OR jobshop) AND schedul* AND (“deep reinforcement learning” OR drl))	42
2	Web of Science	((“job shop” OR “job-shop” OR jobshop) AND schedul* AND (“deep reinforcement learning” OR drl)) (Title) OR ((“job shop” OR “job-shop” OR jobshop) AND schedul* AND (“deep reinforcement learning” OR drl))) (Abstract) OR ((“job shop” OR “job-shop” OR jobshop) AND schedul* AND (“deep reinforcement learning” OR drl))) (Author Keywords)	20
3	Scopus	TITLE-ABS-KEY ((“job shop” OR “job-shop” OR jobshop) AND schedul* AND (“machine learning”))	127
4	Web of Science	((“job shop” OR “job-shop” OR jobshop”) AND schedul* AND “machine learning”) (Title) OR ((“job shop” OR “job-shop” OR jobshop”) AND schedul* AND “machine learning”) (Abstract) OR ((“job shop” OR “job-shop” OR jobshop) AND schedul* AND “machine learning”) (Author Keywords)	42

In addition, query number three (Table 1) was searched in Scopus, with 127 results, and query number four (Table 1) in Web of Science, with 42 results, in order to identify among all of them, as a first refinement filter, only those results related to DRL methods that in their title, abstract or keywords used machine learning as a denominative keyword instead of expressly using DRL. Subsequently, after doing the same second filtering process as with searches one and two to identify the relevant results, five more were obtained which, together with the 14 previous ones, made a total of 19 results.

3 Analysis of Reference Models

In the selected literature, modelling of the JSSP from the DRL methodology perspective is characterised mainly by: (i) the order arrival regimes adopted in modelling and its validation process; (ii) the extensions formulated to the basic JSSP problem; (iii) the DRL framework used in development; (iv) the tools for building the JSSP environment; (v) the defining features of JSSP states; (vi) the approach adopted for the action applied to the environment; (vii) the reward calculation approach; (viii) the type of DRL algorithm employed; and (ix) the benchmarks adopted as a basis for comparatively validating the proposed model. Table 2 shows the proposed classification.

4 Discussion

The following trends can be highlighted for the modelling approach to JSSP using the DRL methodology. Regarding the degree of fidelity with which the model reproduces the real JSSP, a significant number of researchers introduce dynamic arrival of orders on a rolling time horizon into modelling (10), although very few also introduce it into the validation of models (2), which is carried out mostly with static or partially dynamic models (17). Another important researchers group chooses to introduce extensions into the basic problem (8), including the introduction of machine breakdowns (2) and the cost of energy (3). As for the commercial tools used in modelling and implementation, the Python programming language and/or its specialised open-source libraries have been indicated by the majority (10) among those indicating tools, while the rest (7) do not state any of the used tools (7). Regarding modelling the problem as a Markov decision process, especially as regards the definition of states, actions and rewards, three main trends in the definition of states are identified: (i) bringing together the complex features of three elements of the problem or more (8); (ii) using simpler states that derive only from the features of jobs, machines and/or the scheduling state (10); (iii) employing disjunctive graphs (1). Regarding actions, we observe that, although there are variations, the main preferences are deciding the next operation (9) or a dispatching rule (6). On reward modelling, almost all the analysed articles (17) calculate local rewards after each action, but only a few (6), especially those presenting static models, add a final reward after the episode ends. Besides, multi-objective models (11) are commoner than those that take makespan as the only objective (7). On the DRL algorithm choice, the commonest one (9) is the deep Q-network (DQN) and its variants, which is the simplest one and is characterised as a value-based method. Only one of the selected papers opts for a policy-based method, the REINFORCE algorithm. A considerable number of the remaining select more advanced actor-critic methods, such as DDPG (2), PPO (5) or SAC (1). Finally, regarding the stringency applied to select validation methods, we can identify, on the one hand, some works that compare their models only to heuristic rules or very basic methods like Q-learning (5) and, on the other hand, those that use more complex and demanding validation schemes, such as exact solvers, metaheuristics, or even other DRL algorithms (14).

Table 2. Approaches and tools for DRL modelling, implementation, and validation of JSSP

Reference		Entry order flow to model/to validate	JSSP extensions	DRL framework	JSSP environment	JSSP state features	Action approach	Reward approach	DRL algorithm	Baseline benchmarks for validation
1	Altenmüller et al., 2020 [4]	D/D	Strict time constraints	Keras-RL	–	M/J	J/I	L/G/M	DQN	Two heuristic rules
2	Du et al., 2022 [1]	S/S	Electricity constraint	–	–	D/S/O	R	L/M	DQN	Random actions; HMOEA/D, TPM, and BEG-NSGA-II algorithms; exact CPLEX solver
3	Han and Yang, 2021 [5]	D/S	–	–	–	S/M/J	M/J	–	REINFORCE	Nine heuristic rules
4	Kuhnle et al., 2019 [6]	D/D	–	Tensorforce	SimPy DES	S/B	M/B/I	L/M	TRPO	Heuristic rules
5	Lang et al., 2020 [3]	S/S	Integrated process planning	–	Salabim DES	S/J	M/S	L/G/M	DQN	GRASP metaheuristic
6	Li et al., 2022 [1]	D/P	Energy costs and AGV	PyTorch	–	S/M/J	RU	L/M	Hybrid DQN	Heuristic rules, incomplete HDQN, Q-learning with SOM, HDQN with common rules
7	Liu et al., 2020 [6]	D/S	–	–	–	S/J	RU	L/M	DDPG	Heuristic rules, GA, Q-learning, optimal solution
8	Luo, 2020 [7]	D/P	Machine breakdowns	–	MATLAB	S/M/J	RU	L/M	DDQN	Heuristic rules, Q-learning

(*continued*)

Table 2. (*continued*)

Reference		Entry order flow to model/to validate	JSSP extensions	DRL framework	JSSP environment	JSSP state features	Action approach	Reward approach	DRL algorithm	Baseline benchmarks for validation
9	Luo et al., 2021a [8]	D/S	–	–	–	J	J	L/G/M	DDQN	Optimal solution, multi-agent Q-learning, actor-critic DRL algorithm
10	Luo et al., 2021b [9]	D/P	Machine breakdowns	Python	Python	S/M/J	RU/M	L/M	PPO	12 heuristic rules; HEFT and GRASP algorithms; DDQN; PSO and NSGA-II metaheuristics
11	Park et al., 2020 [10]	S/S	Setup changes	–	Unspecified DES	S	M/J	L	DQN	GA, two-phase DQN, heuristic rules
12	Park and Park, 2021 [11]	D/P	–	Python	Python	S/M	J	L	DDPG	GASCO, two-stage genetic algorithm, eight heuristic rules, DQN for job selection, DQN for rule selection
13	Popper et al., 2021 [12]	S/S	Energy costs	–	–	S/M/O	–	L/G	PPO	Two heuristic rules
14	Samsonov et al., 2021 [13]	S/S	–	Python	Python	S/M/J	T	G	DQN SAC*	Two heuristic rules, exact CP-SAT solver of OR-Tools * SAC method is not validated

(*continued*)

Table 2. (*continued*)

Reference		Entry order flow to model/to validate	JSSP extensions	DRL framework	JSSP environment	JSSP state features	Action approach	Reward approach	DRL algorithm	Baseline benchmarks for validation
15	Tassel et al., 2021 [14]	S/S	–	RLlib via Ray	Open AI Gym	J	J/I	L	PPO	Two heuristic rules, exact solver of Google OR-Tools, REINFORCE method of Han and Yang [2], GNN method of Zhang et al. [15]
16	Wang et al., 2021 [16]	S/S	–	–	–	M/J	J	L/M	PPO	Three heuristic rules, GA
17	Zhang et al., 2020 [15]	S/S	–	PyTorch	Python	G	J	L	PPO-GNN	Four heuristic rules, exact solver of Google OR-Tools
18	Zhao et al., 2021 [17]	D/P	–	Python	Python	S/M/J	RU	L	DQN	Nine heuristic rules; Q-learning; HIA, GA, Tabu search, and IPSO algorithms
19	Zhao and Zhang, 2021 [18]	S/S	–	–	–	S/J	J/RU	L/G/M	DQN	GA

Note. Abbreviations for model classification. Entry order flow to model/to validate: **S** (static), **P** (partially dynamic), **D** (dynamic); JSSP state features: **D** (problem size or dimension), **S** (scheduling status), **M** (machine status), **B** (buffer status), **J** (job features), **O** (objectives achievement status), **G** (disjunctive graph); action approach: **M** (machine allocation), **B** (**buffer** allocation), **J** (job selection), **S** (sequence selection), **I** (idle state), **R** (scheduling reconfiguration), **RU** (dispatching rule selection), **T** (calculating the processing time of the following operation); reward approach: **L** (local), **G** (global), **M** (multi-objective); finally, "**–**" indicates that no information about this is available. **Abbreviations for DRL algorithms. DQN** (deep Q-network), **DDQN** (double deep Q-network), **TRPO** (trust region policy optimisation), **DDPG** (deep deterministic policy gradient), **PPO** (proximal policy optimisation), **PPO-GNN** (proximal policy optimisation for graph neural network), **SAC** (soft actor-critic). **Abbreviations for baseline benchmarks. HMOEA/D** (hybrid multi-objective evolutionary algorithm based on decomposition), **TPM** (two-phase metaheuristic), **BEG** (bee evolutionary guiding), **NSGA-II** (non-dominated sorting genetic algorithm II), **GRASP** (greedy randomised adaptive search procedure), **HDQN** (hysteretic deep Q-network), **SOM** (self-organising map), **GA** (genetic algorithm), **HEFT** (heterogeneous earliest finish time algorithm), **PSO** (particle swarm optimisation), **GASCO** (genetic algorithm simulation for codon optimisation), **HIA** (human-inspired algorithm), **IPSO** (immune particle swarm optimisation). **Other acronyms. AGV** (automated guided vehicle), **DES** (discrete-event simulation)

5 Conclusions

This article identifies and presents the main reference models that currently exist for the JSSP approach using the DRL methodology and provides details of the main approaches and tools applied in its modelling, implementation and validation. Based on this information, it introduces the axes of references that mark discussion in terms of: reproduction of the real problem; the software tools used; definition of states, actions and rewards; DRL algorithm; and the validation method.

The main benefit of this article is that it presents the modelling, implementation and validation trends that currently shape research in the field under study to support new research by assisting in not only the selection of approaches, methods and tools, but also the location of reference models. Academics and practitioners can use these referential axes as a baseline for conceptualising, designing, developing, implementing, and validating new DRL models, specifically, aimed at addressing JSSP. Conversely, one of the main limitations of this research stems from the lack of information, in a significant part of the selected literature, on the software tools used to develop DRL models. These tools have a meaningful impact on the performance of the algorithms, and this information could enrich the knowledge on this subject. The forthcoming work aims to examine in-depth critical discussion about the findings so that, in addition to knowing the approaches, methods and tools, their benefits and limitations can be understood and, thus, serve as a basis for the mathematical implementation of a new smart manufacturing scheduling [19, 20] model for a real-world JSSP.

Acknowledgments. The research leading to these results received funding from the Regional Department of Innovation, Universities, Science and Digital Society of the Generalitat Valenciana entitled "Industrial Production and Logistics Optimization in Industry 4.0" (i4OPT) (Ref. PROMETEO/2021/065)", and from the European Union H2020 programs with grant agreements No. 825631 "Zero-Defect Manufacturing Platform (ZDMP)", No. 872548 "Fostering DIHs for Embedding Interoperability in Cyber-Physical Systems of European SMEs (DIH4CPS)", and No. 958205 "Industrial Data Services for Quality Control in Smart Manufacturing (i4Q)".

References

1. Li, Y., Gu, W., Yuan, M., Tang, Y.: Real-time data-driven dynamic scheduling for flexible job shop with insufficient transportation resources using hybrid deep Q network. Rob. Comput.-Integr. Manuf. (2022). https://doi.org/10.1016/j.rcim.2021.102283
2. Du, Y., Li, J., Chen, X., Duan, P., Pan, Q.: Knowledge-based reinforcement learning and estimation of distribution algorithm for flexible job shop scheduling problem. IEEE Trans. Emerg. Top. Comput. Intell. 1–15 (2022)
3. Lang, S., Behrendt, F., Lanzerath, N., Reggelin, T., Muller, M.: Integration of deep reinforcement learning and discrete-event simulation for real-time scheduling of a flexible job shop production. In: Proceedings - Winter Simulation Conference, pp 3057–3068 (2020)
4. Altenmüller, T., Stüker, T., Waschneck, B., Kuhnle, A., Lanza, G.: Reinforcement learning for an intelligent and autonomous production control of complex job-shops under time constraints. Prod. Eng. Res. Devel. **14**, 319–328 (2020)
5. Han, B.A., Yang, J.J.: A deep reinforcement learning based solution for flexible job shop scheduling problem. Int. J. Simul. Model. **20**, 375–386 (2021)

6. Kuhnle, A., Schäfer, L., Stricker, N., Lanza, G.: Design, implementation and evaluation of reinforcement learning for an adaptive order dispatching in job shop manufacturing systems. Procedia CIRP **81**, 234–239 (2019)
7. Liu, C.L., Chang, C.C., Tseng, C.J.: Actor-critic deep reinforcement learning for solving job shop scheduling problems. IEEE Access **8**, 71752–71762 (2020)
8. Luo, S.: Dynamic scheduling for flexible job shop with new job insertions by deep reinforcement learning. Appl. Soft Comput. J. (2020). https://doi.org/10.1016/j.asoc.2020.106208
9. Luo, S., Zhang, L., Fan, Y.: Real-time scheduling for dynamic partial-no-wait multi-objective flexible job shop by deep reinforcement learning. IEEE Trans. Autom. Sci. Eng. (2021). https://doi.org/10.1109/TASE.2021.3104716
10. Luo, B., Wang, S., Yang, B., Yi, L.: An improved deep reinforcement learning approach for the dynamic job shop scheduling problem with random job arrivals. J. Phys: Conf. Ser. (2021). https://doi.org/10.1088/1742-6596/1848/1/012029
11. Park, I.B., et al.: A reinforcement learning approach to robust scheduling of semiconductor manufacturing facilities. IEEE Trans. Autom. Sci. Eng. (2020). https://doi.org/10.1109/TASE.2019.2956762
12. Park, I., Park, J.: Scalable scheduling of semiconductor packaging facilities using deep reinforcement learning. IEEE Trans. Cybern. (2021). https://doi.org/10.1109/TCYB.2021.3128075
13. Popper, J., Motsch, W., David, A., Petzsche, T., Ruskowski, M.: Utilizing multi-agent deep reinforcement learning for flexible job shop scheduling under sustainable viewpoints. In: International Conference on Electrical, Computer, Communications and Mechatronics Engineering, ICECCME 2021 (2021). https://doi.org/10.1109/ICECCME52200.2021.9590925
14. Samsonov, V., et al.: Manufacturing control in job shop environments with reinforcement learning. In: ICAART 2021 - Proceedings of the 13th International Conference on Agents and Artificial Intelligence, pp 589–597 (2021)
15. Tassel, P., Gebser, M., Schekotihin, K.: A Reinforcement Learning Environment for Job-Shop Scheduling. arXiv:2104.03760 (2021). https://doi.org/10.48550/arXiv.2104.03760
16. Zhang, C., Song, W., Cao, Z., Zhang, J., Siew, T.P., Xu, C.: Learning to dispatch for job shop scheduling via deep reinforcement learning. Adv. Neural. Inf. Process. Syst. **33**, 1621–1632 (2020)
17. Wang, L., et al.: Dynamic job-shop scheduling in smart manufacturing using deep reinforcement learning. Comput. Netw. (2021). https://doi.org/10.1016/j.comnet.2021.107969
18. Zhao, Y., Wang, Y., Tan, Y., Zhang, J., Yu, H.: Dynamic jobshop scheduling algorithm based on deep Q network. IEEE Access **9**, 122995–123011 (2021)
19. Zhao, Y., Zhang, H.: Application of machine learning and rule scheduling in a job-shop production control system. Int. J. Simul. Model. **20**, 410–421 (2021)
20. Serrano-Ruiz, J.C., Mula, J., Poler, R.: Smart manufacturing scheduling: a literature review. J. Manuf. Syst. **61**, 265–287 (2021)
21. Serrano-Ruiz, J.C., Mula, J., Poler, R.: Development of a multidimensional conceptual model for job shop smart manufacturing scheduling from the Industry 4.0 perspective. J. Manuf. Syst. **63**, 185–202 (2022)

Industrial Eco-Productivity Tool: A Case Study of Industrial SMEs

Idoia Urain(✉), Daniel Justel, Joan Manuel F. Mendoza, and José Alberto Eguren

Faculty of Engineering, Mechanics and Industrial Production, Mondragon Unibertsitatea, Loramendi 4, 20500 Mondragon, Gipuzkoa, Spain
iurain@mondragon.edu

Abstract. This paper presents a new, unified method to measure and increase production and environmental performance in industrial SMEs (Small and Medium Enterprises), which have very limited resources, by identifying areas to improve and forming related projects. This structured, easy-to-apply method is based on standard systems to measure waste production efficiency and eco-efficiency and unifies them in a single reference value. In addition, a case study is shown where the industrial eco-efficiency of the company is obtained with the developed tool.

Keywords: Industrial eco-productivity · Production sustainability · Resource efficiency

1 Introduction

Resource productivity is understood as the ratio between the input and output of a transformation process, thus making it possible to evaluate the process's degree of efficiency. Therefore, it is necessary for companies to use metrics that reference information and temporal and spatial patterns to continuously evaluate production and environmental performance, as well as be able to quantify them easily and usefully to identify areas for improvement. However, due to SMEs' traditional lack of resources or awareness of their own ecological footprint or responsibility to protect the environment, research on SMEs and the environment has often highlighted their poor environmental performance. Despite this, environmental concern among SMEs has increased in recent years. Even so, eco-efficiency and win-win opportunities are often considered irrelevant by SMEs, who may be more motivated by personal concerns for the environment focusing on their lack of management teams and dependence on but a few individuals and the flexibility, informality, immediate issues, and uncertainty of the environment in which they operate. SMEs thus need tools that allow them to measure and act on production and environmental performance in a simple way, and that enable the development of sustainable manufacturing processes [1]. There are already researchers who have developed metrics applicable in production processes based on environmental and production aspects, including Overall Greenness Performance (OGP) [2] and Overall Environmental Equipment Effectiveness (OEEE) [3].

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 101–106, 2023.
https://doi.org/10.1007/978-3-031-27915-7_19

Organizations widely practise lean, to increase their productivity, reduce waste and address environmental impacts. Lean augments organizations by providing a toolbox of approaches to reduce waste, increase process productivity and advance organizational efficiency in industrial processes [4]. Furthermore, OEE is commonly used as a performance indicator of equipment utilization. It calculates equipment-level efficiency and equipment productivity relative to its maximum capacity, which is assumed constant over time period considered. It also determines the percentage of time spent producing defect-free products [5]. Considering the green and lean vision there are scholars like Muñoz-Villamizar [2] who have used OEE as a basis to develop other metrics through which they can evaluate the production and environmental behaviour of production processes, call OGP. However, despite its widespread use and success, OEE does not provide a global view at the production system level, nor does it distinguish the impact of specific equipment on overall performance [6]. Lastly, eco-efficiency is commonly defined as the relationship between the added value and aggregate environmental impact of a company's operational processes [7]. Generally, their objective is to reduce negative environmental impacts, but this is not enough as it is also necessary to improve efficiency and performance. Consequently, it is necessary for organizations to implement green and lean practices simultaneously, through which they can improve their business performance while generating environmental and economic benefits [8].

This paper shows the development and application of a new metric called Industrial Eco-productivity (IE) focused on the analysis and elimination of production and environmental waste. IE is i) self-assessable for SMEs, ii) intended for internal use, iii) simple and easy to use and iv) does not require external tools. In addition, it provides instant results.

2 Industrial Eco-Productivity Tool

The IE evaluation method for SMEs is a proposed improvement process that can continuously identify all process failures. It is composed of five phases, as shown in Fig. 1.

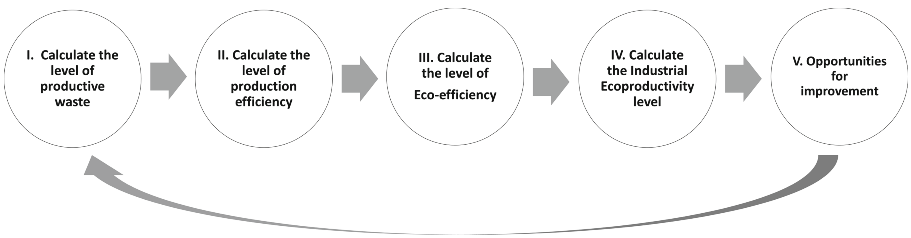


Fig. 1. IE method

I. Calculate the level of production waste

A company's production waste is qualitatively evaluated. The calculation is based on the eight wastes described by Verrier, Rose and Caillaud [9]. Each waste type consists of four levels, and each level has a score of 1.25. Based on the level of each waste type and that of the organization, overall waste can be calculated.

II. Calculate the level of production efficiency

The company must first determine the machine to be analysed. Then, it must collect information that reflects that machine's useful operating time. Accordingly, it is necessary to know the machine's calendar, loading time, operating time and net operating time [6] with which are calculated the availability, throughput, quality rate and performance efficiency are calculated [6].

III. Calculate the level of eco-efficiency

The company must determine the production system to be considered, performing an inventory analysis that considers the inputs and outputs of the production system and the number of good parts manufactured per year. Analyze items are: i) Materials, ii) Energy input, iii) Energy output, iv) Water input, v) Water output, vi) Air emissions, vii) Toxic waste and viii) Non-toxic waste.

IV. Calculate the level of IE

Based on the results obtained in the three previous sections, the company's level of IE is calculated.

$$\text{IE}(\%) = \text{Waste} * \text{Productive Efficiency} * \text{Eco - efficiency} \tag{1}$$

V. Opportunities for improvement

Once IE value is available, the organization must define an action plan to systematically improve it. To do this, the company sets improvement targets.

3 IE Case Study in SME

Forjas S.L. is a SME with 18 workers that supplies parts to the automotive auxiliary, food and pharmaceutical sectors. The company produces 600.000 bolts per year through a process of cutting, stamping and turning.

I. Level of production waste

To determine the company's productive waste, the production manager evaluated the levels of each production waste type using the evaluation questionnaire (Fig. 2). The aspects to improve were identified as overproduction, waiting and inventories.

Fig. 2. Evaluation of productive waste level

II. Production efficiency

The production manager next evaluated the collected waste information to calculate the chosen machine's useful operating time. Obtaining a 69.88% of production system's efficiency (Fig. 3). The areas to improve were related to increased availability by reducing changeover time and less breakdowns by reinforcing the facilities' maintenance management.

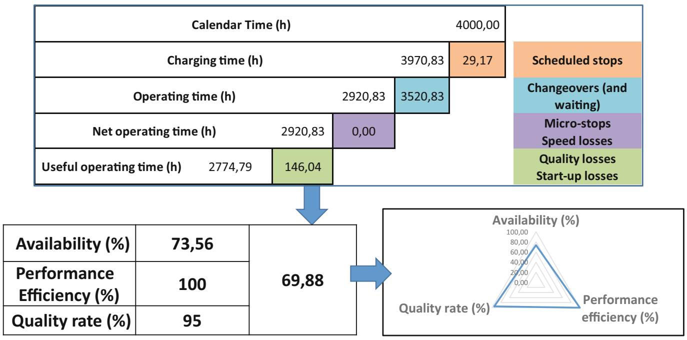


Fig. 3. Evaluation of production efficiency

III. Eco-efficiency

To obtain the eco-efficiency results, the production manager identified the necessary information and completed an inventory of natural resource use and emissions (Fig. 4).

As a result, the company's production eco-efficiency was 89.1%. The identified areas for improvement were related to reduced energy consumption.

Materials (%)	98,33	89,10
Energy (%)	48,33	
Water (%)	99,68	
Air emissions (%)	100,00	
Waste (%)	100,00	

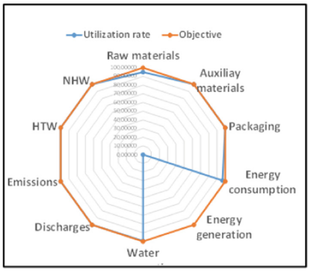


Fig. 4. Evaluation of Eco-efficiency

IV. IE level

As shown in Fig. 5 and based on the results obtained in the previous three steps, the company's IE was 42.81%.

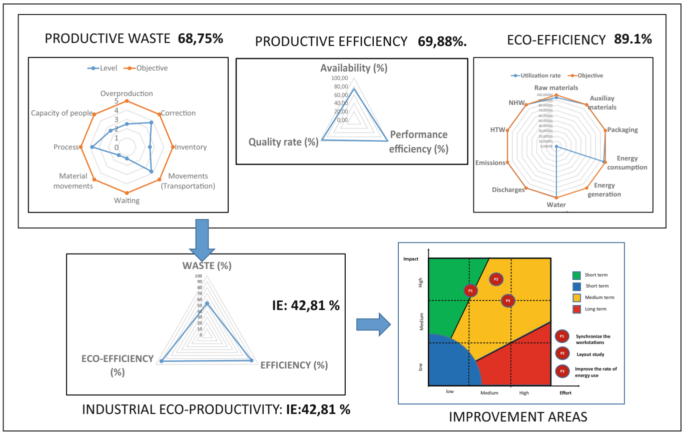


Fig. 5. IE operator panel

V. Opportunities for improvements

For improvements of the company, following was proposed: i) synchronize the workstations, to improve waiting time, overproduction, and inventories, ii) SMED usage, to improve facility availability by reducing changeover time, and iii) preventive maintenances, to reduce breakdowns.

4 Conclusions

It is concluded that the IE tool allows companies to analyze their current situation and consequently propose improvements. Likewise, the results obtained allow companies to calculate aspects such as their carbon footprint and circularity indicators. The proposed IE evaluation tool brings SMEs closer to working in the CE and improving environmentally, as they can apply the measure easily and individually without the need for experts or specific tools. Likewise, the results obtained allow companies to calculate aspects such as their carbon footprint and circularity indicators. IE is implemented in the CircularTRANS project.

Acknowledgements. The authors are grateful for the funding provided to CircularTRANS project by the Economic Promotion, Tourism and Rural Environment Department of Gipuzkoa region council.

References

1. Millard, D.: Management learning and the greening of SMEs: moving beyond problem-solving, Zeitschrift für Personalforschung (ZfP). German J. Res. Hum. Resour. Manag. **25**, 178–195 (2011). https://doi.org/10.1688/1862-0000
2. Muñoz-Villamizar, A., Santos, J., Montoya-Torres, J.R., Ormazábal, M.: Environmental assessment using a lean based tool. In: Borangiu, T., Trentesaux, D., Thomas, A., Cardin, O. (eds.) Service Orientation in Holonic and Multi-Agent Manufacturing. SCI, vol. 762, pp. 41–50. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-73751-5_4
3. Domingo, R., Aguado, S.: Overall environmental equipment effectiveness as a metric of a lean and green manufacturing system. Sustainability **7**, 9031–9047 (2015). https://doi.org/10.3390/SU7079031
4. Liker, J.K.: Las Claves del éxito Toyota. Ediciones Gestión 2000, Barcelona (2006)
5. Singh, R., Shah, D.B., Gohil, A.M., Shah, M.H.: Overall equipment effectiveness (OEE) calculation - automation through hardware & software development. Procedia Eng. **51**, 579–584 (2013). https://doi.org/10.1016/j.proeng.2013.01.082
6. Durán, O., Capaldo, A., Duran, P.A.: Sustainable overall throughputability effectiveness (S.O.T.E.) as a metric for production systems. Sustainability **10**, 362 (2018). https://doi.org/10.3390/su10020362
7. Huppes, G., Ishikawa, M.: Quantified Eco-Efficiency. Springer, Dordrecht (2007). https://doi.org/10.1007/1-4020-5399-1
8. Duarte, S., Cruz Machado, V.: Green and lean implementation: an assessment in the automotive industry. Int. J. Lean Six Sigma **8**, 65–88 (2017)
9. Verrier, B., Rose, B., Caillaud, E.: Lean and green strategy: the lean and green house and maturity deployment model. J. Clean. Prod. **116**, 150–156 (2016). https://doi.org/10.1016/j.jclepro.2015.12.022

Optimisation of Production Scheduling and Sequencing Problems in Industry 4.0

Marta Tarazona, Josefa Mula(✉), and Raul Poler

Research Centre on Production Management and Engineering (CIGIP), Universitat Politècnica de València, Alarcón, 1, 03801 Alcoy, Alicante, Spain
martate@etsid.upv.es, {fmula,rpoler}@cigip.upv.es

Abstract. This article presents an initial overview of optimisation models applied to production scheduling and sequencing in the Industry 4.0 (I4.0) environment. It reviews algorithms based on operational research technologies and artificial intelligence within an I4.0 framework; i.e. models and algorithms that simultaneously incorporate physical and digital Internet solutions, communications and data processing, and intelligence and management. The main findings of this article show that, despite many articles introducing I4.0 concepts or applying some of their principles to production scheduling and sequencing, a real interaction between the real-time data of the physical system and its simulation using digital twins (DTs) is still lacking. Finally, it is important to highlight that one of the most popular scheduling and sequencing approaches is the job shop and most articles are about cross-sector problems.

Keywords: Industry 4.0 · Scheduling · Sequencing · Production · Optimisation

1 Introduction

Instability in markets has become commonplace due to rapidly changing tech-nologies, environments, politics, societies, pandemics and changes in economy [1], such as Industry 4.0 (I4.0) results, COVID-19, global economic crises and military conflicts. In manufacturing, a paradigm shift has been taking place since 2011, the era of smart manufacturing, which promotes computerisation by combining three technological trends: connectivity, intelligence and flexible automation [2]. Scheduling is key for knowing the optimal allocation of manufacturing tasks and resources [3]. In sequencing, the order in which tasks are processed is determined. Here research into optimisation techniques has been a very active field in recent decades. Real-time optimisation is almost impossible in conventional manufacturing systems because it is based on real-time data and status information. Using digital twin (DT) and smart manufacturing technologies, real-time data and status information can be collected from the physical system, and a real-time model can be generated to perform scenario analyses for real-time decision making [4].

Although I4.0 paradigms have quite recently been formulated, the approach that deals with process simulations and optimisation is now well-established and is known as real-time optimisation [5]. The need noted in this article arises from the fact that an

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 107–112, 2023.
https://doi.org/10.1007/978-3-031-27915-7_21

overview of how I4.0 technologies are being developed and applied in the scheduling and sequencing context is lacking. The main purposes of this paper are to: (i) identify current advances and research gaps in production scheduling and sequencing in I4.0 in the scientific field from its history to evolution by a literature review; (ii) theoretically describe the existing optimisation models for the problem under study; (iii) set the main study implications in I4.0 terms by changing traditional production systems. As far as we know, no alternative similar reviews have yet been found. The remainder of the paper is structured as follows. Section 2 describes the review methodology. Section 3 presents an overview of the reviewed literature. Finally, Sect. 4 provides conclusions and further research.

2 Review Methodology

The beginnings of production scheduling and sequencing date back to the early 20th century, which makes it a very mature topic in the scientific community. Adding the I4.0 and DT concepts takes publications closer to the present-day because they are research topics that have become quite popular in the last two decades. The literature search included the words "schedule" and derivatives, "sequence" and derivatives, "optimization" and "optimisation", "industry 4.0" and "digital twin". This search was launched in article titles, abstracts and keywords. The search was conducted on 5 November 2021 in Scopus. The time window was set in articles published from 2010, when the I4.0 concept was emerging [6], to the search date. The search gave 222 publications. The selection of the articles to be reviewed was based on reading the abstracts and the following exclusion criteria applied: (i) not belonging to the production management and engineering/operations management area; (ii) conference reviews and literature reviews were excluded. Thus 31 publications were initially considered for this publication. It should be noted that 90% of these publications correspond to 2021 and the rest to 2020. These figures demonstrate the growing interest in this research area.

3 Literature Review

Articles were classified into scheduling and sequencing categories, and some appeared in them both. The research methodology in 68% of the reviewed articles was empirical. Four groups of empirical problems were identified: production, maintenance, supply chain and human-robot collaborative (HRC). Only two articles studied HRC in a production environment [7, 8] and both used simulation software. The first focused on maximising assembly efficiency and reducing operators' workload, and the second centred on autonomous intelligent robots and minimising the total tardiness of transportation tasks. Two articles dealt with the maintenance subject [9, 10]. Both used mathematical programming and metaheuristic approaches. The first sought to minimise the total system cost by real-time integrated production scheduling and maintenance-planning, while the other was an ensemble learning framework for predictive maintenance. Five articles addressed supply chain problems [3, 4, 11–13], specifically inventory management, production intralogistics, material supply, sequence dependent setup times and batch delivery in the supply chain and smart factor control system. As expected, most were related to production management and engineering [2, 5, 14–24].

Mathematical programming was the most widespread approach to model problems (52%), particularly: linear programming [5, 14]; constraint programming [3, 17]; mixed integer programming [9, 20]; mixed integer non-linear programming [12]; quadratic programming [10]; an integrated assignment and routing problem in matrix production systems by Bányai [4]; a multi-objective mathematical model by An et al. [22] and Zhang et al. [24]; a continuous algorithm in the discrete domain [15]; a linear, non-stationary, finite-dimensional controlled system [23]; non-linear quadratic programming [10]. Simulation models were also frequently used (38%) and the rest were presented as a combination of both. Bányai [4] and Zhang et al. [17] used simulation and mathematical programming models. Simulation models presented two main approaches: discrete-event simulation [2, 7, 8, 11, 16, 18, 19, 21] and system dynamics models [4, 13, 17]. Li and Huang [11] proposed a descriptive five-phase GiMS based on an assemble-to-order and multikind small-quantity mass-customized production mode. Two regression models were developed by Negri et al. [21], who proposed multivariate logistic regression, and by Gungor et al. [10], who converted time series sensor data into a regression problem. Mathematical programming models were solved by heuristics (30.8%) and meta-heuristics (69.2%), mostly with the MATLAB software. Otherwise, simulation models were modelled and solved by simulation software like Net Logo Software, Simevents, Simio and Simtalk.

While 48% focused only on one parameter for the function objective, the rest were a combination of several of them. The following were generally found: time-based focus on minimising makespan, total waiting time, total operation time, cycle time or improving lead-time; operation-based focus on maximising throughput, distribute workload or efficiency; cost-based focus on total cost minimisation.

Moreover, 26% of the articles dealt with the job shop problem [9, 13, 15, 17, 18, 22, 25, 26]. There was an initial conceptual framework of smart DTs for scheduling shop floor orders in a zero-defect manufacturing environment [25], as well as a new intelligent scheduling platform to solve shop scheduling problems based on DT technology and combined with the actual production line scheduling problem [26].

The main changes made in traditional systems and the implications that those changes suppose to the I4.0 empirical analysis were oriented to: use real-time data to optimise production schedules and maintenance plans in a dynamic and stochastic flexible job shop production environment [9]; discrete-event simulation for large-scale dynamic job shop scheduling problems to evaluate the performance of nine dispatching rules [18]; a physical platform for a microsmart factory to verify the applicability and effect of DTs to support information collection, operation control, management, among other functions [13]. The I4.0-related concepts that were most repeated in research were: the Internet of Things (IoT); DT and simulation; real time. While the three concepts together appeared in five articles, simulation and DT followed with four articles. The IoT concept and DT did not appear together unless the simulation concept was presented as a link between them.

The main research gaps found in the reviewed articles were: (i) lack of uncertainty analyses [3, 27]; (ii) scarcely addressing operative decision levels for specific study cases

[1, 9, 28]; (iii) no analyses of the underlying relations in real-time data [10, 11, 16]; (iv) several realistic constraints (e.g. variable processing times, buffer capacity constraints, material shortages, human resources and labour costs, spare parts and other limited resources) not being considered [8, 9, 12, 19, 22]; (v) the need for a more extensive exploration system to enhance DT completeness [2].

4 Conclusions

While many attack the problem with mathematical programming models, very few truly show a real relation to I4.0. Fourteen articles contribute significantly by combining the problem of scheduling or sequencing with I4.0. Reviewed articles are often not applied at the operative decision level, so they are not transferred to real production systems. Another aspect is that many reviewed approaches apply to one problem type (e.g., job shop problems), but can be extended to different production layouts. Many research works seek to optimise a single parameter, and can extend it to a multi-objective approach. Another characteristic is that many problems are modelled as linear ones, but leave aside the non-linearity that characterises real production problems, inherent stochastic parameters, or even more realistic constraints. Thus, traditional mathematical programming models co-exist with increasingly present simulation approaches with DTs, smart manufacturing and artificial intelligence, which are progressively overcoming some limitations of more traditional proposals. This means that the DT is generally conceived as a simulator and optimiser. Hence future research lines are oriented to: (i) study the problems in real industry study cases; (ii) extend approaches to different production layouts, for example, open shops and hybrid flow shops; (iii) transfer research and academic approaches to real production systems and apply it as a DT; simulation-based optimisation and a complete DT; (iv) extend to other modelling domains, such as logistics, planning and transportation; (v) extend to other decision levels, such as master production scheduling.

Acknowledgments. The research leading to these results received funding from the Regional Department of Innovation, Universities, Science and Digital Society of the Generalitat Valenciana entitled "Industrial Production and Logistics Optimization in Industry 4.0" (i4OPT) (Ref. PROMETEO/2021/065)", and from the European Union H2020 programs with grant agreements No. 825631 "Zero-Defect Manufacturing Platform (ZDMP)" and No. 958205 "Industrial Data Services for Quality Control in Smart Manufacturing (i4Q)".

References

1. Reschke, J., Gallego-García, S.: A novel methodology for assessing and modeling manufacturing processes. Appl. Sci. **11**(21), 10117 (2021). https://doi.org/10.3390/app112110117
2. Ganser, P., Landwehr, M., Schiller, S., Vahl, C., Mayer, S., Bergs, T.: Knowledge-based adaptation of product and process design in blisk manufacturing. http://asmedigitalcollection.asme.org/GT/proceedings-pdf/GT2021/85000/V007T17A012/6758417/v007t17a012-gt2021-59562.pdf

3. Suhartanto, J.F., García-Flores, R., Schutt, A.: An integrated framework for reactive production scheduling and inventory management. In: Scholz, S.G., Howlett, R.J., Setchi, R. (eds.) KES-SDM 2021. SIST, vol. 262, pp. 327–338. Springer, Singapore (2022). https://doi.org/10.1007/978-981-16-6128-0_31
4. Bányai, T.: Optimization of material supply in smart manufacturing environment: a metaheuristic approach for matrix production. Machines. **9**(10), 220 (2021). https://doi.org/10.3390/machines9100220
5. Vaccari, M., et al.: Optimally managing chemical plant operations: an example oriented by industry 4.0 paradigms. Ind. Eng. Chem. Res. **60**(21), 7853–7867 (2021). https://doi.org/10.1021/acs.iecr.1c00209
6. Kagermann, H., Lukas, W.D., Wahlster, W.: Industrie 4.0: mit dem internet der dinge auf dem weg zur 4. industriellen revolution. VDI nachrichten **13**(1), 2–3 (2011)
7. Lv, Q., Zhang, R., Sun, X., Lu, Y., Bao, J.: A digital twin-driven human-robot collaborative assembly approach in the wake of COVID-19. J. Manuf. Syst. **60**, 837–851 (2021). https://doi.org/10.1016/j.jmsy.2021.02.011
8. Martin, L., Gonzalez-Romo, M., Sahnoun, M., Bettayeb, B., He, N, Gao, J.: Effect of human-robot interaction on the fleet size of AIV transporters in FMS. (2021). https://doi.org/10.1109/CyMaEn50288.2021.9497273
9. Ghaleb, M., Taghipour, S., Zolfagharinia, H.: Real-time integrated production-scheduling and maintenance-planning in a flexible job shop with machine deterioration and condition-based maintenance. J. Manuf. Syst. **61**, 423–449 (2021). https://doi.org/10.1016/j.jmsy.2021.09.018
10. Gungor, O., Rosing, T.S., Aksanli, B.: DOWELL: diversity-induced optimally weighted ensemble learner for predictive maintenance of industrial internet of things devices. IEEE Internet Things J. (2021). https://doi.org/10.1109/JIOT.2021.3097269
11. Li, M., Huang, G.Q.: Production-intralogistics synchronization of industry 4.0 flexible assembly lines under graduation intelligent manufacturing system. Int. J. Prod. Econ. **241**, 108272 (2021). https://doi.org/10.1016/j.ijpe.2021.108272
12. Rahman, H.F., Janardhanan, M.N., Poon Chuen, L., Ponnambalam, S.G.: Flowshop scheduling with sequence dependent setup times and batch delivery in supply chain. Comput. Ind. Eng. **158**, 107378 (2021). https://doi.org/10.1016/j.cie.2021.107378
13. Bai, Y., You, J.B., Lee, I.K.: Design and optimization of smart factory control system based on digital twin system model. Math. Probl. Eng. (2021). https://doi.org/10.1155/2021/2596946
14. Salah, B., Khan, R., Ramadan, M., Ahmad, R., Saleem, W.: Lab scale implementation of industry 4.0 for an automatic yogurt filling production system—experimentation, modeling and process optimization. Appl. Sci. **11**(21), 9821, (2021). https://doi.org/10.3390/app11219821
15. Awad, M.A., Abd-Elaziz, H.M.: A new perspective for solving manufacturing scheduling based problems respecting new data considerations. Processes **9**(10), 1700 (2021). https://doi.org/10.3390/pr9101700
16. Spindler, J., Kec, T., Ley, T.: Lead-time and risk reduction assessment of a sterile drug product manufacturing line using simulation. Comput. Chem. Eng. **152**, 107401 (2021). https://doi.org/10.1016/j.compchemeng.2021.107401
17. Zhang, S., Tang, F., Li, X., Liu, J., Zhang, B.: A hybrid multi-objective approach for real-time flexible production scheduling and rescheduling under dynamic environment in Industry 4.0 context. Comput. Oper. Res. **132**, 105267 (2021). https://doi.org/10.1016/j.cor.2021.105267
18. Garcia, D., Tlahig, H., Bettayeb, B., Sahnoun, M.: Evaluation of dispatching rules performance for a djssp: towards their application in industry 4.0. (2021). https://doi.org/10.1109/CyMaEn50288.2021.9497286

19. Escriche, S., et al.: A digital twin based approach for simulation and emulation of an automotive paint workshop. In: SAE Technical Papers (2021). https://doi.org/10.4271/2021-01-0240
20. Jiménez-Martín, A., Mateos, A., Hernández, J.Z.: Aluminium parts casting scheduling based on simulated annealing. Mathematics **9**(7), 741 (2021). https://doi.org/10.3390/math9070741
21. Negri, E., Pandhare, V., Cattaneo, L., Singh, J., Macchi, M., Lee, J.: Field-synchronized digital twin framework for production scheduling with uncertainty. J. Intell. Manuf. **32**(4), 1207–1228 (2020). https://doi.org/10.1007/s10845-020-01685-9
22. An, Y., Chen, X., Li, Y., Han, Y., Zhang, J., Shi, H.: An improved non-dominated sorting biogeography-based optimization algorithm for the (hybrid) multi-objective flexible job-shop scheduling problem. Appl. Soft Comput. **99**, 106869 (2021). https://doi.org/10.1016/j.asoc.2020.106869
23. Ivanov, D., Sokolov, B., Chen, W., Dolgui, A., Werner, F., Potryasaev, S.: A control approach to scheduling flexibly configurable jobs with dynamic structural-logical constraints. IISE Trans. **53**(1), 21–38 (2021). https://doi.org/10.1080/24725854.2020.1739787
24. Zhang, Z., Zhu, Z., Zhang, J., Wang, J.: Construction of intelligent integrated model framework for the workshop manufacturing system via digital twin. Int. J. Adv. Manuf. Technol. **118**(9–10), 3119–3132 (2021). https://doi.org/10.1007/s00170-021-08171-3
25. Serrano-Ruiz, J.C., Mula, J., Poler, R.: Smart digital twin for ZDM-based job-shop scheduling. In: IEEE International Workshop on Metrology for Industry 4.0 and IoT, pp. 510–515 (2021). https://doi.org/10.1109/MetroInd4.0IoT51437.2021.9488473
26. Yu, H., Han, S., Yang, D., Wang, Z., Feng, W.: Job shop scheduling based on digital twin technology: a survey and an intelligent platform. Complexity (2021). https://doi.org/10.1155/2021/8823273
27. Serrano, J.C., Mula, J., Poler, R.: Digital twin for supply chain master planning in zero-defect manufacturing. In: Camarinha-Matos, L.M., Ferreira, P., Brito, G. (eds.) DoCEIS 2021. IAICT, vol. 626, pp. 102–111. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-78288-7_10
28. de Giorgio, A., Maffei, A., Onori, M., Wang, L.: Towards online reinforced learning of assembly sequence planning with interactive guidance systems for industry 4.0 adaptive manufacturing. J. Manuf. Syst. **60**, 22–34 (2021). https://doi.org/10.1016/j.jmsy.2021.05.001
29. Guo, X., Zhou, M., Abusorrah, A., Alsokhiry, F., Sedraoui, K.: Disassembly sequence planning: a survey. IEEE/CAA J. Autom. Sinica **8**(7), 1308–1324 (2021). https://doi.org/10.1109/JAS.2020.1003515
30. Ying, J., et al.: Edge-enabled cloud computing management platform for smart manufacturing. In: IEEE International Workshop on Metrology for Industry 4.0 and IoT, pp. 682–686 (2021). https://doi.org/10.1109/MetroInd4.0IoT51437.2021.9488441
31. Manogaran, G., Hsu, C.H., Rawal, B.S., Muthu, B., Mavromoustakis, C.X., Mastorakis, G.: ISOF: information scheduling and optimization framework for improving the performance of agriculture systems aided by industry 4.0. IEEE Internet Things J. **8**(5), 3120–3129 (2021). https://doi.org/10.1109/JIOT.2020.3045479
32. Rai, R., Tiwari, M.K., Ivanov, D., Dolgui, A.: Machine learning in manufacturing and industry 4.0 applications. Int. J. Prod. Res. **59**(16), 4773–4778 (2021). https://doi.org/10.1080/00207543.2021.1956675

Blockchain, IoT Applications and Industry 4.0

S. Fernández-Vázquez(✉), R. Rosillo, D. de la Fuente, and N. Álvarez Gil

Business Management Department, University of Oviedo, Oviedo, Spain
fernandezsimon@uniovi.es

Abstract. The Internet of Things (IoT) has been extensively employed in numerous fields of the industry as a crucial component of Industry 4.0. Nevertheless, in the IoT, cloud-based storage capacity, computation, and communication cause a slew of issues, notably transmission delays, single points of failure, and privacy breaches. Moreover, the IoT's centralized access control limits its flexibility and reliability. It is where blockchain, a decentralised, trust - free, accessible, and irreversible append-only database appears. Smart home, smart vehicle, smart cities, smart industry, smart appliances, and smart control systems have all benefited from the combination of Blockchain and IoT technologies.

Keywords: Blockchain · Industry 4.0 · Internet of Things

1 Introduction

The term blockchain refers to a system of distributed, tamper-proof ledger accounts that operate together rather than a single centralized platform. Anonymity, encrypted data, the consensus process, smart contracts, and reputational systems are all incorporated into a decentralized system using blockchain (Liu et al. 2021). The system can handle a wide range of services for end-users, including decentralized, exact, consistent, verifiable, and secure services, with decreased transaction costs and less interaction. Blockchain provides great assistance to enterprises because of its uniqueness: transparency, safety and behavioural systems, intractability, strategic uses, and sometimes even operational and strategic decision-making, to name a few (Yun et al. 2021).

As we speak, the 4th industrial revolution, dubbed Industry 4.0, is underway. Humans overcame several physical restrictions during the first industrial revolution, using both water and steam as power for production and transportation for the first time. Humans exploited a new technology during the second industrial revolution: electricity, which displaced steam power as the source of production power, allowing machines to be used. Production automation and accuracy, and the use of electronic devices and information technology, all contributed to the third industrial revolution, which increased production capacity (Javaid et al. 2021).

2 Objectives

The fast growth of distributed ledger technology has attracted a lot of attention, notably from the academic community. Many individuals are interested in the technological

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 113–118, 2023.
https://doi.org/10.1007/978-3-031-27915-7_22

aspects of blockchain, including its technical characteristics and possible obstacles. However, blockchain technology is only currently being studied in the information systems field by a small number of people. Scholars have been examining particular block-chain discoveries based on simply descriptive research for as much as blockchain is in development. The majority of such research has focused on blockchain-based service providing and technological applications. This is a clear growing trend in blockchain acceptance, permeability, and value-added studies. Many blockchain studies have been conducted in the domains of finance, economics, sociology, management, and psychology, as well as the more traditional subject of information systems. In this article, we will go into the specifics of blockchain and how it interacts with other technologies (Fig. 1), focusing in the interaction with IoT technologies.

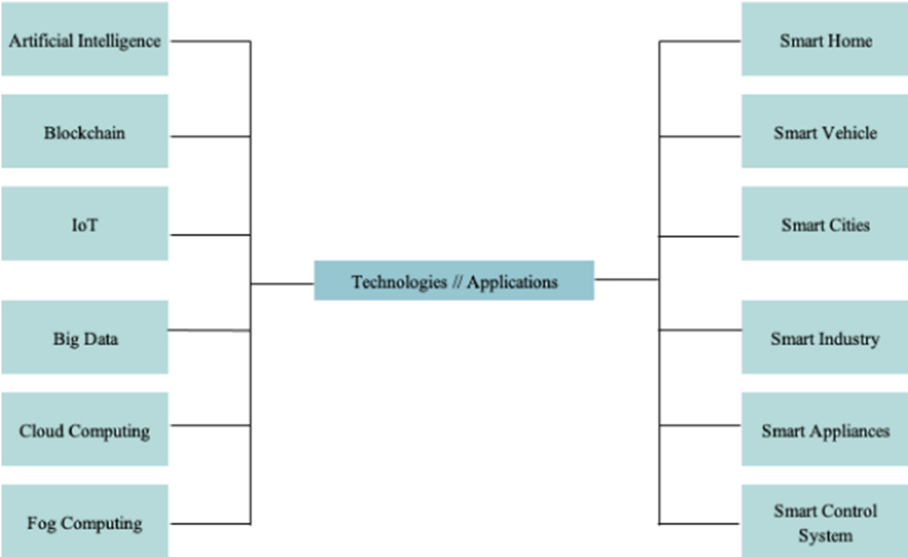


Fig. 1. Some of the most common emerging technologies with their applications.

3 Methods

By enabling security, verification, object tracking, cryptographic protocol exchange, and information sharing, blockchain ushers in a revolutionary transformation in Industry 4.0. The blockchain technology has become widely employed in the processing of bitcoin transactions (Balasubramanian et al. 2020; Elmamy et al. 2020). Later, with the introduction of Ethereum, which allows for the implementation and development of smart contracts, uses other than cryptocurrencies began to be created and investigated. Smart contracts are brief scripts of predetermined code that may be auto executed on Blockchain without the involvement of third parties to eliminate the need for middlemen and reduce the risk of human error or counterfeiting (Alwabel et al. 2021; Centobelli et al. 2021).

Many Blockchains are customizable and include smart contract functionality. Blockchain's better security, greater traceability, and low-cost infrastructure enable it to navigate through a wide range of industries (Yu et al. 2021). It is increasingly being seen as a game changer for all centralized things, as it provides a new infrastructure for developing robust distributed IoT-based applications, such as smart healthcare, smart cities, smart homes, smart metering, infrastructure, smart factory, smart distribution network, smart banking, and smart insurance, among others (Das et al. 2021; Lone et al. 2021).

3.1 Smart Homes

A smart home is a home with several sensors and devices that can detect door openings, room illumination, temperature and humidity, and other events. However, it may also be used to manage some of the equipment used every day, such as heating, shutters, lights, or domestic appliances. These gadgets are becoming increasingly networked and controllable from afar. Intelligent TVs, freezers, and washers and dryers, which have sensors and can be controlled remotely, are already available in homes. Communication protocols can connect all of these systems, sensors, actuators, and objects (Zhou et al. 2020; Alhusayni et al. 2021; Gadekallu et al. 2021).

3.2 Smart Vehicle

Simultaneously, the car industry is creating the technology that underpin smart vehicles, and as a result, the vehicles are altering the experience and manner of travel. In this context, the control units rely on data supplied by sensors and cameras to conduct appropriate actions, and connections between all of these components are built on various forms of wired and wireless (Bluetooth) technologies. These cutting-edge technology might be included into ordinary automobiles in the near future. Furthermore, cars are becoming more autonomous and semi-autonomous as a result of these new technology (Farivar et al. 2021; Sabri et al. 2021; Mollah et al. 2020).

3.3 Smart Cities

A smart city is a digital system that is intelligent and efficient and is made up of a vast IoT-based network. It collects and analyses real-time data to provide citizens with a variety of applications. One application that provides ease to people's lives and has radically improved the life quality is smart home. Although smart cities provide convenience to inhabitants, digital information services might raise security and privacy concerns (Hussain et al. 2021; Ren et al. 2021). Crowdsourcing, for example, is a new and informative municipal service paradigm in which requesters and workers are expected to utilize the crowdsourcing platform as a trust centre. Because the payment is reliant on third-party central payment institutions, this poses a significant security risk (Li et al. 2021; Liu et al. 2021).

3.4 Smart Industry

Traditional industrial systems are designed with a centralized architecture, which leads in significant security risks, inefficient resource utilization, lack of data openness, unbearable latency, and insufficient flexibility in dealing with industrial disruptions. In manufacturing, blockchain has been used to create an automated, distributed smart manufacturing system with great efficiency and productivity (Sarier, 2020; Manogaran et al. 2021; Uysal et al. 2021). IoT and intelligent computation are used to implement automation and self-sufficient processing and computing capabilities for smart industries. The field level to the management level in traditional industrial processing performs several duties underpinning production and consumer reactions. The expanding expectations of users and the necessity for productivity need the industries' speed and increased production rate. Intelligent robots and automated robotic elements replace manual or human-intervened operations (Cheng, 2018; Plaga et al. 2018; Kong et al. 2019).

4 Results

In order to investigate both blockchain use and acceptance, as well as blockchain-centric management concerns, deployment risks and governance, technological characteristics, possible benefits, adoption and absorption, and the commercial value of blockchain must be taken into account. Furthermore, the blockchain's ability to integrate and work collaboratively with other new technologies – such as IoT, cloud services, and 6G – demonstrates that the related research objects are not just one or two businesses, but the a whole blockchain network and, possibly, the entire business ecosystem.

5 Conclusions

Blockchain is among the most innovative inventions in the annals of information technology. Blockchain provides flexibility, ability, openness, and sustainability, laying the groundwork for future study in the IoT disciplines. Future research on blockchain will most likely focus on its acceptance and absorption; nevertheless, both established and rising blockchain-related businesses will be looking for methods to modify blockchain to fit and fulfil their corporate principles.

Acknowledgements. This work was financially supported by the State Research Agency of the Spanish Ministry of Science and Innovation (MCIN/AEI/10.13039/501100011033), via the project 'Speeding Up the transition towards Resilient circular economy networks: forecasting, inventory and production control, reverse logistics and supply chain dynamics" (SPUR, grant ref. PID2020-117021GB-I00).

References

Alhusayni, S.A., Alsuwat, S.K., Altalhi, S.H., Almalki, F.A., Alzahrani, H.S.: Experimental study of a tethered balloon using 5G antenna to enhance internet connectivity. In: Arai, K. (ed.) Intelligent Computing. LNNS, vol. 285, pp. 649–663. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-80129-8_46

Alwabel, M., Kwon, Y.: Blockchain consistency check protocol for improved reliability. Comput. Syst. Sci. Eng. **36**, 281–292 (2021). https://doi.org/10.32604/csse.2021.014630

Balasubramanian, V., Karpagam, G.: Investigation on blockchain technology for web service composition: a case study. Int. J. Web Serv. Res. **18**, 1–23 (2020). https://doi.org/10.4018/IJWSR.20210101.oa1

Centobelli, P., Cerchione, R., Esposito, E., Oropallo, E.: Surfing blockchain wave, or drowning? Shaping the future of distributed ledgers and decentralized technologies. Technol. Forecast. Soc. Chang. **165**, 120463 (2021). https://doi.org/10.1016/j.techfore.2020.120463

Das, D., Banerjee, S., Ghosh, U., Biswas, U., Bashir, A.K.: A decentralized vehicle anti-theft system using Blockchain and smart contracts. Peer Peer Netw. Appl. **14**(5), 2775–2788 (2021). https://doi.org/10.1007/s12083-021-01097-3

Elmamy, S.B., Mrabet, H., Gharbi, H., Jemai, A., Trentesaux, D.: A survey on the usage of blockchain technology for cyber-threats in the context of industry 4.0. Sustainability **12**, 9179 (2020). https://doi.org/10.3390/su12219179

Farivar, F., Sayad Haghighi, M., Jolfaei, A., Wen, S.: On the security of networked control systems in smart vehicle and its adaptive cruise control. IEEE Trans. Intell. Transp. Syst. 1–8 (2021). https://doi.org/10.1109/TITS.2021.3053406

Gadekallu, T., et al.: Blockchain for edge of things: applications, opportunities, and challenges. IEEE Internet Things J. (2021). https://doi.org/10.1109/JIOT.2021.3119639

Hussain, S., Mahmood, K., Khan, K., Chen, C., Alzahrani, B., Chaudhry, S.: Designing secure and lightweight user access to drone for smart city surveillance. Comput. Stand. Interfaces **80**, 103566 (2021). https://doi.org/10.1016/j.csi.2021.103566

Javaid, M., Haleem, A., Singh, R., Suman, R.: Significant applications of big data in industry 4.0. J. Ind. Integr. Manag. **6**, 429–447 (2021). https://doi.org/10.1142/S2424862221500135

Li, X., Liu, H., Wang, W., Zheng, Y., Lv, H., Lv, Z.: Big data analysis of the internet of things in the digital twins of smart city based on deep learning. Futur. Gener. Comput. Syst. **128**, 167–177 (2021). https://doi.org/10.1016/j.future.2021.10.006

Liu, J., Gong, B., Wang, Q.: A trusted proof mechanism of data source for smart city. Futur. Gener. Comput. Syst. **128**, 349–364 (2021). https://doi.org/10.1016/j.future.2021.10.012

Lone, A., Mir, R.: Applicability of Blockchain smart contracts in securing Internet and IoT: a systematic literature review. Comput. Sci. Rev. **39**, 100360 (2021). https://doi.org/10.1016/j.cosrev.2020.100360

Mollah, M.B., et al.: Blockchain for the internet of vehicles towards intelligent transportation systems: a survey. IEEE Internet Things J. 1–28 (2020). https://doi.org/10.1109/JIOT.2020.3028368

Ren, W., Wan, X., Gan, P.: A double-blockchain solution for agricultural sampled data security in internet of things network. Futur. Gener. Comput. Syst. **117**, 453–461 (2021). https://doi.org/10.1016/j.future.2020.12.007

Sabri, Y., Aouad, S., Maizate, A.: Internet of things (IoT) based smart vehicle security and safety system. Int. J. Adv. Comput. Sci. Appl. **12** (2021) https://doi.org/10.14569/IJACSA.2021.0120487

Yu, Z., Song, L., Jiang, L., Khold Sharafi, O.: Systematic literature review on the security challenges of blockchain in IoT-based smart cities. Kybernetes (2021). https://doi.org/10.1108/K-07-2020-0449

Yun, G., Zhygulin, V., Zheng, Q.P.: Residential energy trading with blockchain technology. Energy Systems **12**(3), 619–636 (2021). https://doi.org/10.1007/s12667-021-00426-y

Zhou, Q., Huang, H., Zheng, Z.: Solutions to scalability of blockchain: a survey. IEEE Access (2020). https://doi.org/10.1109/ACCESS.2020.2967218

Sarier, N.: Efficient biometric-based identity management on the blockchain for smart industrial applications. Pervasive Mob. Comput. **71**, 101322 (2020). https://doi.org/10.1016/j.pmcj.2020.101322

Manogaran, G., Alazab, M., Shakeel, P.M., Hsu, C.: Blockchain assisted secure data sharing model for internet of things based smart industries. IEEE Trans. Reliab. (2021) 1–11. https://doi.org/10.1109/TR.2020.3047833

Uysal, M.P., Mergen, A.: Smart manufacturing in intelligent digital mesh: integration of enterprise architecture and software product line engineering. J. Ind. Inf. Integr. **22**, 100202 (2021). https://doi.org/10.1016/j.jii.2021.100202

Cheng, J.: Industrial IoT in 5G environment towards smart manufacturing. J. Ind. Inf. Integr. **10**, 10–19 (2018). https://doi.org/10.1016/j.jii.2018.04.001

Plaga, S., Wiedermann, N., Duque Anton, S., Tatschner, S., Schotten, H., Newe, T.: Securing future decentralised industrial IoT infrastructures: challenges and free open source solutions. Futur. Gener. Comput. Syst. **93**, 596–608 (2018). https://doi.org/10.1016/j.future.2018.11.008

Kong, L., Liu, X., Sheng, H., Zeng, P., Chen, G.: Federated tensor mining for secure industrial internet of things. IEEE Trans. Ind. Inform. (2019). https://doi.org/10.1109/TII.2019.2937876

Methodology for Integrated Multicriteria Decision-Making with Uncertainty (MIMDU) for Robust Analysis. Case Study About Agricultural Efficiency in Colombia

Marc Juanpera[1](✉), B. Domenech[1], L. Ferrer-Martí[1], M. Garfi[2], and R. Pastor[1]

[1] IOC - Institute of Industrial and Control Engineering, Universitat Politècnica de Catalunya, Barcelona, Spain
{marc.juanpera,bruno.domenech,laia.ferrer,rafael.pastor}@upc.edu
[2] Group of Environment Engineering and Microbiology (GEMMA), Department of Civil and Environmental Engineering, Universitat Politècnica de Catalunya, Barcelona, Spain
marianna.garfi@upc.edu

Abstract. Selecting the best among different alternatives may require asking for experts' opinions to weight key criteria and assess the alternatives. Their opinions can be: 1) hesitant, and 2) difficult to quantify on a numerical scale. The Methodology for Integrated Multicriteria Decision-making with Uncertainty (MIMDU) allows performing robust multicriteria analysis considering both factors of uncertainty. Fuzzy rating scales are integrated into the Compromise Ranking Method to finally rank alternatives based on a comparison of a crisp ranking (without uncertainty) and a fuzzy-based ranking (with uncertainty). The soundness of MIMDU is shown with an example case which highlights its capacity of precisely modelling uncertain opinions and assist decision-making. Finally, MIMDU is used to select the most sustainable technology to improve agriculture efficiency in rural underprivileged areas by means of a real small-scale farm in Colombia.

Keywords: Multicriteria decision-making · MIMDU · Confidence · Uncertainty rural areas development · Agricultural efficiency

1 Introduction

The management of industrial and service sectors requires making decisions, which usually involve selecting one of several feasible alternatives. This selection is not an easy task, since different criteria (e.g. economic, technical, social, environmental) can be conflicting. Multicriteria decision-making is a suitable approach to handle such problems, and usually requires the participation of experts to weight the criteria and assess feasible alternatives [1, p. 188].

Experts' opinions are surrounded by uncertainty due to two factors: the potential lack of confidence when providing an answer (for example, if the importance of a criterion should be high or low) and the difficulty of quantifying the answer. Literature has until

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 119–123, 2023.
https://doi.org/10.1007/978-3-031-27915-7_23

now focused on the second factor, as proven by the wide use of Fuzzy Linguistic Scales (FLS) in industrial applications and for sustainable development [2, p. 97]. With FLS, experts are required to choose from different terms (e.g. high or low importance of a criterion), which are quantified through fuzzy numbers (FN) equidistantly distributed along a numerical scale. However, such approach does not consider the potential lack of confidence of experts, who can be more informed about some criteria but less about others. Thus, the developed Methodology for Multicriteria Decision-Making with Uncertainty (MIMDU) addresses a research gap by considering the lack of confidence in human opinions.

For decisions aiming at sustainable development, experts are required to take into account at the same time economic criteria (e.g. implementation costs), technical (e.g. systems reliability, ease of maintenance), social (e.g. job creation, degree of acceptance over population), or environmental (e.g., particles emissions, waste generation). Thus, it often occurs that the limited expertise of an expert does not reach all the considered criteria, and hesitance can more easily arise. In this work, we enhance the efficiency of low-cost biogas digesters, which have been implemented in Colombia. Such digesters degrade cattle manure in anaerobic conditions to produce biogas, for cooking or heating, and a liquid effluent called digestate. Digestate can be used as a biofertilizer, but it needs to be post-treated for its safe and efficient application to agricultural soil.

In this context, the aim of this study is to present the developed MIMDU to robustly assist multicriteria decision-making and apply it for the first time to select the best alternative for digestate post-treatment before its efficient use in agriculture. The rest of the study details the phases of MIMDU (Sect. 2), displays the results of the case study in Colombia (Sect. 3) and concludes the work (Sect. 4).

2 MIMDU. Process and Potential

MIMDU is composed of three phases (P1–P3):

P1. Modelling Opinions: Triangular FN are used in the form of fuzzy rating scales [3, p. 133] to model uncertain opinions. Two steps are defined:

Step 1: The expert must choose a value on a 0–5 scale to rate the importance of a criterion (high value means high importance) and to evaluate an alternative according to a criterion (high value means high adequacy of the alternative to the criterion).

Step 2: The expert must express his/her confidence with the above reference value, from five options (Table 1). The less confident is the expert, the higher support (base of the FN) will have the answer quantification: e.g. Fig. 1 shows example answers of three experts (E1–E3) for the importance of a criterion: E1 is *sure* the importance is 3 out of 5, E2 is *indecisive* about it being 4 and the E3 rates it with a 1 but is *very unsure*.

This approach establishes a more precise modelling of opinions compared to literature, since FN are not defined beforehand, and may reduce the pressure felt by experts when answering, as they express their lack of confidence.

P2. Alternatives Ranking: The Compromise Ranking Method (CRM) is used, which aims to calculate the distance of each alternative to an ideal solution which is the best

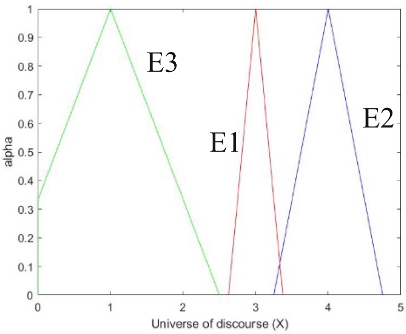


Fig. 1. Example of answers for three different experts (Source: [4, p. 147])

Table 1. Options to express the level of confidence and quantify the support of the FN

Confidence in the response	Relative support
Completely sure	0%
Sure	15%
Indecisive	30%
Unsure	45%
Very unsure	60%

of all the alternatives for all the criteria. In particular, a fuzzy version F-CRM is defined (1) and (2) using α-cut intervals. The reader is referred to [4, p. 139] for an exhaustive explanation of α-cut arithmetic.

$$ {}^{\alpha}L_{i,p} = \left[\sum_{j=1}^{n} \left({}^{\alpha}W_j \right)^p \cdot \left(\frac{{}^{\alpha}F_j^* - {}^{\alpha}f_{ij}}{{}^{\alpha}F_j^* - {}^{\alpha}f_j^*} \right)^p \right]^{1/p} \tag{1} $$

$$ {}^{\alpha}L_i = 0.5 \cdot {}^{\alpha}L_{i,1} + 0.5 \cdot {}^{\alpha}L_{i,\infty} \tag{2} $$

where ${}^{\alpha}W_j$ is the weight of criteria j, ${}^{\alpha}f_{ij}$ is the evaluation of alternative i according to criterion j, ${}^{\alpha}F_j^*$ and ${}^{\alpha}f_j^*$ are the best and worst value obtained for any alternative on criterion j, and p allows to calculate different distances to the ideal solution. An average (${}^{\alpha}L_i$) is calculated from the two usual and extreme metrics, p = 1, for maximum global utility (${}^{\alpha}L_{i,1}$) and p =∞, for the minimum individual regret (${}^{\alpha}L_{i,\infty}$).

Applying (1) and (2) for 11 values of α (from 0 to 1, time-step: 0.1) in a case with 3 alternatives (A1–A3) [4, p. 146], the results of the distance to the ideal solution for each alternative (${}^{\alpha}L_i$) are shown in Fig. 2. As it can be seen, all alternatives have distances to the ideal solution above 0. Also, a Results Interpretation phase is useful to highlight which one is the best (minor distance), since fuzzy numbers clearly overlap.

P3. Results Interpretation: Ranking alternatives from their fuzzy values might be misleading (e.g. it is not clear if A1 or A3 achieves lower fuzzy distance to the ideal solution). Thus, a comparison of a crisp and a fuzzy-based analysis is proposed:

- Crisp: the results of ${}^{1}L_i$, which does not consider the experts' confidence. This result meant the only decision-aid source in some studies [1, p. 191].
- Fuzzy-based: The Middle Point of the Mean Interval [5, p. 63] is used to calculate a best non-fuzzy performance value (3):

$$ MPMI\left(\tilde{A}\right) = \int_0^1 \frac{min^{\alpha}A + max^{\alpha}A}{2} d\alpha \tag{3} $$

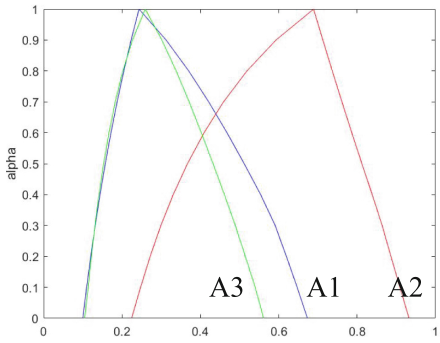


Fig. 2. FN for the distance of A1–A3 to the ideal solution (Source: [4, p. 150])

Table 2 shows that the two rankings diverge and, taking into account the uncertainty introduced by experts' lack of confidence, the preferable alternative should be A3.

Table 2. Crisp and fuzzy rankings of the alternatives in the example case

	A1	A2	A3
Crisp: ${}^{1}L_i$	**0.243**	0.689	0.259
Fuzzy-based: $MPMI_i$	0.329	0.603	**0.294**

3 Application: Selection of the Best Alternative for Digestate Post-treatment for Low-Cost Digesters in Small-Scale Farms

Five alternatives are considered to treat the digestate obtained in a low-cost biogas digester in a small farm in Colombia:

- A1. Degassing tank. to recover the remaining diluted methane.
- A2. Sand filter, to reduce the digestate turbidity and remove suspended solids and pathogens
- A3. Vermifilter: to accelerate the decomposition of organic matter with a biofilter composed of earthworms.
- A4. Recirculating the digestate once again into the digester to recover the remaining methane and stabilizing the organic matter.
- A5. Facultative pond, shallow basins to remove pathogens, remove ammonia nitrogen and clarify the effluent.

Also, combined alternatives are considered: A1 + A2, A1 + A3 and A1 + A5.

After designing the alternatives from input data of the digestate characteristics obtained in-situ, they have been evaluated according to several criteria, which included:

metals and pathogens removal, ease of maintenance, investment and operation cost, sustainability of materials and degree of acceptance by population.

Table 3 shows the results of the crisp and the fuzzy-based ranking, which allow to robustly conclude that the best alternative is the Vermifilter (A3), which produces a high-quality fertilizer with sustainable materials.

Table 3. Crisp and fuzzy rankings of the alternatives for digestate post-treatment

	A1	A2	**A3**	A4	A5	A1 + A2	A1 + A3	A1 + A5
Crisp	0.348	0.309	**0.186**	0.272	0.406	0.414	0.331	0.486
Fuzzy-based	0.358	0.293	**0.213**	0.288	0.394	0.391	0.329	0.450

4 Conclusions

MIMDU presents two major contributions: 1) a better estimation of hesitant opinions due to the flexibility when defining the FN; and 2) complimentary information for a robust decision-making, highlighting the effect of uncertainty in the ranking results. It has been applied to robustly select the Vermifilter as the best digestate post-treatment technique for small-scale farms with low-cost biodigesters.

Acknowledgements. This research was possible thanks to the grant FPU18/05389 and the research project RTI2018-097962-B-I00, funded by the Spanish Ministry of Science, Innovation and Universities MCIN/AEI/https://doi.org/10.13039/501100011033 and FEDER. The research was cofunded by the UPC Centre for Development Cooperation (CCD2021-J004).

References

1. Domenech, B., Ferrer-Martí, L., Pastor, R.: Hierarchical methodology to optimize the design of stand-alone electrification systems for rural communities considering technical and social criteria. Ren. Sus. Energy Rev. **51**, 182–196 (2015)
2. Abdel-Baset, M., Chang, V., Gamal, A., Smarandache, F.: An integrated neutrosophic ANP and VIKOR method for achieving sustainable supplier selection: a case study in importin field. Comp. Indus. **106**, 11–94 (2019)
3. Lubiano, M.A., Rosa de Sáa, S., Montenegro, M., Sinova, B., Gil, M.A.: Descriptive analysis of responses to items in questionnaires. Why not using a fuzzy rating scale? Inform. Sci. **360**, 131–148 (2016)
4. Juanpera, M., Domenech, B., Ferrer-Martí, L., García-Villoria, A., Pastor. R.: Methodology for integrated multicriteria decision-making with uncertainty: extending the compromise ranking method for uncertain evaluation of alternatives. Fuzzy Sets Sys. **434**, 135–158 (2022)
5. Dubois, D.: Possibility theory and statistical reasoning. Comp. Stat. Data Analysis. **51**, 47–69 (2006)

Industry 4.0 in Large Pharma Companies

J. Jesús Morcillo-Bellido[1](✉), Ramón Merino-Fuentes[2], and Jesús Morcillo-García[3]

[1] Universidad Carlos III, Av. de la Universidad, 30, 28911 Madrid, Spain
morcillo@ing.uc3m.es
[2] GMS Management Solutions, S.L., Pl. Pablo Ruiz Picasso, 1, 28020 Madrid, Spain
[3] Facultad de Ciencias Económicas y Empresariales, Departamento de Organización de Empresas, Universidad Nacional de Educación a Distancia (UNED), Senda del Rey, 11, 28040 Madrid, Spain
jmorcillo@cee.uned.es

Abstract. The term Industry 4.0 (I4.0) refers to an innovative industrial model based on the widespread application of digitalization and monitoring of different operational processes. The aim of this study is to gain a deeper understanding I4.0 impact on a sample of large companies in the pharma sector. From the analyses carried out, it could be inferred that the adoption of the new industrial model could enable and facilitate an increase on company´s customer responsiveness, through efficiency improvement along their supply chains and their level of innovation and service.

Keywords: Industry 4.0 · Pharma sector · Industry 4.0 in pharma

1 Introduction

The concept of Industry 4.0 could be considered a new conceptual model that is based on the digitalization and monitoring of the most advanced business models [1]. According to some authors, the main factor that push towards the adoption of this model is the significant change that is happening on customer demand behavior. In such a way that the consumer is demanding greater product customization and service levels on purchased items, and this has a significant influence in the whole supply chain [3]. In line with the Council of Supply Chain Management [6] the supply chain is understood as the set of business processes that deliver value to customers. The customer requirement for increased responsiveness use to be driven by a number of factors like: the sourcing of specialized goods and services, including on-demand products, and the inter-connectivity to the customer at all stages of the supply chain [7]. Table 1 summarizes the potential impact of adopting Industry 4.0 in the supply chain, according to different authors,

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 124–129, 2023.
https://doi.org/10.1007/978-3-031-27915-7_24

Table 1. Impact of I4.0 in the supply chain. Source: Compiled by the authors

Phases	Impacts
Design	Product design focuses on achieving greater demand satisfaction. A higher degree of customization is sought in the design [7, 8]
Sourcing	The implementation of IoT technologies and predictive modelling helps to manage stock higher reliability [10]
Manufacturing	Additive manufacturing enables products with a higher degree of customization, and the production and delivery decoupling [11]
Distribution	IoT technologies and automation allow predictive modelling increase, higher responsiveness and cost reduction [6, 13]
After-sales service	With the customization of products and services, returns decrease and the associated costs are reduced [6, 11]

2 Study Objective and Methodology

The objective of this study is linked to the interest of the authors in getting a better understanding to what extent I4.0 practices have been adopted, or not, by large world pharma companies, and what impact this represents in their supply chains. This document is the result of a deep study of nineteen pharma company cases. Given the nature of the topic, it was decided to apply case study methodology. A method that according to Eisenhardt [14] is suitable for topics related to business management strategic areas and as it could be very relevant and suitable tool for theory building purpose, being a key when it is necessary to develop theory inductively. Also according to other authors like Rialp [15] and Voss et al. [16], case study methodology is very suitable for issues related to management decisions. The information collection was carried out from published data in different information sources (mainly web pages and company reports). Company selection was decided following company's relevance criteria as business size, worldwide presence and data availability.

Case Studies Analysis

In order to gain a deeper understanding of the use of I0.4 in the pharmaceutical industry, an analysis of a sample of nineteen global pharmaceutical companies has been carried out. Table 2 summarizes the practices found in each of the companies.

Table 2. I4.0 technologies applied in different pharmaceutical companies Source: Compiled by the authors

Pharma company	I4.0 main applications found
Pfizer	IoT for warehouses and production centers monitoring and automation. Project to get continuous connectivity with patients. Company ty to reduce cost and timing on new products launch [17]
Roche	IoT to ensure a continuous flow of information to increase management control system in factories. Use of predictive models based on big data analysis and artificial intelligence [18]. Additive manufacturing extensive application for prototypes [19]
Novartis	Artificial intelligence used to increase the effectiveness of cancer treatments applied to individual patients [20]. Use of additive manufacturing to design human tissues for clinical trials [21]
Johnson & Johnson	IoT technology for obtaining real-time patient data enabling the efficiency of production centers [22]. Additive manufacturing to produce surgical material more suitable to customers [23]
Merck & Co	Big data to store and analyze information. Monitoring of production centers using RFID and IoT technologies, reducing time and associated costs [24]
Sanofi	IoT technology and automation of production centers to improve efficiency and safety. Artificial intelligence to prevent possible stock outs situations. Monitoring distribution and transports between warehouses and customers [25]
AbbVie	Design of clinical trials using big data and IoT techniques to improve quality and reduce associated timing and costs [26]. Prototypes for clinical trials using additive manufacturing [27]
GSK	Obtaining artificial human tissue applying additive manufacturing in clinical trials on new drugs development [28]
Amgen	Implementation of the Supplier Relationship Excellence (SER) program, based on IoT, to establish transparent communication with suppliers [29]
Gilead Sciences	IoT and big data technologies for dynamic and continuous end-to-end data collection and analysis. This data is used to provide a higher customer response [30]
BMS	IoT and data mining to monitor the distribution activities. Company decided to outsources it to specialized third parties [31]
AstraZeneca	Implementation of IoT-based disease diagnosis and treatment systems to accelerate disease detection. Development of predictive models based on artificial intelligence and big data [32]

(continued)

Table 2. (*continued*)

Pharma company	I4.0 main applications found
Eli Lilly	Automation and digitization of production centers and warehouses, relying on IoT, artificial intelligence and dig data, to increase their performance and reduce associated logistics costs [33]
Bayer	Development of predictive models based on artificial intelligence to simulate the behavior of active substances in the human organism, reducing the time to market of new drugs [34]
Novo Nordisk	Use of a platform based on 4.0 technologies (IoT, AI and big data) to reduce manufacturing inefficiencies, improve the quality of end products and monitor compliance with current legal regulations [35]
Takeda	Control of production site information using artificial intelligence-based technology to monitor medicine stability having a more accurate quality control [36]
Boehringer Ingelheim	Technologies based on IoT, AI and big data to support drug research. Use of additive manufacturing techniques to obtain high quality prototypes for testing [37]
Teva	Automation and monitoring of production centers using IoT technology to increase its manufacturing efficiency [38]
Astellas	Adoption of IoT-based technology for processes digitalization, achieving complete monitoring of different activities and processes [39]

3 Discussion and Conclusions

Based on previous analysis it is possible to infer that companies tend to have two objectives when they decide to implement I4.0: continuous improvement on customer/patient service and the pursuit of improved operational efficiency that could be supported by the use of I4.0 practices.

From case studies analysis it appears that virtually all companies are applying IoT solutions in their supply chain processes in order to monitor and excel research and development area, manufacturing or customer service processes. Other I4.0 technologies that are widely used in the large pharmaceutical companies supply chains are big data, application of artificial intelligence and additive manufacturing.

Regarding big data and artificial intelligence, it could be considered that they have a functional complementarity role with the aforementioned IoT, as when applied simultaneously they tend to achieve multiplicative operational results. In the case of additive manufacturing, or 3D manufacturing, its application tends to be successful mainly for very small batches economically feasible and its practical application is very much oriented towards the creation of prototypes or the search for therapeutic solutions for very specific patients. When analyzing the nineteen companies analyzed, there seems to be a certain greater propensity to apply I4.0 in the companies that are recognized as leaders in innovation in the sector, which could suggest a certain relationship between innovation capacity in company processes and the adoption of innovation practices supported by I4.0 tools. Nevertheless, authors consider that the size of the sample does not allow to make general assumption applicable for the whole industry since companies could differ in size or strategy that would make different their I4.0 practices adoption, if any.

Acknowledgment. This work has been supported by the Madrid Government (Comunidad de Madrid-Spain) under the Multiannual Agreement with UC3M in the line of Excellence of University Professors (EPUC3M20), and in the context of the V PRICIT (Regional Programme of Research and Technological Innovation).

References

1. Rojko, A.: Industry 4.0 concept: background and overview. Int. J. Interact. Mob. Technol. (iJIM) **11**(5), 77 (2017). https://doi.org/10.3991/ijim.v11i5.7072
2. Arbulu, I., Vivek, L., Mancini, M., Alpesh, P., Tonby, O.: Industry 4.0: reinvigorating ASEAN manufacturing for the future. In: Digital Capability Center. McKinsey & Company, Singapore (2018)
3. Tjahjono, B., Esplugues, C., Ares, E., Pelaez, G.: What does industry 4.0 mean to supply chain? Proc. Manuf. **13**, 1175–1182 (2017). https://doi.org/10.1016/j.promfg.2017.09.191
4. Chopra, S.; Meindl, P.: Administración de la cadena de suministros. Estrategia, planeación y operación, Pearson (2013)
5. Council of Supply Chain Management Professionals Homepage: Supply Chain Management Definitions and Glossary (2020). https://cscmp.org/CSCMP/Educate/SCM_Definitions_and_Glossary_of_Terms.aspx
6. Alicke., K.; Rexhausen, D.; Seyfert, A.: Supply Chain 4.0 un Consumer Goods. McKinsey & Company (2017)
7. RüBmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J.; Pascal, E., Harnisch, M.: Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries. Boston Consulting Group (2015)
8. Hague, R.; Campbell, I.; Dickens, P.: Implications on design of rapid manufacturing. Proc. Inst. Mech. Eng. Part C. J. Mech. Eng. Sci. **217**, 25–30 (2003)
9. Glas, H., Andreas, C., Kleemann, F.: The impact of industry 4.0 on procurement and supply management: a conceptual and qualitative analysis. Int. J. Bus. Manage. Invent. **5**, 55–66 (2016)
10. Janssen, R., Blankers, I., Moolenburgh, E., Posthumus, B.: TNO: The impact of 3-D printing on supply chain management. TNOinfo (2014)
11. Siavash, H. K.; Partansen, J.; Holmström, J.: Additive manufacturing in the spare parts supply chain. Comput. Indus. **65**, 50–63 (2013)
12. Pfohl, H.C., Yahsi, B., Kurnaz, T.: The impact of the industry 4.0 on the supply chain. Proc. Hamburg Int. Conf. Logist. **20**, 31–58 (2015)
13. Eisenhardt, K.M.: Building theories from case study research. Acad. Manag. Rev. **14**(4), 532–550 (1989)
14. Rialp, A.: El método del caso como técnica de investigación y su aplicación al estudio de la función directiva. IV Taller de Metodología. Sesión: Técnicas de la Investigación Cualitativas. Análisis de casos. La Rioja (1998)
15. Voss, C., Tsikriktsis, N., Frohlich, M.: Case research in operations management. International Journal of Operations & Production Management (2002)

16. Yin, R.K.: Discovering the future of the case study. Method Eval. Res. Eval. Pract. **15**(3), 283–290 (1994)
17. Mullin, E.: Pfizer And IBM Launch Ambitious ‘Internet of Things’ For Parkinson’s Research. Forbes Homepage. https://www.forbes.com/sites. Accessed Feb 2020
18. Steiner, J.: A connected future. PharmaTimes. http://www.pharmatimes.com. Accessed Apr 2020
19. Smith, S.: 43 Pharma Companies Using Artificial Intelligence in Drug Discovery. BenchSci. https://blog.benchsci.com. Accessed March 2020
20. Novartis Global Hompage: Manufacturing CAR-T Cell Therapies: The Novartis Approach. https://www.novartis.com. Accessed Apr 2020
21. O’Brien, T.: 3-D printing: Scientists reinvent research tools. Novartis Global Hompage. https://www.novartis.com. Accessed March 2020
22. Bradbury, D.: 3 Ways Johnson & Johnson Is Harnessing Digital Innovation to Better Deliver Medicine to You. Johnson & Johnson Hompegae. https://www.jnj.com. Accessed Apr 2020
23. Brewster, S.: The Power of 3-D Printing: How This Technology Is Blazing New Medical Frontiers. Johnson & Johnson Hompegae. https://www.jnj.com. Accessed Apr 2020
24. Henschen, D.: Merck Optimizes Manufacturing with Big Data Analytics. InformationWeek Homepage. https://www.informationweek.com. Accessed May 2020
25. Sanofi Homepage: The Fourth Industrial Revolution. https://www.sanofi.com. Accessed May 2020
26. Holen, K.: Inside our Design Lab: Building a Clinical Trial. AbbVie Homepage. https://news.abbvie.com. Accessed Dec 2021
27. Finley, J.: 3D printing puts patients at the heart of design. AbbVie Homepage. https://news.abbvie.com. Accessed Dec 2021
28. Goulding, C.: The R&D Aspects of 3D Printing Pharmaceuticals. 3dprinting Homepage. https://3dprint.com. Accessed Dec 2021
29. Undey, C.: Linking raw material data from suppliers to patients. Gelifesciences Homepage. https://www.gelifesciences.com. Accessed Dec 2021
30. Neil, S.: Managing Big Data in Healthcare. Automation World Homepage. https://www.automationworld.com. Accessed Dec 2021
31. Ward, J.: The latest of cold chain: IoT and data mining smarten solutions. DHL Homepage. http://www.delivered.dhl.com. Accessed Dec 2021
32. Unknown: How the CPI, GlaxoSmithKline, and AstraZeneca are Collaborating to Establish a Continuous Wet Granulation Manufacturing Facility. ManuPharma Homepage. https://manupharma.wbresearch.com. Accessed Dec 2021
33. Markarian, J.: Digital Transformation at Lilly Manufacturing. PharmaTech Homepage. http://www.pharmtech.com. Accessed Dec 2021
34. Digitalization in Drug Discovery Bayer Pharmaceuticals Homepage. https://pharma.bayer.com. Accessed Dec 2021
35. A story about adoption – Pharma 4.0 at the world’s largest insulin manufacturers. Bigfinite Hompege. https://www.bigfinite.com. Accessed Dec 2021
36. Takeda breaks ground on a state-of-the-art facility in Osaka, Japan. Takeda Home page. https://www.takeda.com. Accessed Dec 2021
37. Eppelmann, M.: Industry 4.0 at our Biberach site. Boehringer Ingelheim Homepage. https://careers.boehringer-ingelheim.com. Accessed Dec 2021
38. Sandle, T.: Digital Transformation of Pharmaceuticals and Healthcare. IVT Network Homeoage. https://www.ivtnetwork.com. Accessed Dec 2021
39. Allen, G.: Digital trailblazers. WorldPharma Homepage. http://www.worldpharmaceuticals.net. Accessed Dec 2021

Production Scheduling in the Aquaculture Industry Based on Bio-economic Simulation and Genetic Algorithms

Manuel Luna(✉), David de la Fuente, José Parreño, and Omar León

Business Management Department, Polytechnic School of Engineering, University of Oviedo. Edificio Departamental Este, 1 Planta. Campus de Viesques S/N. Gijón, 33204 Asturias, Spain
lunamanuel@uniovi.es

Abstract. Production scheduling is a key process to optimize the operational activities in most production industries. Aquaculture is not an exception, especially considering that its decision-making processes are especially complex, due to the large number of, external and internal, influencing factors. Furthermore, the industry finds itself going through a difficult time as the competition among companies is at its peak and the new consumers' demands in terms of efficiency and sustainability are increasingly complex. In this context, the application of decision support methods in order to maximize the economic efficiency of operational processes is required more than ever for the advancement of the industry. The objective of this work is to address the production scheduling problem in the case of a fish farm with different production units (cages or tanks). To do this, it integrates a bio-economic model with a genetic algorithm. Results show its utility to generate and evaluate different alternatives, determining the best production schedule in different scenarios.

Keywords: Production planning · Scheduling · Aquaculture industry · Genetic algorithm

1 Introduction

Production scheduling is defined as the decision-making process that deals with the allocation of resources to a task at a precise time [1]. Although it is a complex process, due to the large number of potential solutions, it is already applied in many production and service enterprises with the aim of optimizing operational activities. In particular, many different planning and scheduling problems have been successfully solved using optimization algorithms and metaheuristics, such as Genetic Algorithms, Particle Swarm Optimization, or Neural Networks [2, 3].

It has been decades since aquaculture ceased to be an artisanal activity and has become one of the fastest-growing industries in the world, mainly due to the development of new technologies and the use of intensive production methods [4]. However, its production planning and scheduling processes are still difficult due to the technical, biological, environmental, and economic factors that influence its production processes.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 130–135, 2023.
https://doi.org/10.1007/978-3-031-27915-7_25

Furthermore, competition among companies is at its peak and producers must respond to new consumers' demands in terms of efficiency and sustainability [5]. Thus, the aquaculture industry is still considered a high-risk industry [6], in which decisions made throughout the production process are not based entirely on planning and control systems. This points out a major need for optimization techniques to maximize efficiency and minimize the risk.

The main objective of this work is to develop and test a methodology to support aquaculture producers in the production scheduling of several production units (cages or tanks). This is especially complex as the economic viability of aquaculture farms depends on the producers' capacity to find the seeding scheduling that leads the farm to an optimal selling strategy taking into account that: (I) production times are highly dependent on some exogenous factors, such as the water temperature and (II) the optimal selling strategy it is not only determined by the possibility to get high prices in the free market, but also by the farm capacity to accomplish commercial agreements with big players.

To address this problem, we propose a methodology that integrates industry-specific bio-economic models with an optimization method, like Genetic Algorithms, in order to find the strategy that responds to the existing constraints while taking advantage of the best periods to produce.Bio-economic models have already proven their capacity to simulate the production process of aquaculture farms based on internal and external processes [7]. Similarly, GAs are metaheuristic search and optimization techniques based on principles present in natural evolution that are especially useful in this case since they are designed to work on large spaces involving states that can be represented by strings [8].

2 Materials and Methods

The present process start by carrying out a search process in which different seeding strategies, in the form of a vector with one seeding date for each production unit, will be proposed. Then, with the support of the bio-economic model, we will determine the evolution of the fattening process, the harvesting date for each cage (date in which the minimum selling weight is reached) and the final revenue, based on the expected temperature and the market prices.

2.1 Bio-economic Simulation

In order to simulate the production process of an aquaculture farm throughout the on-growing phase, we have integrated a bio-economic model based on those proposed by [4, 9–11]. These models take the assumption that there are a range of abiotic factors (temperature, light, salinity, and oxygen) on which, as the process is done in sea cages, the producer cannot influence in an economically efficient way [12]. However, aquaculture producers can optimize the production schedule in order to take advantage of the best environmental conditions in order to reach the selling weight at times of the year when better sales prices are expected.

In most cases, the biological model is estimated by each farm in cooperation with the feed suppliers. Thus, biological models determine the growth and mortality functions relying on the characteristics of the feed stuff and the recommended feeding rates provided by the feed suppliers. Those functions are usually based on two factors: The water temperature, influenced by the location and the seeding and harvesting dates, and the fish weight, which evolves over time. On the other hand, the expected economic performance of a farm, represented by the operational profit, can be estimated based on two factors: The revenue, which is calculated as a function of the average mass, provided by the biological model, and the expected market price at the selling date. The operating cost that is estimated based only in the feeding costs provided by feed suppliers, making the assumption that the other costs are not influenced by the production schedule.

In this way, the on-growing process is simulated based on the information acknowledged by each farm and its interaction with external factors.

2.2 Optimization Process

Given the difficulties of finding an optimal strategy for the problem addressed in this work, such as the complex constraints or the large number of alternatives, classic optimization techniques would lead to large computation times. However, metaheuristic techniques, such us Genetic Algorithms, work better in these conditions as they sacrifice the guarantee to find the optimal solution for the sake of getting good solutions in a significantly reduced amount of time [13].

In the present work, the steps of the search and optimization process follows the standard of Genetic Algorithms:

- The process starts with the generation of a random set (population) of production schedules (individuals). It is necessary to assign the crossover and mutation probabilities and the size of the population [14].
- Secondly, each individual has to be evaluated using the fitness function. To do so, we first simulate the growing process until the selling weight is reached and then we estimate the results of the production process.
- The next step of the GA methodology is to improve the initial population sequentially. This algorithm receives three operators to guide the algorithm towards a solution to the given problem. The "selection" process determines the best individuals, which participate in the reproduction process. The classic genetic "crossover" operator is used to create new individuals by taking more than one parent solutions and combining them into a child solution. Lastly, to prevent GA from converging to a local minimum we apply a "mutation operator" that randomly changes a chromosome of some individuals.
- In this way, the solutions of every new generation are evaluated by applying the biological model and the step 3 is repeated, creating new generations, until the stopping criterion is met. This criterion is represented by the number of movements without any improvement in the fitness function.

Table 1. Problem Characteristics

Parameter	Value
Starting date	01/03/2020
Time horizon	2 years
Cage capacity	200 m3
Starting weights	30 g
Location	Tarragona (Buoy 2720)

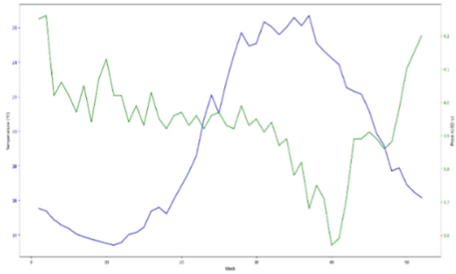


Fig. 1. Expected price and temperature

In this way, the integration of a Genetic Algorithm with the bio-economic model allow us to find a near-optimal solution without much computational cost.

3 Application to the Scheduling Process in a Seabream Farm

Once the methodology has been developed, the process of selecting the optimal production schedule has been tested for two theoretical scenarios: (I) the first one in which the production planning is subject to the expected market price, with no constraints and (II) a second scenario assuming the existence of a commercial agreement to sell a certain amount of fish in four specific times of the year.

The simulation and optimization processes have been calculated for the case of a gilthead seabream farm in the Mediterranean (Table 1). The information used has been collected from primary, such as oceanographic buoys or Spanish market prices (Fig. 1), and secondary sources of information, both published in [4].

Regarding the search and optimization process, Figs. 2 and 3 show the proper functioning of the evolutionary process as in both scenarios it has managed to reach some improvement in the fitness quality (Operational profit). Furthermore, it reached those results in just a few minutes using an Intel Core i7 2.81 GHz processor and 16 Gb SDRAM.

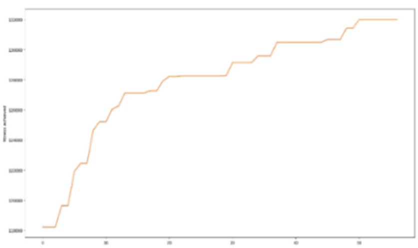


Fig. 2. Evolution of the average fitness for scenario 1

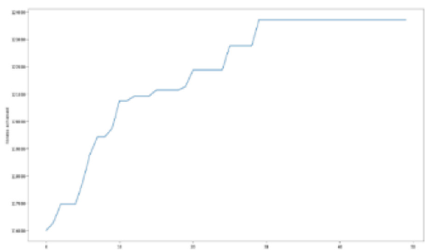


Fig. 3. Evolution of the average fitness for scenario 2

With respect to the scheduling process, in the first scenario, the algorithm provided the decision-maker with an optimal production strategy for 10 cages, which consist of all of the cages seeding and harvesting at the same time. This led us to the conclusion that it is the optimal strategy for the data provided. When we entered a constraint consisting of a selling agreement in four weeks (40,50,60, and 70) it was also capable of finding a good solution that accomplish the constraint (Table 2).

Table 2. Resulting production scheduling

	Cages	1	2	3	4	5	6	7	8	9	10
Selling Date	S1	80	80	79	80	80	80	80	80	80	80
	S2	40	50	60	70	80	80	80	80	80	80

Acknowledgements. This work was financially supported by the State Research Agency of the Spanish Ministry of Science and Innovation (MCIN/AEI/https://doi.org/10.13039/501100011033), via the project 'Speeding Up the transition towards Resilient circular economy networks: forecasting, inventory and production control, reverse logistics and supply chain dynamics" (SPUR, grant ref. PID2020-117021GB-I00).

References

1. Pinedo, M.: Scheduling: Theory, Algorithms, and Systems, 4th edn. Springer, New York (2012)
2. Ojsterseka, R., Brezocnika, M., Buchmeister, B.: Multi-objective optimization of production scheduling with evolutionary computation: a review. Int. J. Ind. Eng. Comput. **11**, 359–376 (2020)
3. Priore, P., De La Fuente, D., Gomez, A., Puente, J.: A review of machine learning in dynamic scheduling of flexible manufacturing systems. Artif. Intell. Eng. Design, Anal. Manuf. Arch. **15**(3), 251–263 (2001)
4. Luna, M., Llorente, I., Cobo, A.: Aquaculture production optimization in multi-cage farms subject to commercial and operational constraints. Biosys. Eng. **196**, 29–45 (2020)
5. Luna, M., Llorente, I., Cobo, A.: Integration of environmental sustainability and product quality criteria in the decision-making process for feeding strategies inSeabream aquaculture companies. J. Clean. Prod. **217**, 691–701 (2019)
6. Watson, J., Armerin, F., Klinger, D., Belton, B.: Resilience through risk management: cooperative insurance in small-holder aquaculture systems. Heliyon **4**(9), e00799 (2018)
7. Llorente, I., Luna, L.: Bioeconomic modelling in aquaculture: an overview of the literature. Aquacult. Int. **24**(4), 931–948 (2015). https://doi.org/10.1007/s10499-015-9962-z
8. Goldberg, D., Holland, J.: Genetic algorithms and machine learning. Mach. Learn. **3**(2–3), 95–99 (1988)
9. Llorente, I., Luna, L.: Economic optimisation in seabream (Sparus aurata) aquaculture production using a particle swarm optimisation algorithm. Aquacult. Int. **22**(6), 1837–1849 (2014)

10. Cobo, Á., Llorente, I., Luna, L., Luna, M.: A decision support system for fish farming using particle swarm optimization. Comput. Electron. Agric. **161**, 121–130 (2019)
11. Luna, M., Llorente, I., Cobo, A.: Determination of feeding strategies in aquaculture farms using a multiple-criteria approach and genetic algorithms. Ann. Oper. Res. **314**, 1–26 (2019). https://doi.org/10.1007/s10479-019-03227-w
12. Brett, J.R.: Environmental factors and growth. Fish Physiol. **8**, 599–675 (1979)
13. Blum, C., Roli, A.: Metaheuristics in combinatorial optimization. ACM Comput. Surv. **35**(3), 268–308 (2003)
14. Siriwardene, N., Perera, B.: Selection of genetic algorithm operators for urban drainage model parameter optimisation. Math. Comput. Model. **44**, 415–429 (2006)

Optimization Planning Scheduling Problem in Industry 4.0 Using Deep Reinforcement Learning

Marcos Terol, Pedro Gomez-Gasquet(✉), and Andrés Boza

Centro de Investigación de Gestión E Ingeniería de Producción (CIGIP), Universitat Politècnica de Valencia. Cno/ de Vera S/N, 46022 Valencia, Spain
{mterol,pgomez,aboza}@cigip.upv.es

Abstract. Industry 4.0 provides us with more precise real-time information about each factory element. Reinforcement Learning gives us new opportunities to improve old methodologies to resolve planning and scheduling problems using this information. Reinforcement Learning models can learn about old Master Plans and correct the mistakes that traditional algorithms cannot predict. This proposal improves the form to create a plan reducing the backlogged cost using Reinforcement Learning, specifically by means of a DQN Agent.

Keywords: Reinforcement learning · Industry 4.0 · DQN · Planification · Scheduling · Agent

1 Introduction

With the emergence of Industry 4.0 [1, 2], we have the possibility of obtaining all kinds of information in real-time, such as the energy consumption of the machines, production, wear of a component, forecast of lack of material, etc.

Before this fourth industrial revolution, we did not have this information, but now we have it in real-time. This information is not crucial if it is not treated and managed simultaneously. To take advantage of the data, we need intelligent systems that somehow learn from this information and somehow improve the coordination between data and performance in production without the intervention of a human component that involves considerable time.

The literature has multiple algorithms of mathematical models for production in the industry that have been endorsed over the years. Still, these algorithms have reached a theoretical level that little progress can be made on paper. For this reason, it could be convenient to involve new systems to unite and improve the various existing algorithms, thus finding a more efficient, fast, and optimal system.

This proposal is focused on adjusting the quantities to be produced for one or more products of the Master Production to try to reduce the initial cost of the plan using Machine Learning systems, specifically, reinforcement learning. This new system tries to minimize the cost associated with the backlogged demand.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 136–140, 2023.
https://doi.org/10.1007/978-3-031-27915-7_26

2 DQN'S Agent Framework

This paper proposes the use of Neural Networks (NN) [3] to coordinate planning and sequencing by applying Reinforcement Learning(RL) [4]. For this purpose, NN applies Deep Q-Network(DQN) [5]. This algorithm consists of the Q-learning algorithm's union of Deep Neural Networks(DNN) [6].

For them, it has been created two independent neural networks. On the one hand, the Q-Network(Q) and on the other hand, the Target Q-Network(Q'). The use of the second network Q' gives more stability to the learning; the data are copied from Q to Q', in certain moments, after the learning. This gives us a trained copy of the learning process.

In addition to the neural networks, it is necessary to use a Replay Buffer(RB) [7], where we will store the information of the transitions. In our case it will be the state(s), the action(a), the reward(r) and the next state(s').

The agent decides the action to be taken based on the information previously stored during learning based on the data obtained in the environment.

The structure of our network can be seen graphically in Fig. 1. The general parameters used in our framework can be found in Table 1.

The proposal develops the most essential parts of the framework in the following.

Table 1. Hyperparameters of neuronal network.

Hyperparameters	Value
Number of hidden layers	4
Learning rate	10–3
Decay factor	0.9
Batch Size	64
Initial collect steps	100
Eval Interval	1000

2.1 Environment

The environment defines the whole problem. The problem must be determined by indicating the state(s), the steps to be taken by actions(a), and the reward(r) for performing those steps.

Steps and rewards are closely related since completing a step leads to a reward, which can be negative or positive.

Actions. The proposal defines two actions; one is the delay of the lot to the next period (t + 1), and the other is the transfer which is the return to t from t + 1.

State. These actions are performed by observing the state; our state varies according to two criteria; the first one is the capacity that we divide into three sub-states. They are based on the capacity; the first one, we have the capacity adjusted, in the second one, we have not managed to have a shortened capacity, and in the third one, we do not have it, but there is a possibility of adjusting it.

The second criterion is based on backlogged products; there are only two possible sub-states, there are or are not backlogged.

Rewards. As for the rewards, our proposal is based on cost reduction. For this, the rewards are proportional to the variation of the cost; if we increase the cost employing the realization of the cost, we give a negative reward from -10 to 0 proportionally to the rise. On the contrary, if we have a cost decrease, we reward 0 to 10. We do not contemplate rewards for reaching a final episode but apply a negative reward of -5 per action not allowed in our model.

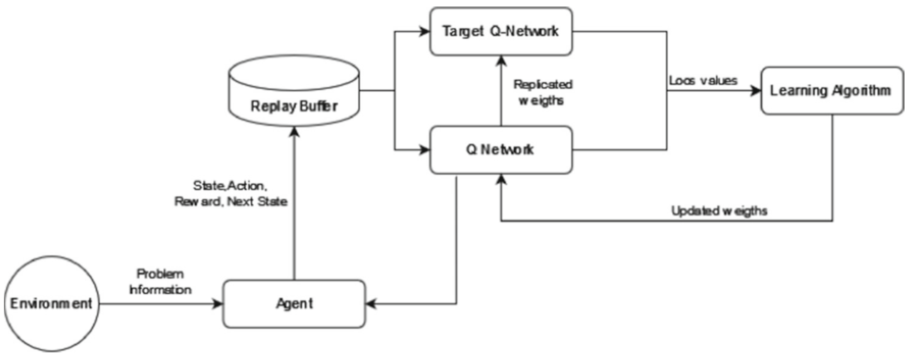


Fig. 1. Neuronal network using DQN's agent Framework

2.2 Neuronal Network

We use a fully connected NN to create the Q-Network(Q) for the project. We use only one input layer, four hidden density layers 100 and 50, and one output layer. The input layer is passed the state, and the output layer is of density equal to the number of actions. The output layer tells us the probability of taking each action. The network Q' is of the same size and density as Q.

3 Agent's Learning

Agent's learning uses each of the components described above in the Framework for training.

The training of our neural network, as in all cases of Reinforcement Learning, is done by repetition. In our problem, previously selected test cases are used to control better the information with which it works and its results. In this way, the system can evaluate whether the agent's solution, once trained, is feasible or not. Specifically, the information to do the state is taken from the backlogged solution and demand of each product in a resolved planning.

Before performing the training, the system evaluates the environment and the agent policy by running our agent on a few occasions, verifying its correct operation, and resetting the environment.

Another step before training is creating the driver, which is in charge of collecting the agent's experience during training by applying our policy.

The system stores some steps in the Replay Buffer starting the training since the training cannot start if the network does not have some data used by the agent's network. Then the agent begins to work by performing actions previously defined in the environment, getting experience. From this experience, the agent receives a loss or error, so the agent learns from this loss and corrects its actions toward a result with a greater reward.

It can be observed that the agent is learning by the reduction of the loss and is obtaining results closer to the optimum; the system checks it in the eval_interval, that is nothing more than the number of iterations that the agent makes before consulting the average of its results.

4 Conclusions

This paper described the disadvantages of using traditional algorithms, the new opportunities that give us Industry 4.0, and new approaches with Artificial Intelligence.

This study proposes using reinforcement learning with the creation of a Neuronal Network with the capacity to revolve planning and scheduling problems in both connections reducing the cost of the Master Plan.

This paper has described what components are in the Framework and descriptions of works for each part. Furthermore, it introduces how our DQN agent works using our state, actions, and rewards system. On the other hand, we present how the agent learns and resolves the problem.

Resolved theoretically the backlogged problem, this research is going to focus on using real data in real scenarios to prove that Industry can benefit from this research. Besides, the proposal will be enriched by including new agents, using other parameters to optimize like demand or production.

Acknowledgments. Grant NIOTOME Ref. RTI2018–102020-B-I00 funded by MCIN/AEI/ https://doi.org/10.13039/501100011033 and ERDF A way of making Europe.

This research has been partially funded by the Agència Valenciana de la Innovació, under the program Proyectos Estratègics en Cooperació 2021 (exp. INNEST/2021/226.

References

1. Gilchrist, A.: Introducing industry 4.0. In: Gilchrist, A. (ed.) Industry 4.0, pp. 195–215. Apress, Berkeley (2016). https://doi.org/10.1007/978-1-4842-2047-4_13

2. Boza, A., Alarcón, F., Perez, D., GómezGasquet, P.: Industry 4.0 from the supply chain perspective: case study in the food sector. In: Ferreira, L., Lopes, N., Silva, J., Putnik, G.D., Cruz-Cunha, M.M., Ávila, P.S. (eds.) Technological Developments in Industry 4.0 for Business Applications, pp. 331–351. IGI Global (2019). https://doi.org/10.4018/978-1-5225-4936-9.ch014
3. Hopfield, J.J.: Neural networks and physical systems with emergent collective computational abilities. Proc. Natl. Acad. Sci. U.S.A. **79**(8), 2554–2558 (1982). https://doi.org/10.1073/pnas.79.8.2554
4. Sutton, R.S., Barto, A.G.: Reinforcement learning: an introduction. IEEE Trans. Neural Netw. **9**(5), 1054 (1998)
5. Watkins, C.J.C.H., Dayan, P.: Q-learning. Mach. Learn. **8**(3–4), 279–292 (1992). https://doi.org/10.1007/BF00992698
6. Hinton, G.E., Osindero, S., Teh, Y.-W.: A fast learning algorithm for deep belief nets. Neural Comput. **18**(7), 1527–1554 (2006). https://doi.org/10.1162/neco.2006.18.7.1527
7. Zhang, S., Sutton, R.S.: A deeper look at experience replay (2017). arXiv:1712.01275

Circular Economy in the Textile Sector

Jesús Morcillo-Bellido[1](✉) and Beatriz Recalte Vazquez-Añón[2]

[1] Universidad Carlos III, Av. de la Universidad 30, 28911 Madrid, Spain
morcillo@ing.uc3m.es

[2] Universidad Carlos III, GITI, Av. de la Universidad 30, 28911 Madrid, Spain

Abstract. Circular economy arises as a potential alternative solution to the current problem of intensive resource consumption and as consequence, massive waste generation. Circular economy is trying to close the circle through the maximum reuse and minimum recycling of products at end of its life. The circularity concept could be applicable to many sectors, and in particular the objective of this research is to increase the knowledge trying to get a greater depth on the specific practices of circularity applied within a sample of textile companies. This study tries to analyze the circularity initiatives and practices in a sample of four textile companies. From the study carried out it can be inferred that this group of textile companies are adopting clear practices in search of circularity, nevertheless each company is at a different step of circularity level and using different ways.

Keywords: Circular economy · Textile sector · Circular practices

1 Introduction

According to different authors there is a need for more sustainable systems to carry out company operations within supply chain. [1]. Current economic practices are creating environmental problems that endanger the planet's life [2, 3]. The concept of circular economy arises as an attempt to alleviate and compensate these problems, by providing a circular vision in the use of resources [4, 5].

By the application of the "circularity concept" the general use of discarded products is promoted, giving them a second (or more) life and reintroducing them again into production processes after its use, as raw materials, through reuse and recycling. Thus minimizing the amount of waste generated [6, 7]. The concept of circular economy was first presented in 1989, by economists Pearce and Turner [8]. According to the specific study carried out by Kirchherr et al. [9], most attempts to define this concept arise from 2012. Year in which the recognized Ellen MacArthur Foundation (EMF) [10], among other authors, publishes its first study that delves into the analysis of the potential of a proposed circular model.

There are several definitions of the circular economy concept [9], both Geissdoerfer et al. [11] and Schut et al. [12] indicate that perhaps the most complete definition of this term is that presented by the EMF [10], that stablish that "*it is an industrial system that is restorative or regenerative by intention and design*". Circular economy practices are applicable to many sectors, however, there are certain industries with a pressing and

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 141–146, 2023.
https://doi.org/10.1007/978-3-031-27915-7_27

urgent need for implementation due to their significant and evident environment impact on their operations [13, 14].

Within these sectors with significant negative impact on the environment, the textile sector stands out as one of the negative leaders, being one of the most polluting industries. In addition, the presence of the phenomenon known as *"fast fashion"* [15] increase the waste dimension issue.

Certain institutions, such as the EMF, observed opportunities for the application of circularity practices by proposing the development of three pillars on which organizations should base their circularity long term strategy. Following this approach, each company could implement a set of different measures and practices, but all should be focused on the same directions (pillars).

The first pillar is based on the concept of lengthening the use of garments. In other words, trying to manufacture garments more focused on durability and the way of using them than in quick goods replacement by fashion. The second pillar proposes the manufacture of products that can (and must) serve as raw materials for the manufacture of others at the end of their live cycle. And the third pillar is based on the whole concept that garment manufacturing should integrate many more materials that favor the reuse, reconstruction and recycling many times.

Likewise, the European Union (EU) has promoted the development of eco-design practices that ensure the suitability of textile products for circularity in a broad sense. The EU strategy in the area tries to achieve the selective collection of these products and facilitate their recycling. Both the EMF and the European Union highlight the need to make use of recycled or reused materials in the textile industry's supply chain. The main reason for this approach, as previously mentioned, is the need of controlling and reducing the huge amount of pollution created by companies belonging to the textile sector. The objective of this study is to analyze the circularity initiatives and practices in a sample of four textile companies, to identify what type of circular practices they have applied. And if they apply similar or different approaches to achieve its circularity strategies.

2 Objectives and Methodology

This document is the result of an inductive study of four cases of textile companies. Given the nature of the investigated topics in this research, it was decided to carry out a case study, a method that according to Eisenhardt [16] is suitable for topics related to business management strategic areas. Also, this method isa very relevant tool for theory building purpose, being key when it is necessary to develop theory inductively. The theory emerges by recognizing patterns of relationships. The case study method, according to other authors like Rialp [17], is very suitable for issues related to strategic management decisions and with special applicability when theory building is still necessary.

The information collected for these case studies was obtained from data published in different information sources (mainly web pages and company reports), trying to get a different mix on sources. Company selection was decided following company's relevance criteria as business size and access to relevant information applicable to this research. An important aim of the authors was focusing on using mainly accurate data.

3 Case Studies

3.1 Inditex Case

The Inditex group carries out three circularity initiatives: *Closing the Loop, Zero Waste* and *Green to Pack.* The initiative *Closing the Loop* aims to close the product life cycle giving a second life to discarded garments. It is based on two programs: i) material collection program, and ii) reuse and recycling garments program. The first program focuses on developing initiatives that allow the collection of textile waste from its factories in order to recycle it and create new raw materials for the production process.

The second program is based on Inditex's collaboration with social organizations to collect discarded products and give them a second life. *Zero Waste* supports correct classification of waste in Inditex facilities, for subsequent recycling and reuse, and thus drastically reduce the amount of waste generated. *Green to Pack,* establishes the quality standards of Inditex packaging, allowing the use of recycled materials.

Regarding circularity / sustainability standards they comply with several standards like Responsible Wool Standard, Organic Content Standard, Higg Index, LEED (Leadership in Energy and Environment Design), BREEAM (green buildings), FSC Standard, PEFC Standard and others.

3.2 Ecoalf Case

The Ecoalf company develops three circularity initiatives: i) upcycling the Oceans, ii) recycled materials and iii) use of sustainable packaging. The first initiative is based on the collection of different garbage from the sea, through its collaboration with fishermen, to later proceed with the classification and recycling of this garbage, obtaining pellets to create threads. Through its second initiative, Ecoalf manages to obtain the basic raw material for the elaboration of its garment collection, which leads to its next initiative (recycled materials). From the garbage collected from the oceans, Ecoalf manages to obtain recycled polyester, cotton and rubber. Ecoalf's third initiative is based on the use of eco-design and reused fabrics from its manufacturing processes for the manufacture of packaging.

Regarding circularity / sustainability standards, Ecoalf is in compliance with several global standards like B Corp, BSCI y SMETA, SA8000 and Responsible Down Standard.

3.3 Desigual Case

The Desigual brand presents two circular economy initiatives: the use of sustainable packaging and the practices of responsible waste management. The first initiative is based on the replacement of most of the plastic packaging with packaging composed of sustainable materials, both in its physical points of sale and in its online shopping shipments, aiming at the gradual elimination of the use of plastic in the company operations. Desigual's second initiative (responsible waste management) aims at the reuse of cardboard boxes, minimizing the use of virgin raw materials and unnecessary production.

This company has decided to follow several circularity /sustainability standards across its processes, such as Higg Index, LEED (Leadership in Energy and Environment

Design), BREEAM (green buildings, FSC Standard, PEFC Standard and ethic audits BSCI y SMETA.

3.4 Zalando Case

The Zalando company carries out two circularity initiatives: i) redesign of the packaging to minimize waste and ii) extension of the life cycle of the garments. The brand's first initiative focuses on reducing the amount of plastic packaging used through the packaging efficient design, in order to protect garments along logistics and transport crucial processes. On top of that, as part of its circular economy initiative, it is incorporating into its business model the use of sustainable and recycled materials, such as recycled paper.

The second initiative is based on the manufacturing of garments with longer durability, allowing customers to extend the products life cycle to more years of proper use. To support and facilitate this goal, Zalando launched the category *Pre-owned,* in which consumers are allowed to exchange or buy second-hand garments that meet the quality standards established by the brand. In addition, Zalando has created the collection *redeZIGN for Circularity,* in which all garments are designed to be recycled.

This company has decided to apply several circularity /sustainability standards in its processes like Global Organic Textile Standard, Fairtrade Cotton, Responsible Wool Standard, Responsible Down Standard, Recycled Content Standard, Higg Index and ethic audits BSCI y SMETA.

4 Discussion and Conclusions

Table 1 compares the different six circularity practices advocated by the EU and EMF models and their respective correspondence with specific practices in the sample of analyzed companies.

Table 1. EU /EMF practices vs. sample companies (Source: own elaboration)

Practices included in the EU/EMF models	Inditex	Ecoalf	Desigual	Zalando
1.Design of garments for subsequent recycling				X
2.Manufacture of more durable garments				X
3.Sale and exchange of used garments				X
4.Containers for the donation of garments	X			
5.Waste management	X		X	X
6.Recycling of waste for subsequent reuse	X	X	X	X

When comparing the six circular practices within the EU/EFM models with real circularity practices found within the research sample, it is observed that the recycling of waste for subsequent reuse is the only practice carried out by the four companies analyzed, all of them having introduced key activities to fulfil this objective. Each of the companies has developed specific initiatives in waste treatment (no evidence has been found for Ecoalf), highlighting that in almost all cases the companies exceed the levels of legal requirements.

In general, regarding the practices defined by the EU/EFM, the Zalando company has a scoring that shows almost a full fulfilment of all the EU/EFM practices. This company shows a greater propensity than the others regarding the compliance of defined practices. When research authors tried to get a better understanding of the reason that moved the company to this strategy, it was not clear the reasons for it. Perhaps it could be motivated by the recent company foundation and the establishment from the beginning of a clear circularity/sustainability strategy.

From the study carried out it can be inferred that this group of textile companies are adopting clear practices in search of circularity, including an extensive compliance strategy with well-known sustainability standards. However, the authors consider that it is possible that this could be a little bit particular to this group of companies, and it could not happen in other textile companies of similar size. It could be a limitation since the studied companies are possibly the most innovative in process management improvement, and this clear innovation strategy also could have an influence in the circularity and sustainability practices of the analyzed sample.

Acknowledgment. This work has been supported by the Madrid Government (Comunidad de Madrid-Spain) under the Multiannual Agreement with UC3M in the line of Excellence of University Professors (EPUC3M20), and in the context of the V PRICIT (Regional Programme of Research and Technological Innovation).

References

1. NASA. Is it too late to prevent climate change? https://climate.nasa.gov/faq/16/is-it-too-late-to-prevent-climate-change/. Accessed 07 Nov 2021
2. Forbes. Sustainability In Fast Fashion: How Tech Can Minimize Waste. https://www.forbes.com/sites/forbestechcouncil/2022/01/31/sustainability-in-fast-fashion-how-tech-can-minimize-waste/?sh=471ff9631e62. Accessed 20 Nov 2021
3. Prieto-Sandoval, V., Jaca, C., Ormazabal, M.: Towards a consensus on the circular economy. J. Clean. Prod. **179**, 605–615 (2018)
4. Boulding, K.: The Economics of the Coming Spaceship Earth. Resources for the Future, pp. 1–14 (1966)
5. Ayres, R. U.: Industrial metabolism. Technology and environment, pp. 23–49 (1989)
6. Ayres, R., Kneese, A.: Production, consumption, and externalities. Am. Econ. Rev. **59**(3), 282–297 (1969)
7. Stahel, W.: The circular economy. Nature **531**, 435–438 (2016)
8. Pearce, D. W.: Economics of Natural Resources and the Environment. Johns Hopkins University Press, Baltimore (1989)
9. Kirchherr, J., Reike, D., Hekkert, M.: Conceptualizing the circular economy: an analysis of 114 definitions. Resour. Conserv. Recycl. **127**, 221–232 (2017)
10. Ellen MacArthur Foundation About us: What we do. https://ellenmacarthurfoundation.org/about-us/what-we-do. Accessed 27 Nov 2021

11. Geissdoerfer, M., Savaget, P., Bocken, N.M.P., Hultink, E.J.: The circular economy – a new sustainability paradigm? J. Clean. Prod. **143**, 757–768 (2017). https://doi.org/10.1016/j.jclepro.2016.12.048
12. Schut, E., Crielaard, M., Mesman, M.: Circular economy in the Dutch construction sector: A perspective for the market and government (2016)
13. UNEP - UN Environment Programme. Sustainable and circular textiles. https://www.unep.org/explore-topics/resource-efficiency/what-we-do/sustainable-and-circular-fashion. Accessed 03 Dec 2021
14. Vogue. Fast Fashion vs Slow Fashion: Cuáles son las principales diferencias? https://www.vogue.mx/moda/articulo/fast-fashion-y-slow-fashion-principales-diferencias. Accessed 08 Dec 2021
15. Ellen MacArthur Foundation. Fashion and the circular economy. https://archive.ellenmacarthurfoundation.org/explore/fashion-and-the-circular-economy. Accessed 17 Dec 2021
16. Eisenhardt, K.M.: Building theories from case study research. Acad. Manage. Rev. **14**(4), 532–550 (1989)
17. Rialp, A.: The case method as a research technique and its application to the study of the managerial function. In: IV ACEDE Methodology Workshop, La Rioja (1998)

Rural Electrification Management Models: A Systematic Literature Review

Laura Del-Río-Carazo(✉), Santiago Iglesias-Pradas, Emiliano Acquila-Natale, and Carlos Cuenca-Enrique

ETSI de Telecomunicación, Universidad Politécnica de Madrid, Av. Complutense 30, 28040 Madrid, Spain
{laura.delrio,s.iglesias,emiliano.acquila}@upm.es, carlos.cuencae@alumnos.upm.es

Abstract. The development of off-grid technologies is facilitating the electrification of last mile communities. However, such solutions require an adequate management model to ensure the sustainability and success of the projects. The objective of this research is to contribute to the development of management models for rural electrification that help organizations successfully carry out these projects. The research is based on a systematic literature review that offers a detailed analysis of 34 publications (63 case studies), from an initial selection of 175 publications. The study presents a bibliographic and academic analysis of the management models identified in each case study. The analysis highlights the key issues found in the review and extends prior model proposals, serving as a starting point for future research.

Keywords: Rural electrification · Systematic review · Management models · Case studies · Developing countries

1 Introduction

Despite the efforts made by the different countries of the world, the Sustainable Development Goal (SDG) 7 ("Universal access to energy") will not be achieved by 2030 (United Nations 2019). There are many reasons why the initial objectives will not be achieved, but one of the main challenges is the electrification of *last mile communities*, which refer to those areas of the world that are so far from the conventional electricity grid that their electrification is not profitable for large energy companies (Gómez and Silveira 2015). While grid extension is the predominant way to provide energy access, it is generally not suitable for last-mile areas (Garces et al. 2021). Instead, and to help stop using fossil fuels (e.g., kerosene) as the main source of lighting, off-grid solutions are preferred in these cases (Katre et al. 2019).

Nonetheless, off-grid solutions require careful attention to management-related issues to be properly appropriated by the community and ensure the sustainability and success of the electricity provision (Pinheiro et al. 2012). These managerial issues usually cover the technical elements, financing and the roles of the actors involved in the

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 147–151, 2023.
https://doi.org/10.1007/978-3-031-27915-7_28

project; however, other important aspects, such as the assignment of responsibilities and duties for operation and maintenance, affordability, or energy resources, must also be clearly defined.

Previous research has proposed management model configurations for rural electrification projects (Del-Río-Carazo et al. 2022), based on a small number of case studies, and identify three key management areas: governance, technology and business. The governance area includes the definition of the actors involved in the project (owners or operators) and their relationships with the rest of agents and stakeholders, such as financiers, regulators, academic institutions and the communities and end users of the service. Technology encompasses the different decisions on the technical solution for energy provision, which may depend on the location of the communities, their dispersion, the proximity to an existing grid and the available energy generation sources. Lastly, the business area covers how the systems are provided and owned, as well as the consideration of maintenance costs and the type of contract under which the service is provided to end users. This study seeks to validate and extend existing management model configurations of rural electrification projects by offering a complete coverage of case studies through a systematic literature review.

2 Methodology

The systematic literature review (SLR) approach allows for easy replicability due to the transparency of the process (Grant and Booth 2009). Following Khan (2003), an SLR is carried out in five stages: (1) formulation of the research question, (2) identification of relevant studies, (3) selection of studies, (4) summarizing the evidence, and (5) interpretation of the results. The research proposes the following research questions:

RQ1: What types of management models are used in rural electrification projects in developing countries, based on the three key management areas?

RQ2: Is it necessary to revise and extend prior models?

For the SLR, the records were retrieved from the Web of Science and Scopus databases, using the terms *"rural electrification" AND management AND model NOT "energy management"* as the search terms in title, abstract and keywords. The criteria used for the screening are: publications in English or Spanish that include case studies of electrification projects in developing countries and mention any component of the management model (governance, technology, business). The selection of articles (Fig. 1) follows the PRISMA statement (Page et al. 2021).

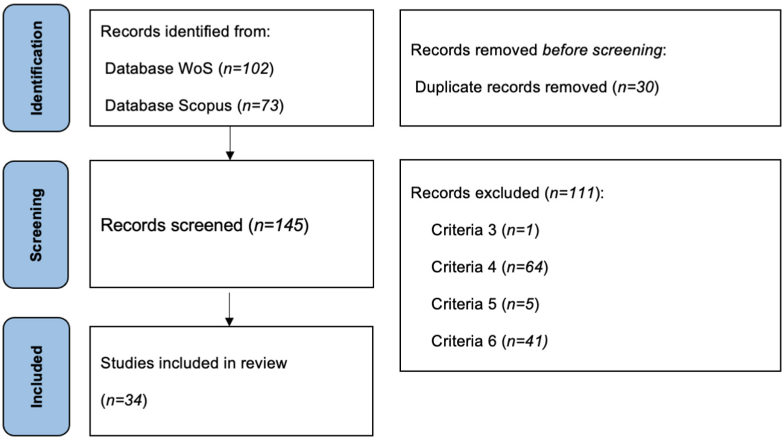


Fig. 1. PRISMA flow diagram for article selection.

3 Results

3.1 Bibliographic Analysis

Sixty-three case studies were identified in the 34 publications analyzed. The full set of articles identified in the SLR have been explored in detail to classify them according to certain key aspects (the SLR process can be accessed at http://tiny.cc/o0ipuz). Regarding publication dates, the number of publications in the field of rural electrification management has increased significantly since 2015, coinciding with the declaration of the Sustainable Development Goals: out of the 34 selected publications, 22 of them (64.7%) were published after 2014. Regarding publication types, the analysis shows a predominance of journal articles (22 articles, 64.7% of total publications). These findings confirm the current relevance and timeliness of this research.

The largest number of articles was published in *Energy* and *Renewable Energy* (3 each, 8,8% of total publications). "Renewable rural electrification: Sustainability assessment of mini-hybrid off-grid technological systems in the African context" (Brent and Rogers 2010) is the article with the highest number of citations (87 in Web of Science, 103 in Scopus). Most of the studies (10, 29.4% of publications) were authored by researchers affiliated to Spanish institutions. Peru (17, 27,0% of case studies) and India (6, 9.5% of case studies) are the countries with the largest number of case studies under analysis.

3.2 Content Analysis

The thematic analysis of the case studies used Del-Río-Carazo et al. (2022) management model configuration as the baseline framework. All case studies (63) specified the technology model, whereas the business and governance model were only specified in 34 case studies (53.9%). From the analysis, the results seem to confirm the suitability of the baseline framework, but also provide information for its improvement.

For instance, in the governance model, it is considered necessary to distinguish between the promoters of the projects and the owners of the systems; in some instances, the projects with cooperative ownership are not initiated or promoted by local agents; instead, the community receives the systems as a donation and then establishes the cooperative (Ferrer-Martí et al. 2012; Pinheiro et al. 2012). It is also recommended to differentiate between two elements relative to the operation of the project: tasks related to quota management and maintenance, on the one hand, and recharging of the systems, on the other hand, because devices are often recharged at a kiosk, rather than at the users' homes (Mohns and Stein 2008; Wong and Mathur 2011).

Concerning the business model, the analysis suggests that it is recommended to specify the different modalities for the management of users' default on payment plans and of equipment damage (Katre et al. 2019). Additionally, alternatives not included in the baseline framework, such as having a credit line available in advance without paying the corresponding installments, should be incorporated into the model (Loayza 2015).

At the technological level, the results show nuances with respect to the type of uses for the energy, such as only for lighting purposes, or lighting and other productive applications (e.g., cooking) (Lillo et al. 2015; McLean Sloughter et al. 2016; Sampath Kumar et al. 2018), and to the number and variety of sources involved in energy production (Rajanna and Saini 2017; Ranaboldo et al. 2015).

4 Conclusion

Two main contributions are derived from the study. First, the analysis confirms the relevance of the research topic, especially from the declaration of the Sustainable Development Goals in 2015. Second, the results support the adequacy of the baseline framework, but also give directions on how to improve it and make it more complete and comprehensive. Third, after reformulation of the management model configuration framework, the SLR in this study may be used as the starting point to further investigate the efficacy of the different management model configurations, as well as their effects on the sustainability of the rural electrification projects.

References

Brent, A.C., Rogers, D.E.: Renewable rural electrification: sustainability assessment of mini-hybrid off-grid technological systems in the African context. Renew. Energy **35**(1), 257–265 (2010). https://doi.org/10.1016/j.renene.2009.03.028

Del-Río-Carazo, L., Acquila-Natale, E., Iglesias-Pradas, S., Hernández-García, A.: Sustainable rural electrification project management: an analysis of three case studies. Energies **15**, 1203 (2022). https://doi.org/10.3390/en15031203

Ferrer-Martí, L., et al.: Evaluating and comparing three community small-scale wind electrification projects. Renew. Sustain. Energy Rev. **16**(7), 5379–5390 (2012). https://doi.org/10.1016/j.rser.2012.04.015

Garces, E., Tomei, J., Franco, C.J., Dyner, I.: Lessons from last mile electrification in Colombia: examining the policy framework and outcomes for sustainability. Energy Res. Soc. Sci. **79**(April), 102156 (2021). https://doi.org/10.1016/j.erss.2021.102156

Gómez, M.F., Silveira, S.: The last mile in the Brazilian Amazon - A potential pathway for universal electricity access. Energy Policy **82**(1), 23–37 (2015). https://doi.org/10.1016/j.enpol.2015.02.018

Grant, M.J., Booth, A.: A typology of reviews: an analysis of 14 review types and associated methodologies. Health Info. Libr. J. **26**(2), 91–108 (2009). https://doi.org/10.1111/j.1471-1842.2009.00848.x

Katre, A., Tozzi, A., Bhattacharyya, S.: Sustainability of community-owned mini-grids: evidence from India. Energy, Sustainab. Soc. **9**(1), 1–17 (2019). https://doi.org/10.1186/s13705-018-0185-9

Khan, K.S., Kunz, R., Kleijnen, J., Antes, G.: Five steps to conducting a systematic review. J. R. Soc. Med. **96**(3), 118–121 (2003). https://doi.org/10.1258/jrsm.96.3.118

Lillo, P., Ferrer-Martí, L., Boni, A., FernándezBaldor, Á.: Assessing management models for off-grid renewable energy electrification projects using the human development approach: case study in Peru. Energy Sustain. Dev. **25**, 17–26 (2015). https://doi.org/10.1016/j.esd.2014.11.003

Loayza, R.P.: Rural electrification at the ecuadorian jungle a new management model, prepaid system. In: ISES Solar World Congress 2015, Conference Proceedings (November), pp. 1633–1638 (2015). https://doi.org/10.18086/swc.2015.03.01

McLean Sloughter, J., Isakson, J., Ping Mak, Y., Schleicher, A.K., Louie, H., Shields, K., Salmon, M.: Designing a sustainable business plan for an off-grid energy kiosk in Chalokwa, Zambia. In: GHTC 2016 - IEEE Global Humanitarian Technology Conference: Technology for the Benefit of Humanity, Conference Proceedings, pp. 401–405 (2016). https://doi.org/10.1109/GHTC.2016.7857312

Mohns, W., Stein, D.: Community powerhouse: a rural electrification model for Vanuatu. Living Dark Energy Dev. **13**, 25 (2008)

Page, M.J., et al.: The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. The BMJ **372**, 71 (2021). https://doi.org/10.1136/bmj.n71

Pinheiro, G., Rendeiro, G., Pinho, J., Macedo, E.: Sustainable management model for rural electrification: case study based on biomass solid waste considering the Brazilian regulation policy. Renew. Energy **37**(1), 379–386 (2012). https://doi.org/10.1016/j.renene.2011.07.004

Rajanna, S., Saini, R.P.: Optimal modeling of an integrated renewable energy system with battery storage for off grid electrification of remote rural area. In: 1st IEEE International Conference on Power Electronics, Intelligent Control and Energy Systems, ICPEICES 2016 (2017). https://doi.org/10.1109/ICPEICES.2016.7853114

Ranaboldo, M., Domenech, B., Reyes, G.A., FerrerMartí, L., Moreno, R.P., GarcíaVilloria, A.: Off-grid community electrification projects based on wind and solar energies: a case study in Nicaragua. Sol. Energy **117**(2015), 268–281 (2015). https://doi.org/10.1016/j.solener.2015.05.005

Sampath Kumar, V., Prasad, J., Samikannu, R.: Barriers to implementation of smart grids and virtual power plant in sub-Saharan region—focus Botswana. Energy Rep. **4**, 119–128 (2018). https://doi.org/10.1016/j.egyr.2018.02.001

United Nations 2019: Report of the Secretary-General on SDG Progress 2019. Special Edition. United Nations Publications, pp. 1–64. Accessed 19 Oct 2021. https://sustainabledevelopment.un.org/content/documents/24978Report_of_the_SG_on_SDG_Progress_2019.pdf

Wong, S., Mathur, V.: Entrepreneurialising solar lanterns to solve energy poverty in India - potential and limitations. J. Sci. Ind. Res. **70**(8), 737–740 (2011)

Mathematical Programming Models for Sustainable Inventory Management in a Supply Chain

Pablo Becerra[1,2], Josefa Mula[1], and Raquel Sanchis[1](✉)

[1] Research Centre on Production Management and Engineering (CIGIP), Universitat Politècnica de València, C/ Alarcón, 1, 03801 Alcoy, Alicante, Spain
{fmula,rsanchis}@cigip.upv.es

[2] Universidad de Atacama, Copayapu 485, 1530000 Copiapó, Región de Atacama, Chile
pablo.becerra@uda.cl

Abstract. Supply chain network design is a systematic approach to determine the best combination of facilities, suppliers and products using mathematical modelling. Inventory management models aim to strike a balance between customer satisfaction and inventory carrying costs based on order size and timing decisions. Demand volatility is the reason for holding inventory. Here four mathematical programming inventory management models that consider some sustainability factors in a green supply chain context are studied.

Keywords: Mathematical programming · Sustainability · Inventory management · Supply chain

1 Introduction

There is growing pressure on companies to reduce the environmental impact of their production activities and to be economically sustainable. They must also seek to reduce their social impacts, or even have a positive impact, on local communities. Increasing customer awareness and expectations, coupled with stringent carbon policies call for a reduction in carbon emissions along supply chains, including inventory management [1]. CO_2 emission rates have increased in more recent years by around 2–3% per year [2]. According to the World Economic Forum [3], 13% of greenhouse gas (GHG) emissions that occur globally are due to the logistics industry.

Network design is one of the most important decisions in managing a supply chain, which determines their configuration, the location of facilities and their communications with one another [4]. This is because society has been developing an increasing sustainability awareness level and companies have realised that economic goals should no longer be supply chains' sole concern [5]. Sustainable inventory management (SIM) models [6] consider the economic, environmental, and social sustainability aspects. It is also described that inventory decisions must be made integrally alongside facility and routing decisions. In practice, neither tactical and strategic decisions are considered in

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 152–157, 2023.
https://doi.org/10.1007/978-3-031-27915-7_29

an integrated manner, nor is the social factor contemplated in many studied cases. In addition, the inventory models that bear in mind the three sustainability aspects have been developed, but neither take into account the company within a supply chain nor incorporate location and routing decisions. However, several authors have studied the design of supply chains with an integrated formulation of location, inventory and routing (LIR) decisions with mathematical programming models. Here four optimisation formulations are identified as reference models, and are analysed to solve LIR problems by considering sustainability aspects. Specifically, they are the models developed by Zhalechian et al. [7], Moslemi et al. [8], Asadi et al. [9] and Tavana et al. [10]. The remainder of the paper is structured as follows. Section 2 presents a comparative analysis of models on SIM in supply chains. Finally, Sect. 3 offers the conclusions.

2 Comparative Analysis

Based on previous studies by Becerra et al. [6, 11], four mathematical programming models were selected as a reference for developing a future optimisation model for managing SIM models in a supply chain context. Of all the articles reviewed in [6, 11], we selected those that developed a mathematical programming model, sought to solve a multi-objective LIR problem, and whose objectives, at least, considered environmental sustainability aspects. One of the selection criteria was for research to have been conducted in the last 10 years. After selecting the models, they were analysed and compared according to their main characteristics: modelling approach, model objectives, inventory policies, and solution approach. Finally, the contributions made by the authors in their models were identified according to their similarities and those specific to each one.

Table 1 summarises each of the models analysed in terms of: (i) modelling approach, (ii) model objectives, (iii) inventory policies, and (iv) the solution approach.

Firstly, Zhalechian et al. [7] propose a fuzzy multi-objective mixed integer linear programming (MO-MILP) model for an LIR problem to design a sustainable closed-loop supply chain under mixed uncertainty by considering economic, environmental and social impacts. Specifically, the environmental impacts of CO_2 emissions, fuel consumption and energy waste are considered, as is the social impact of job creation and economic development. The uncertain nature of the network is dealt with by applying a stochastic-possibilistic programming approach. A hybrid metaheuristic algorithm is used for large problems. The model minimises environmental impacts due to the energy wasted by vehicles waiting to be loaded/unloaded in remanufacturing centres. For this purpose, an M/M/c queuing system is formulated to model the queue formed by vehicles.

Moslemi et al. [8] develop an MO-MILP model in the healthcare supply chain by considering quality and environmental issues. The proposed model includes three objective functions: the first objective considers total manufacturing costs, including transportation, inventory holding, deterioration, order preparation, recycling, collection and disposal costs; the second objective maximises the production quality level; the third objective minimises the environmental effects of products and transportation. A multi-objective mathematical model for the green supply cha- in of the healthcare industry is formulated with many production targets and various stages. This model includes suppliers, manufacturers, cross-docking, hospitals, collection, recycling and waste disposal centres. Given the complexity of manufacturing medical devices and the required quality, they apply acceptance sampling for quality inspection to avoid dispatching faulty products. To address the environmental issue, the following aspects are considered: distance travelled by vehicles, fuel consumption per kilometre (depending on vehicle loads) and CO_2 emissions per trip to obtain the total amount of emissions. The solution approach is based on a non-dominated sorting genetic algorithm (NSGA II).

Table 1. Summary of the reference models.

Ref	Modelling approach	Objectives	Inventory policies	Solution approach
[7]	Fuzzy MO-MILP	-Minimisation of total costs -Minimisation of environmental impacts -Maximisation of social impacts	Continuous review policy (*s*, *Q*)	Hybrid two-stage: -Mixed possibilistic-stochastic programming approach and its crisp counterpart -Modified game theory approach
[8]	MO-MILP	-Minimisation of total costs -Maximisation of production quality -Minimisation of environmental effects	Not defined	Metaheuristic, NSGA II
[9]	MO-MINLP	-Minimisation of total system costs -Minimisation of total system pollution	Stock base policy (*S*-1, *S*)	Metaheuristics, NSGA II and MOPSO
[10]	MO-MILP	-Minimisation of total supply chain costs -Maximisation of orders from the most valuable suppliers	Not defined	Weighted fuzzy logic approach and a simulation algorithm

Asadi et al. [9] present a multi-objective mixed integer non-linear programming (MO-MINLP) model to design a distribution and production supply chain for algae biofuel by considering location, inventory and routing decisions formulated in an integrated manner. The model consists of an algae biomass production facility, several distribution facilities, many extraction sites and transport vehicles. The model's objectives are to minimise the system's implementation costs and the impact of pollution by CO_2 emissions. The biofuel production supply chain has three levels: the microalgae biomass production facility, distribution facilities and extraction sites. In the first stage, algae are converted into biomass by a batch production process. The biomass generated in this stage is transported to the distribution facilities. In this stage, the produced biomass is stored according to a base-stock inventory policy (S-1, S), which is distributed when demand arrives from the extraction sites. Then the microalgae biomass is converted into biofuel and glycerin. The model allows the following to be determined: the location and number of distribution facilities, the location of extraction sites for these facilities, the routes by which these sites are served, and the minimum inventory level that should be maintained in each distribution centre to fulfil the above objectives. The use of queuing theory concepts, together with inventory management principles, can lead to the formulation of more practical and general models. Inventory parameters are modelled using Markov chain concepts. The solution approach is based on NSGA II and multi-objective particle swarm optimization (MOPSO) metaheuristics.

Tavana et al. [10] formulate and solve an LIR problem in low-carbon green supply chains under uncertainty. The model allows for supplier selection and order allocation by considering location priorities, heterogeneous vehicle routing, storage needs, uncertain demand and backorder shortages. An MO-MILP model is presented for supply chain design by contemplating the location of distribution centres, green vehicle routing, inventory control, supplier selection and order allocation. The supply chain is a multiproduct, multiperiod and multistage network with supply, distribution and customer levels. For supplier selection, a mathematical model considers supplier score, procurement price, ordering costs, supplier capacity and order allocation. The products purchased from suppliers are firstly shipped to distribution centres and then to customers via an optimal route. The proposed model contemplates the storage and shortages possibilities in distribution centres.

3 Conclusions

The four analysed models apply a multi-objective mathematical programming modelling approach for the optimal decision-making purpose. Moslemi et al. [8] develop an MO-MILP model that considers deterministic parameters like demand or procurement and transportation costs. Asadi et al. [9] also consider deterministic parameters for their model, which differs by developing an MO-MINLP model. Zhalechian et al. [7] develop a fuzzy MO-MILP model under fuzzy logic incorporating uncertainty in demand, which follows normal distribution. It includes other parameters like shipping costs, distance travelled, delivery times, among others. Tavana et al. [10] incorporate uncertainty into their MO-MILP model through demand. Minimising supply chain costs is a common objective in the analysed models. Facility setup, inventory and transportation costs are the parameters shared in all four models. The incorporation of environmental effects is diverse. The model in [7] defines a target that seeks to minimise environmental impacts by reducing CO_2 emissions, fuel consumption and wasted energy. The model of Moslemi et al. [8] seeks to minimise the environmental effects produced by suppliers and manufacturers, and to reduce CO_2 emissions from vehicles. Asadi et al. [9] introduce the polluting effects of distribution centres and inventory activities, in addition to the pollution generated by vehicles. Unlike the aforementioned models, Tavana et al. [10] do not consider an explicit objective to reduce the environmental impact, but do so implicitly by incorporating fuel consumption into the cost minimisation objective. As for incorporating an objective that impacts the social factor of sustainability, only Zhalechian et al. [7] consider it by seeking to maximise this impact through employment opportunities and local economic development. The four models define the optimal location of their facilities regardless of them being distribution centres or cross-docking centres. The assignment of vehicles to optimal routes to transport raw materials and products is also incorporated. The models also determine the size of orders between suppliers and manufacturers or distribution centres. The inventory level is a widely used parameter in relation to inventory management policies. Of the analysed models, two incorporate some inventory policy, which are a continuous review policy (s, Q) [7] and a stock-based policy (S-1, S) [9]. The closed-loop supply chain design is present in two forms; firstly, the collection of returned products from retailers to remanufacture [7]; secondly, the collection of material from hospitals and then the management of its disposal or shipment to recycling centres to suppliers as raw material [8]. The models present varied solution approaches. The development of metaheuristic algorithms is a common approach to solve large problems. Of the analysed models, one solves the problem with an NSGA II [8], while another makes a comparison by applying two metaheuristics: an MOPSO algorithm and NSGA II [9]. It is important to highlight that the only model to incorporate supplier selection is that of Tavana et al. [10]. Finally, a future study aims to build and solve a multi-objective mathematical programming model based also on [6, 11]. The main identified shortcoming of the compared models is the difficulty of incorporating the social factor, in this sense, only one author does so, and it is difficult to measure the social impact that the supply chain can generate. So, the purpose of the forthcoming model is to manage supply chain inventories in a closed-loop structure by incorporating the three sustainable aspects, integrating location and routing decisions, and applying it to a copper mining supply chain. This model will correspond to a MO-MINLP, which seeks to minimise logistics costs, minimise GHG emissions and maximise positive social impacts and minimise negative ones. It will consider the emission of gases in the transportation, manufacturing, and inventory processes. The potential positive social impacts incorporated in the model will be based on the amount of direct and indirect employment generated in nearby communities and the negative impacts will be associated with occupational accidents as result of inventory activities and damage from potential accidents on transportation routes.

Acknowledgment. The research leading to these results received funding from the Regional Department of Innovation, Universities, Science and Digital Society of the Generalitat Valenciana entitled "Industrial Production and Logistics Optimization in Industry 4.0" (i4OPT) (Ref. PROMETEO/2021/065). It was also funded by the National Agency for Research and Development (ANID)/Scholarship Program/Doctorado Becas en el Extranjero/2020 - 72210174.

References

1. Ahmadini, A.A.H., Modibbo, U.M., Shaikh, A.A., Ali, I.: Multi-objective optimization modelling of sustainable green supply chain in inventory and production management. Alexandria Eng. J. **60**, 5129–5146 (2021). https://doi.org/10.1016/j.aej.2021.03.075
2. Ritchie, H., Roser, M.: CO2 and Greenhouse Gas Emissions, ourworldindata.org/co2-and-other-greenhouse-gas-emissions. Accessed 23 Feb 2022
3. World Economic Forum: The future of jobs report 2020, Geneva (2020)
4. Chopra, S., Meindl, P.: Supply chain management. strategy, planning & operation. In: Das Summa Summarum des Management, pp. 265–275. Gabler, Wiesbaden (2007). https://doi.org/10.1007/978-3-8349-9320-5_22
5. ChibelesMartins, N., PintoVarela, T., BarbosaPóvoa, A.P., Novais, A.Q.: A multi-objective meta-heuristic approach for the design and planning of green supply chains - MBSA. Expert Syst. Appl. **47**, 71–84 (2016). https://doi.org/10.1016/j.eswa.2015.10.036
6. Becerra, P., Mula, J., Sanchis, R.: Green supply chain quantitative models for sustainable inventory management: a review. J. Clean. Prod. **328**, 129544 (2021). https://doi.org/10.1016/j.jclepro.2021.129544
7. Zhalechian, M., TavakkoliMoghaddam, R., Zahiri, B., Mohammadi, M.: Sustainable design of a closed-loop location-routing-inventory supply chain network under mixed uncertainty. Transp. Res. Part E Logist. Transp. Rev. **89**, 182–214 (2016). https://doi.org/10.1016/j.tre.2016.02.011
8. Moslemi, S., ZavvarSabegh, M.H., Mirzazadeh, A., Ozturkoglu, Y., Maass, E.: A multi-objective model for multi-production and multi-echelon closed-loop pharmaceutical supply chain considering quality concepts: NSGAII approach. Int. J. Syst. Assur. Eng. Manage. **8**, 1–17 (2017). https://doi.org/10.1007/s13198-017-0650-4
9. Asadi, E., Habibi, F., Nickel, S., Sahebi, H.: A bi-objective stochastic location-inventory-routing model for microalgae-based biofuel supply chain. Appl. Energy **228**, 2235–2261 (2018). https://doi.org/10.1016/j.apenergy.2018.07.067
10. Tavana, M., Tohidi, H., Alimohammadi, M., Lesansalmasi, R.: A location-inventory-routing model for green supply chains with low-carbon emissions under uncertainty. Environ. Sci. Pollut. Res. **28**, 50636–50648 (2021). https://doi.org/10.1007/s11356-021-13815-8/Published
11. Becerra, P., Mula, J., Sanchis, R.: Sustainable inventory management in supply chains: trends and further research. Sustainability. **14**, 2613 (2022). https://doi.org/10.3390/su14052613

Joint Maintenance and Spare Machines Management Policies Assessment

Jesus Maria Pinar-Perez[1](✉), Diego Ruiz-Hernandez[2], Roberto Morales-Arsenal[1], and Alberto Pliego-Marugan[1]

[1] Department of Quantitative Methods, CUNEF University, Madrid, Spain
{jesusmaria.pinar,rmorales,alberto.pliego}@cunef.edu
[2] Sheffield Univ. Management School, Conduit Road, Sheffield S10 1FL, UK
d.ruiz-hernandez@sheffield.ac.uk

Abstract. This work presents an assessment and comparison of a collection of joint maintenance and spare machine management policies. Resource dependence is considered to schedule preventive maintenance interventions for a multi-unit system with deteriorating machines. A limited number of workers is taken into account to perform maintenance tasks. The maintenace policies considered in this work are the Threshold policy, the Periodic policy and the Index policy. The (s,S) continuous review spare machines policy is employed considering a stochastic replenishment lead time. Results show the advantages reached with the joint approaches and suggests that the Index joint policy achieves to keep the system less deteriorated at a lower cost than other policies.

Keywords: Maintenance management · Spare machines · Scheduling

1 Introduction

Maintenance and spare machines are closely related activities. Maintenance interventions generate a demand of spare machines. This leads managers to keep an inventory to quickly supply the maintenance needs. The scheduling of maintenance interventions is very important to reach an adequate system´s availability, reliability and safety. A system well-maintaned performs better, extends its life cycle and reduces costs. The literature shows a great effort done to reduce operation and maintenance costs in some systems such as wind farms [1, 2]. Maitenance includes two type of interventions: corrective and preventive. Corrective interventions are carry out when a machine fails. Preventive interventios are planned taken into account the age of machines, the operation time or their wear/deterioration condition. Condition monitoring systems allow managers to know the real deterioration state of machines and to predict future failures [3]. Moreover, literature collects the advancements in maintenance scheduling optimization, with a particular focus on the development and assesment of mathematical models [4]. Different dependencies, such as economic, structural, stochastic, and resource dependencies, can be used to characterize maintenance scheduling optimization [5]. Most of these studies present economic or stochastic dependencies. The literature considering resources

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 158–163, 2023.
https://doi.org/10.1007/978-3-031-27915-7_30

dependence has been sparse [4]. The existence of an infinite amount of resources, such as spare machines and repairmen, is frequently assumed in maintenance management policies which is not usually the case in practice.

The main task of inventory is to provide spare machines to fulfill maintenance requirements. However, the inventory of spare machines involves some costs such as holding costs, ordering costs and backlog costs. Reference [6] reviews the stoking policies commonly implemented in practice that can be clasified into the following four policies: i) (T, R) policy is a periodic review policy in which orders are placed in a fixed interval T to reach the order-up-to level R. ii) (Q,r) continuous review policy has a fixed order size Q and a fixed reorder point r. iii) (s,S) policy is a continuous review policy where a new order (order-up-to level S) is placed when the inventory on hand go down the reorder point s. iv) (S-1,S) continuous review policy is called one-for-one replenishement policy and is used for repairable spare machines. To reduce operating costs, managers must address maintenance scheduling and spare machines management simultaneously. Literature collects the efforts done for the joint maintenance and inventory optimization showing that problems considering multi-machines systems with resources dependence had not enough attention [7].

The aim of this work is to assess a collection of joint maintenance and spare machine management policies. Resource dependence is considered to schedule preventive maintenance activities for a multi-unit system with deteriorating machines. A limited number of workers is taken into account to performs maintenance tasks. The deterioration of machines is modelled by a Markov process. The (s,S) spare machines policy is employed considering a stochastic replenishment lead time.

2 Problem Formulation

The problem consists on scheduling maintenance interventions over time for a group of machines. We assume that these machines are independent and maintenance interventions are perfect. Maintenance interventions depend on the number of technicians and the spare machines available. The main objective is both to reduce downtimes and to minimize the total costs incurred by maintenance tasks, operation of the system and inventory.

Machines are subject to stochastic breakdowns and deterioration. A discrete multi-state Markov process is employed to model the deterioration of machines. Figure 1 shows the Markov decision chain used in this work. A machine in state θ can experiment any of the following actions: i) Operation, where the machine evolves to a higher deterioration state $\theta + 1$ incurring in an operation cost and a higher transition probability $p^0(\theta, \theta + 1)$; ii) Preventive maintenance intervention, where the machine intervened returns to its initial state or state $\theta = 0$ with a probability $p^1(\theta, 0)$ and incurring a cost; iii) Corrective maintenance intervention, if a breakdown or a major failure appears. Corrective maintenance replaces a failed machine with a spare machine ($\theta = 0$) incurring a large cost. Preventive interventions are scheduled at each decision epoch and implemented by a limited number of technicians to maintain those machines selected by a maintenance policy. Corrective interventions are unplanned and require spare machines from inventory. Spare machines must be available, otherwise corrective maintenance interventions cannot be carried out incurring in a backlog inventory cost. The continuous review inventory policy (s,S) is employed in this work where a new order (order-up-to level S) is placed when the inventory on hand (IH) falls below the reorder point s involving an ordering cost C_O. Spare machines in inventory involves holding costs C_H. After the replenishment lead time, the new order will be available in the inventory. For more realistic view, a stochastic replenishment lead time RLT_t is considered in this work.

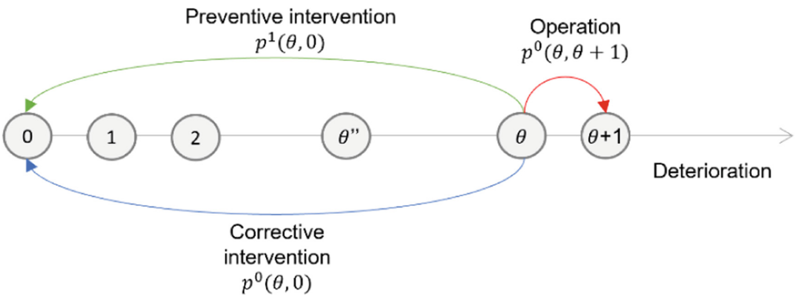


Fig. 1. Multi-state Markov decision chain

The set Ω collects the states $\theta(t)$ of a machine m at any decicion epoch t, where $\psi(t) = \{\theta_m(t), m = 1, ..., M\} \in \Omega$. M represents the number of machines in the system. Maintenance interventions conducted for the machine m at any decision epoch t are represented by $a_m(t) = 1$, and $a_m(t) = 0$ means that this machine must be operated. The objective of the problem is to minimize the discounted costs of the system for each joint policy π used.

$$\min_{\pi}\left\{E_{\pi}\left[\sum_{t=0}^{\infty}\beta^{t}\cdot TC^{a(t)}(\psi)\right]\right\} \quad (1)$$

where β is the discount factor and $TC^{a(t)}(\psi)$ represents the total costs of the system (including operation, intervention and spare machine costs) for any state of the set ψ.

Standard dynamic programming techniques are impractical for finding an optimal solution in real applications due to the size of the problem. Therefore, we're more interested in evaluating and comparing different joint policies used in practice.

3 Maintenance Policies

Considering the continuous review inventory policy (s,S) and based on the maintenance approaches presented in [8], three joint maintenance and spare machines policies are assesed. This work extends and improves the joint policies presented in [9] including a periodic-based maintenance policy and a stochastic replenishment lead time in the stock policy for a more realistic view. Threshold and Periodic policies are classical approaches that do not consider the characteristics of the machines such as age, deterioration rate and operation and intervention costs. Index join policy takes into account all information about the system.

Threshold joint Policy. In this policy, a deterioration state limit is stablished to carry out the preventive intervention. The number of machines to intervene depends on the number of technicians (R) available in this period. In the case that the number of machines up to the threshold is higher than R, technicians will maintain the machines with larger deterioration state.

The Markov decision actions set can be defined as

$$a_m(t) = \begin{cases} 1, & \theta_m(t) \geq T \\ 0, & otherwise \end{cases}, \quad \sum_{m=1}^{M} a_m(t) \leq R \tag{2}$$

where T is the deterioration state threshold stablished. Note that the number of technicians R is much less than the number of machines M.

Periodic Joint Policy. In this approach, machines are preventively maintained in periodic cycles predefined by the manufacturer. First, at each decision epoch, technicians intervene the R machines with the largest state of deterioration and assign them a future date for the coming cycle intervention. The next step is to implement preventive interventions based on the scheduling established before and repeat this schedule for the next cycles. If a machine fails, a corrective intervention will carry out involving a spare machine demand. In this case, the preventive intervention for this machine is not neccesary in this cycle and it will be re-scheduling for the next cycle.

Index Joint Policy. In this approach all information available to schedule intervention indices is considered. Reference [10] presents a description of this Index intervention policy. This indices are calculated for each machine and its deterioration state $I(m, \theta_m(t))$ and they are a function considering the deterioration state space of the system, the transition probabilities and the costs associated.

$$I(m, \theta_m(t)) = f\left(\psi(t), p^{a_m(t)}(\psi(t)), C^{a_m(t)}(\psi(t), \beta)\right) \tag{3}$$

Interventions must be allocated to those R machines with largest indices. The Markov decision actions set can be defined as

$$a_m(t) = \begin{cases} 1, & \forall m : I(m, \theta_m(t)) \geq \Gamma \\ 0, & otherwise \end{cases}, \quad \sum_{m=1}^{M} a_m(t) \leq R \tag{4}$$

where Γ is the R^{th} largest index from Eq. (3).

4 Results-Conclusions

The joint maintenance and spare machines management policies were developed and series of numerical examples were conducted to assess these different approaches. An initial analysis of the results reveals that the costs incurred by the Index joint policy is less than other approaches (see Fig. 2a), keeping the deterioration of the system at lower states (see Fig. 2b). The Periodic joint policy is the approach that reached the higher deterioration for the system although the total costs are very similar to the Threshold policy. The holding cost was higher for the Index policy (see Fig. 2c) because more spare machines has remained in the inventory. In this case, the variance of the average inventory-on-hand is higher for the Index policy compared with other policies. Figure 2d shows that the Index policy replaced less machines than other approaches. Results displays the trade offs made by the joint policies rather than implementing the optimization of maintenance management and spare parts management separately.

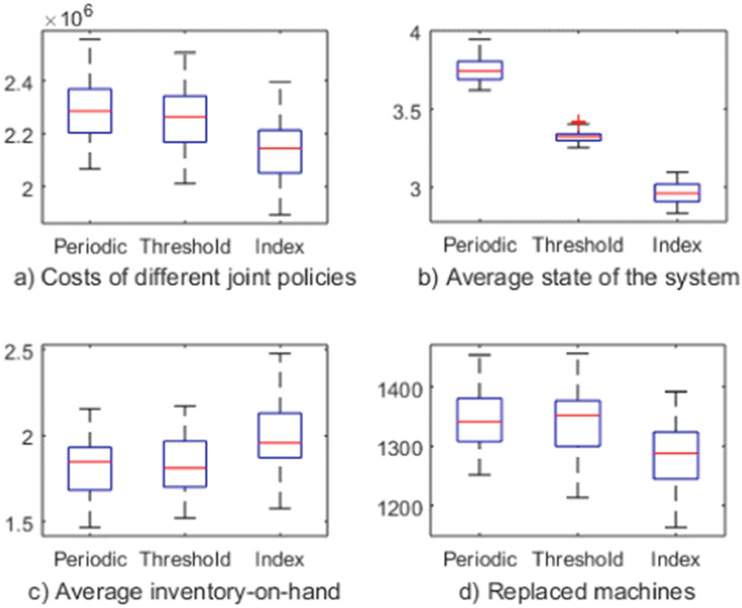


Fig. 2. Simulation results for the three joint policies considering 50 machines, 2 technicians, reorder point s = 2, inventory target S = 8 and 1040 intervention periods.

References

1. Segura Asensio, E., Pinar Pérez, J.M., García Márquez, F.P.: Economic viability study for offshore wind turbines maintenance management. In: Xu, J., Nickel, S., Machado, V.C., Hajiyev, A. (eds.) Proceedings of the Ninth International Conference on Management Science and Engineering Management. AISC, vol. 362, pp. 235–244. Springer, Heidelberg (2015). https://doi.org/10.1007/978-3-662-47241-5_19
2. Pliego, A., Garcia Marquez, F.P., Pinar Perez, J.M.: Optimal maintenance management of offshore wind farms. Energies **9**(1), 46 (2016)
3. Pérez, J.M.P., Márquez, F.P.G.: Condition monitoring and fault diagnosis in wind energy systems. In: Eco-Friendly Innovation in Electricity Transmission and Distribution Networks, pp. 221–241. Elsevier (2015). https://doi.org/10.1016/B978-1-78242-010-1.00011-2
4. de Jonge, B., Scarf, P.A.: A review on maintenance optimization. Eur. J. Oper. Res. **285**, 805–824 (2020)

5. Keizer, M.C., Flapper, S.D., Teunter, R.H.: Condition-based maintenance policies for systems with multiple dependent components: a review. Eur. J. Oper. Res. **261**, 405–420 (2017)
6. Hu, Q., Boylan, J.E., Chen, H., Labib, A.: OR in spare parts management: a review. Eur. J. Oper. Res. **266**(2), 395–414 (2018)
7. Van Horenbeek, A., Buré, J., Cattrysse, D., Pintelon, L., Vansteenwegen, P.: Joint maintenance and inventory optimization systems: a review. Int. J. Prod. Econ. **143**(2), 499–508 (2013)
8. RuizHernández, D., PinarPérez, J.M.: Cost/efficiency assessment of alternative maintenance management policies. In: Xu, J., Gen, M., Hajiyev, A., Cooke, F.L. (eds.) Proceedings of the Eleventh International Conference on Management Science and Engineering Management. LNMIE, pp. 1395–1406. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-59280-0_117
9. Pinar-Pérez, J.M., Ruiz-Hernández, D., Marugán, A.P.: Assessment of joint maintenance and inventory management policies. In: Xu, J., GarcíaMárquez, F.P., AliHassan, M.H., Duca, G., Hajiyev, A., Altiparmak, F. (eds.) Proceedings of the Fifteenth International Conference on Management Science and Engineering Management. LNDECT, vol. 79, pp. 789–798. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-79206-0_59
10. Glazebrook, K., Mitchell, H., Ansell, P.: Index policies for the maintenance of a collection of machines by a set of repairmen. Eur. J. Oper. Res. **165**, 267–284 (2005)

Measuring Social Trends of Foodtech

Enara Zarrabeitia-Bilbao[1] (✉), Izaskun Álvarez-Meaza[1], Rosa María Rio-Belve[2], and Jon Borregan-Alvarado[1]

[1] University of the Basque Country, 1. 48013, Plaza Ingeniero Torres Quevedo, Bilbao, Spain
enara.zarrabeitia@ehu.eus

[2] University of the Basque Country, C/ Nieves Cano 12, 01007 Vitoria, Spain

Abstract. The research carried out analyzes more than 1.5 million tweets posted in the last decade (from 2012 to 2021) and captured through Twitter API for Academic Research. The study reveals that in the last decade, foodtech has been a sidestream topic, debated among expert subgroups. Concretely, actors related to entrepreneurial and startup ecosystems, food innovation, and academic world have led the digital discussion. The conversations have been mostly inter-territorial, with the US acting as the backbone of the communication. The debate that is taking hold in terms of presence and content is aligned with digital transformation and Industry 4.0. Moreover, although the dialogues are generally taking place in positive terms, the negative peaks that occur should be analyzed in more depth.

Keywords: Foodtech · Food technologies · Twitter · Social trends

1 Introduction

New technologies have changed the world and the rules of the game in many industries. The food industry, however, is still wondering how to apply innovations such as big data and the Internet of Things (IoT) to its business. The sector faces numerous challenges, including food sustainability; however, foodtech is leading the way [1].

Foodtech are companies and projects that exploit technologies such as the IoT, big data and artificial intelligence, among others, to transform the agri-food industry into a more modern, sustainable and efficient sector at all stages, from product, to distribution, marketing or business model. These projects are generally highly innovative start-ups and it is estimated that the sector's total value will be over US$250 billion in 2022 [1, 2].

In this context, it should be noted that the microblogging platform Twitter allows researchers, technology experts, inventors, and other users of the digital sphere to share their knowledge, opinions, comments and expectations about specific sectors or technologies on the social network. Hence, extracting data from tweets and Twitter user characteristics makes it possible to study social trends with respect to strategic or emerging sectors or technologies [3].

In short, the main objective of this research is to analyze what the social trends of foodtech have been in the last decade.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 164–170, 2023.
https://doi.org/10.1007/978-3-031-27915-7_31

2 Research Methodology

The procedure followed for the analysis of the social impact of foodtech started with gathering tweets published on the subject in the last decade (from 2012 to 2021).

For the selection of the tweets that make up the sample of this study, the search query considered was: *foodtech OR "food tech" OR foodtechnology OR "food technology"*. The tweets were downloaded using the Twitter API for Academic Research and Twarc (a command line tool and Python library for collecting and archiving Twitter JSON data via the Twitter API).

Once the tweets were obtained and processed, the two lustrums for the decade in question were studied and compared, as shown in Table 1.

Table 1. Methodology followed for the empirical approach

Triggering questions	Data analysis methodology (over the two lustrums)
What has been the social presence of foodtech?	-Temporal distribution of the number of tweets analysis
Who have been the protagonists of the digital discussion?	-Main communities analysis: Louvain Multilevel Algorithm -Key players analysis: Node-level metrics (input degree centrality)
In what terms has the discussion developed in the virtual sphere?	-Hashtag analysis: Frequency analysis (word cloud) -Sentiment analysis: VADER model

3 Results and Discussion

The research collected a total sample of 1,564,240 tweets. 41.8% of the tweets correspond to the period 2012–2016 (see Fig. 1) and 58.2% of the tweets correspond to the period 2017–2021 (see Fig. 2), indicating general increased interest in the subject on the social network.

The two figures (Figs. 1 and 2) show that the distribution of tweets has been relatively homogeneous over time. However, different discussion topics or events have led to increased activity on the network.

Surprisingly, the topics that have generated unusual activity in both periods have not been directly related to either foodtech start-ups or to food innovative projects. On the one hand, in the first lustrum, the event that generated unusual activity on March 30, 2014 was a graduate fellowship in food technology in Indonesia[1]. And, on the other hand, in the second lustrum, the events that generated unusual activity (on September 12, December

[1] The tweet that triggered a great deal of activity on the social network:https://twitter.com/BeasiswaIndo/status/450263983056904192.

14 and May 9, 2019, respectively) were an initiative promoted by the Department of Food Technology of the Mahasarakham University to help people affected by the floods in Thailand[2], and two tweets that used satire or parody as a strategy to criticize food technologies[3].

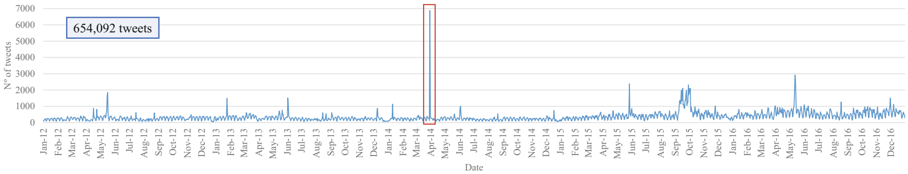


Fig. 1. General trend of tweets over the period 2012–2016

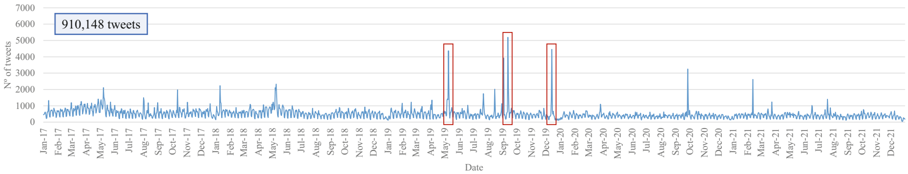


Fig. 2. General trend of tweets over the period 2017–2021

Regarding the central characters of the digital discussion, Figs. 3 and 4 illustrate which main communities have participated in the conversation and the position that each community holds; and Tables 2 and 3 show who the leaders or protagonists of the conversation in each of the communities have been.

	Name assigned	Presence
1	U.S. agents (start-up ecosystem)	36.68%
2	French agents (start-up ecosystem)	20.75%
3	Global and local agents (start-up ecosystem)	11.21%
4	Indian agents (start-up ecosystem)	9.63%
5	UK food and education personalities and agents	8.45%
6	Food and education events and companies	6.88%
7	Food education and information personalities and agents	6.41%

Fig. 3. Seven most important communities' network from 2012 to 2016

[2] The tweet that triggered a great deal of activity on the social network:https://twitter.com/leesujin97/status/1172056550828986370.

[3] The tweets that triggered a great deal of activity on the social network:https://twitter.com/lilyyyates/status/1205255164610990081.https://twitter.com/sb_emeka/status/1126248447026388994

	Name assigned	Presence
1	French agents (start-up ecosystem)	25.76%
2	U.S. and global agents (start-up ecosystem)	16.4%
3	U.S. agents (start-up ecosystem)	11.96%
4	European agents (start-up ecosystem)	10.74%
5	Meat industry	10.15%
6	Personalities (digital transformation.)	9.62%
7	Indian and U.S. companies (online food home delivery)	7.76%
8	Spanish agents (food innovation)	7.61%

Fig. 4. Nine most important communities' network from 2017 to 2021

Table 2. Brief description of the main communities' leaders from 2012 to 2016

	Leaders (input degree centrality)[4]	Profile of leaders
1	**@foodtechconnect, @dhgisme, @techcrunch, @baconista, @forbes**	U.S. agents related to the entrepreneurial and foodtech start-up ecosystem
2	**@bymaddyness**, @lusinedigitale, @smartfood-paris, @33entrepreneurs, @lsaconsommation	French agents related to technology start-ups and food innovation
3	**@seedsandchips**, @startup_italia, @sbcfoodtech, @shakeupfactory, @sbootcamp	Global and local agents related to innovation and start-ups, and foodtech start-up accelerators
4	@yourstoryco, @zomato, @linkedin, @swiggy_in, @inner_chef	Indian agents related to entrepreneurship and the restaurant industry, and the world's largest professional network on the Internet
5	@jamieoliver, @teachertoolkit, @joclarkyhage, @7mrsjames, @foodtcentre	UK personalities and agents related to food and education
6	@foodtechweek, @justeatuk, @thefoodrush, @bluecarthq, @ga	Events and companies related to food and education
7	@ift, @calestous, @foodmanufacture, @foodinsight, @ucdavis	Personalities and agents related to food education and information

Table 3. Brief description of the main communities' leaders from 2017 to 2021

	Leaders (input degree centrality)[1]	Profile of leaders
1	@bymaddyness, @lafoodtech, @digitalfoodlab, @lesechos, @frichtifrichti	French agents related to technology start-ups and food innovation
2	**@seedsandchips**, @forbes, @agfunder, @techcrunch, @foodtank	U.S. and global agents related to the entrepreneurial and foodtech start-up ecosystem
3	@thespoontech, @foodbytes, @foodtechconnect, @techstars, @ces	U.S. agents related to the entrepreneurial and start-up ecosystem, and food innovation
4	@forwardfooding, @yfood_, @solar_foods, @eit_food, @swefoodtech	European agents related to the entrepreneurial and start-up ecosystem, and food innovation
5	@impossiblefoods, @foodtechinvest, @good-foodinst, @memphismeats, @perfectdayfoods	Events and industry related to food innovation (especially meat)
6	**@jblefevre60, @haroldsinnott, @mvollmer1, @ipfconline1, @chboursin**	Personalities working with technologies related to digital transformation
7	@zomato, @swiggy_in, @amazon, @ubereats, @zomatoin	U.S. and Indian online food home delivery platforms and U.S. e-commerce company
8	@foodtechbcn, @bculinary, @eatableadv, @tech-foodmag, @techfood_mag	Spanish agents related to foodtech start-ups and food innovation

As to be expected, all communities have been led by actors related to entrepreneurial and start-up ecosystems, food innovation issues, and academic-related agents.

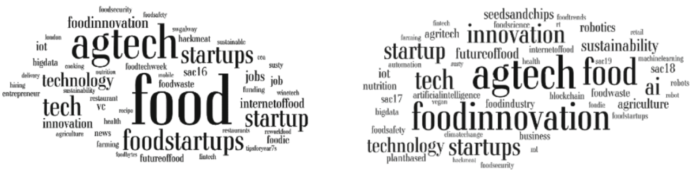
In addition, it is observed that digital activity key players tend to be grouped by the country to which they belong; therefore, it cannot be said that the debates generated, in general, have been inter-territorial. Thus, the countries with the greatest prominence, worldwide, have been the United States and India, and at a European level, France, United

Kingdom and Spain. This is consistent with the fact that the United States, China[4], Israel and India lead the ranking of the entities where there is greater investment in foodtech start-ups, and that in Europe investment is led by the United Kingdom, France and Spain [4].

It can also be seen that the United States (primarily due to the central position it adopted in the last period) is the backbone of communication.

Another significant fact from the second lustrum is the emergence of a community composed of personalities or influencers related to technologies such as IoT, big data and artificial intelligence, enabling digital transformation (in line with the definition of food technologies itself). Likewise, these personalities, in addition to leading one of the communities, also lead the general conversation that has taken place throughout the entire last five-year period, i.e., they are the leaders of the overall network.

Similarly, aware that digital transformation and industry 4.0 offers significant benefits to the food sector at an operational and strategic level; Fig. 5 shows how in the second period terms like "ai", "robotics", "iot", "blockchain" and "bigdata" gained more presence on most highlighted hashtags (the 50 that most frequently appear in the tweets, once #foodtech and #foodtechnology are removed).



Period 2012 to 2016 **Period 2017 to 2021**

Fig. 5. Main hashtags used in the digital conversations from 2012 to 2016 and from 2017 to 2021

Finally, Figs. 6 and 7 show the average tweet sentiment per day in the digital discussion (after removing all non-English tweets, i.e. 25% of the tweets). In both periods, the overall emotional state has been positive. However, especially in the second period, there are positive and, above all, negative peaks, which require further analysis.

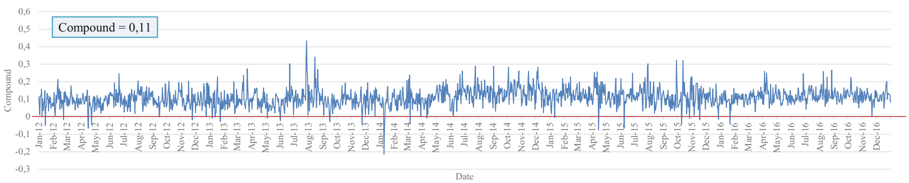


Fig. 6. Average tweet sentiment per day from 2012 to 2016

4 In China, Twitter has been blocked since 2009.

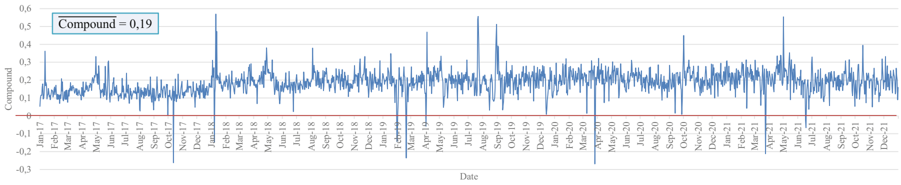


Fig. 7. Average tweet sentiment per day from 2017 to 2021

4 Conclusions and Future Lines of Research

From the scientific study carried out, it can be inferred that actors related to entrepreneurial and start-up ecosystems, food innovation, and academic world lead the digital discussions about foodtech on Twitter. Therefore, this social network is a dissemination tool that works, in this case, as a means of expression for a specific community. Namely a technical or collegiate community, which knows about the subject or is interested in it, and which has its own registry or code. In the last 10 years foodtech has been a sidestream rather than trending topic and the debate has been among expert subgroups. In addition, without inter-territorial cohesion, it is difficult to make a debate emerging from the alternative or sidestream world into a mainstream one.

With regard to the participation of the countries on the social network, the US clearly leads, being a channel for the different conversations thanks to its central position on the main network.

The debate coming to the fore, in terms of presence and content, is aligned with digital transformation and Industry 4.0. And, although the dialogues are generally taking place in positive terms, the events that have given rise to negative responses from society require further analysis, owing, in recent years, to the emergence of naturalist movements, among others, that tend to emphasize the role of natural food.

Finally, despite the fact that twitter plays an important role as a space for local, national and international conversation, and the different debates created on the digital platform have a great impact on various sectors of real life, it should be noted the methodological limitations of research on Twitter, based on the restrictions of the data collected, the bias of representation when making general assumptions and other problems, derived, for example, from the language of use of the users [5–7].

All in all, it would be interesting to extend the study to identify the development trends in science and technology using different data from scientific databases (WoS / Scopus) and patent databases.

References

1. Iberdrola Food Tech, the technological transformation of the food sector. https://www.iberdrola.com/innovation/foodtech. Accessed 20 Feb 2022
2. DigitalFoodLab What is FoodTech? https://www.digitalfoodlab.com/foodtech/. Accessed 20 Feb 2022
3. Li, X., Xie, Q., Jiang, J., Zhou, Y., Huang, L.: Identifying and monitoring the development trends of emerging technologies using patent analysis and Twitter data mining: the case of

perovskite solar cell technology. Technol. Forecast. Soc. Change **146**, 687–705 (2019). https://doi.org/10.1016/J.TECHFORE.2018.06.004
4. AGRIFOOD21 Smart Agrifood Summit. https://smartagrifoodsummit.com/startup-europe-smart-agrifood-summit-will-call-more-than-300-startups-with-innovative-projects-in-agricultural-and-food-technology/. Accessed 27 Feb 2022
5. Ruiz-Soler, J.: Twitter research for social scientists: a brief introduction to the benefits, limitations and tools for analysing Twitter data. Rev. Dígitos **1**, 17–32 (2017). https://doi.org/10.7203/rd.v1i3.87
6. MoralesiGras, J., OrbegozoTerradillos, J., LarrondoUreta, A., PeñaFernández, S.: Networks and stories. Analyzing the transmission of the feminist intangible cultural heritage on twitter. Big Data Cogn. Comput. **5**(4), 69 (2021). https://doi.org/10.3390/bdcc5040069
7. Cossu, J., Dugué, N., Labatut, V.: Detecting real-world influence through Twitter. In Proceedings of the 2nd European Network Intelligence Conference, pp. 1–8 (2015)

Lean Manufacturing Powered by IoT: A Bibliometric Analysis of the Emerging Literature

Jesús Rodríguez-Martín(✉) and Patxi Ruiz-de-Arbulo-López

University of the Basque Country (UPV/EHU), Bilbao, Spain
{jesus.rodriguez,patxi.ruizdearbulo}@ehu.eus

Abstract. IoT is an important part of business digitization. But in addition, companies already have LM tools in their factories, so their interaction must be key, they must benefit. The development of I4.0, with an IoT that is part of the LM tools, leads us to ask ourselves two questions in relation to the current lines of research and on which cluster scientific development is being grouped. It is something fundamental, which will allow companies to make decisions effectively and clearly. After detecting 147 publications in relation to our research, we carry out a bibliometric analysis, and generate important network maps. They let us know the main authors, as well as countries that are collaborating intensely with each other. What's more, the analysis of the words gave rise to a series of work clusters that ratified the above and allow, together with the above, to answer the questions posed. The results may be interesting to continue research and allow decision makers in companies to have the verified information necessary to move towards digitization, smart manufacturing, and improve performance in manufacturing and in the use of manufacturing tools. LM.

Keywords: IoT · Lean manufacturing · Industry 4.0 · Digitalization

1 Introduction

Within the development of I4.0, a fundamental technological element is the Internet of Things (IoT), as it enables its development [1]. There are many definitions of this concept, following [2], IoT represents a key part of the digital transformation (DT) of the enterprise, improving the manufacturing of products, with an efficient outcome [14]. This TD creates complex connected systems, and generates more optimal manufacturing activities.

The other fully recognized and researched concept is Lean Manufacturing. Many industries, mainly manufacturing, have adopted some lean practices to achieve efficiency goals in productivity, financial goals and market situation [13]. This objective of improvement and suppression of unnecessary activities means acquiring competitiveness in the markets and integrating some of the tools that make up the LM. As stated in [3], the first combination of LM and TIC was not clearly supported, but after Germany's push with I4.0, the scenario has completely changed.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 171–178, 2023.
https://doi.org/10.1007/978-3-031-27915-7_32

This potential of digital transformation, thanks to IoT, is currently being explored because of the great improvements it brings to the efficiency of industrial plants, especially those that follow the smart manufacturing path and have different LM tools applied in their manufacturing design.

This is due to the capacity for immediate responses and the storage of information for internal study. [4]. Different authors emphasize that it is not yet clear that the effect of IoT is as positive as expected in organizations with extensive experience in applying LM tolos [5, 6, 7]. The expectations of the interaction between both concepts are a research gap to be developed. Hence the importance at this time of reviewing the existing literature, and thus being able to answer the following questions:

-. *What Are the Topics Introduced in Studies Related to the Relationship Between IoT and LM, What Currents of Research Are Being Developed?*

-. *What Are the Main Approaches in the Current Study Groups and What Cluster of Analyzes Are Being Produced?*

This article, based on the bibliometric analysis, can add value for the future, by recognizing the best academics in this scientific domain.

2 Methodology

To quantitatively describe the publications in relation to the two concepts studied, a bibliometric analysis is performed and a sufficient amount of data is collected to obtain the highest quality of the review.

The use of the two major reference sources, Web of Science (WOS) and Scopus [8], was considered. As a bibliometric study is going to be carried out with the VOSwiewer tool, it was decided to use a single database, and Scopus was chosen because it was broader. To decide the search terms, brainstorming meetings were held, in the fields title, abstract or keywords. It was decided to specify terms in English. The search was carried out until January 2021.

The search string used was: TITLE-ABS-KEY ("lean manufact*" OR "LM" OR "lean") AND TITLE-ABS-KEY ("IOT" OR "internet of things" OR "digital lean manufact*" OR "digital production" OR "I4.0"). Figure 1 shows the process followed in more detail to obtain the documents to be used in the Vosview software.

Of the 147 selected papers, 73 are conference papers, 65 articles, 11 reviews, and 3 book chapters. When performing the bibliographic search, 7 previous review documents were observed, although there are differences between them due to the period covered, the strategy of search and the objectives of the work.

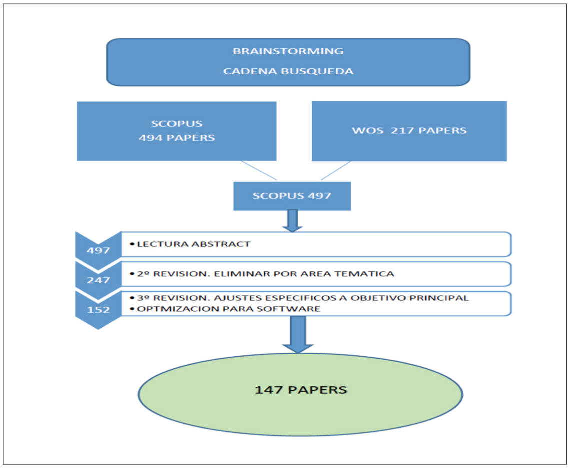


Fig. 1. Study process

3 Results and Discussion

3.1 General Trends in the Literature

The interaction between both concepts is a field that can be considered young, the number of publications has increased notably (Fig. 2). The first 3 articles that study the implications of working with both concepts are in 2012, with 37 citations to date. The publications until 2016 are only 3, but with great weight in the scientific community, given that the number of citations for these is 216 (Fig. 2). An upward trend is seen, in 2018 with 23 publications and 621 citations. This reflects the notable interest of researchers in delving into the relationship between both concepts.

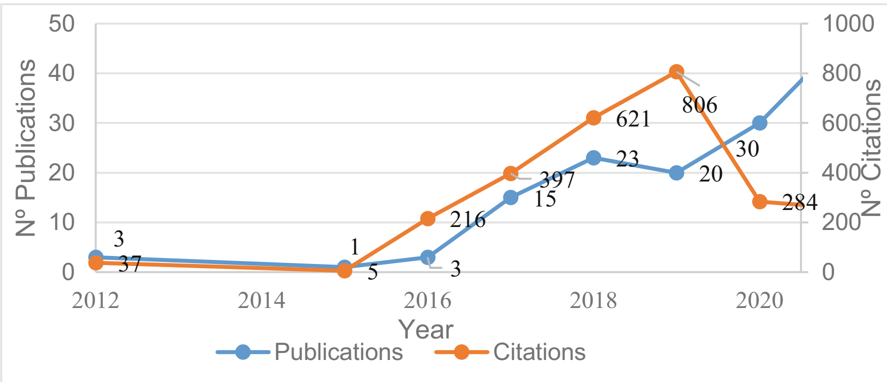


Fig. 2. Publications and citations by year

Some of the most cited articles are: *The evolution of production systems from Industry 2.0 through Industry 4.0″* (Yin Y., Stecke KE, Li D)(235 cited), "Opportunities for enhanced lean construction management using Internet of Things standards" (Dave B., Kubler S., Främling K., Koskela L.)(129 cited), and "Cloud asset-enabled integrated IoT platform for lean prefabricated construction" (Xu G., Li M., Chen C.-H., Wei Y.)(71 cited).

3.2 Academic Performance: Country, Organizations and Authors

In relation to the most fruitful authors, as reflected in Table 2, they are from different countries, of which 7 are European (Denmark (2), Portugal (2), France (1), Italy (2)). This fact is so because in Europe the I4.0 was started. And in many of them, not only research is being developed, but also applications and studies in companies. As in the case of Italy, where the manufacturing industry is of great economic and development importance to the country (Fig. 3).

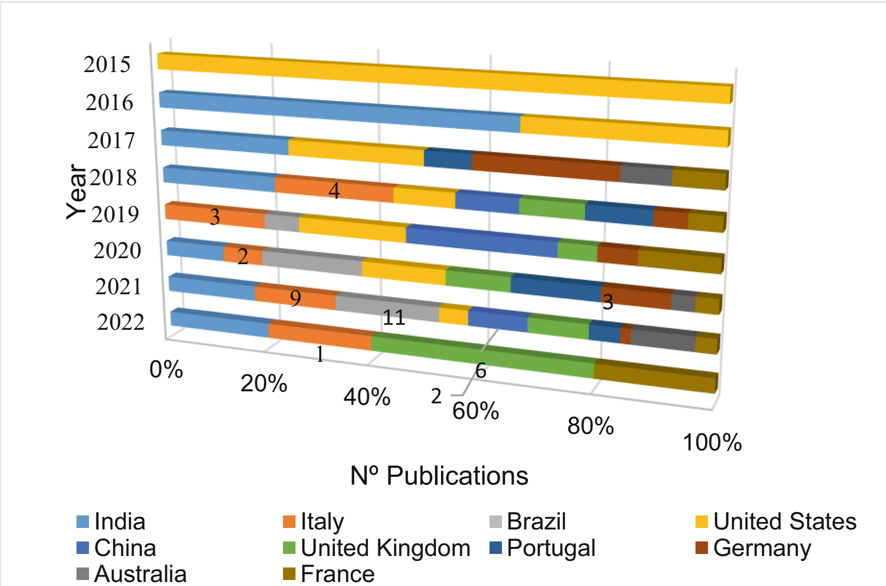


Fig. 3. Analysis by Country.

The most prolific authors, including Tortorella, GL, with 6 publications, and with 4 publications each, the authors Teixeira, L. and Teizer, J.

We high light two, due to their number of works and number of citations, which are:

– Teixeira, L. Which, in addition to 4 publications, has already received more than 70 citations for his participation as the first author of the article: "Maintenance 4.0: Intelligent and Predictive Maintenance System Architecture" (IEEE International Conference on Emerging Technologies and Factory Automation, ETFA 2018 -September,

8502489, pp. 139–146 Industrial Zone of Mós, Bragança). Where you can read the applications that are being investigated from the point of view of these concepts, and their link with predictive maintenance
– Teizer, J.. Which has four publications, and 44 citations for the article: "Internet of things (IoT) to integrate environmental and location data in building information modeling (BIM)" (ISARC 2017 - Proceedings of the 34th International Symposium on Automation and Robotics in Construction pp. 603–609 Department of Engineering Informatics, Ruhr-University Bochum, Germany). This author, along with others, are investigating digitization and its implications for smart manufacturing, based on IoT, and LM tools already included.

3.3 Analysis Bibliometric

To carry out the quantitative analysis of the selected publications, the Voswiewer tool was used. This tool, developed by Nees Jan Van Eck and Ludo Waltman from the Science and Technology Study Center of Leide, allows the construction and visualization of bibliometric networks. These networks offer very important information on the analysis of cocitation, co-authorship and co-occurrence of words.

Cocitation Analysis. It's a dynamic method because the frequency of cocitation will increase over time, moreover, and due to the accumulation of citations over time, their roots of knowledge can be followed [10, 11]. Figure 4 clearly shows the research groups that are being formed, as well as highly cited authors such as Teizer, J.

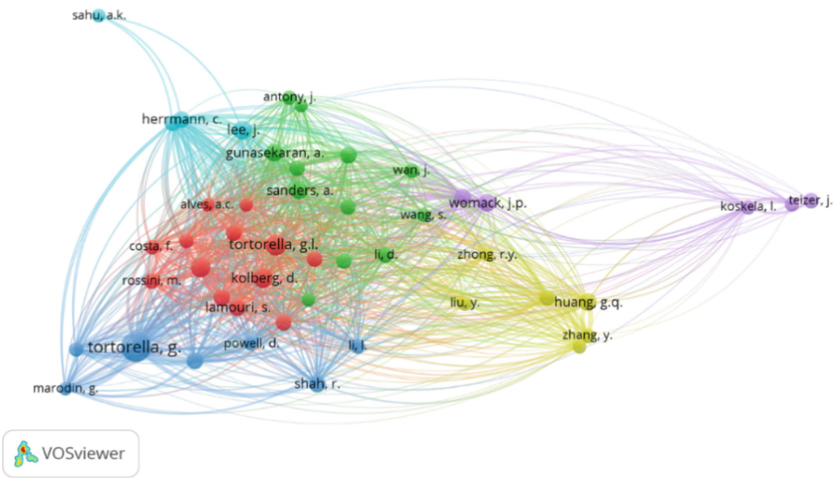


Fig. 4. Cocitation networks between LM and IoT

Co-occurrence Analysis. A very suitable method for analyzing research topics and trends is word co-occurrence analysis. Keywords give us precise information about the

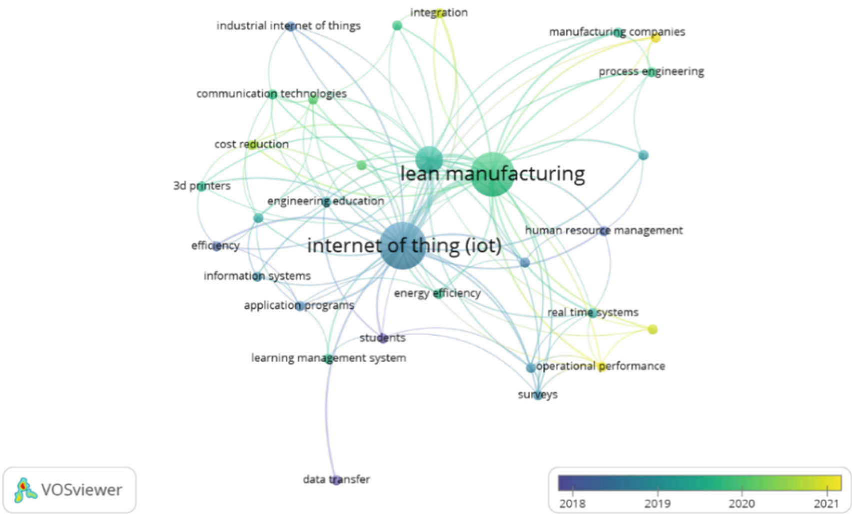


Fig. 5. Co-occurrence analysis.

document [12]. VoSviewer extracts the keywords from the document and then provides a keyword co-occurrence matrix.[12].

Cluster 1. Describes the information systems that are being developed, for the way forward in intelligent manufacturing.

Cluster 2.- This grouping is important, since it encompasses the digital transformation of manufacturing, and includes a term that is increasingly used, IIoT. (industrial internet of things).

Clusters 1 and 2 also include the terms referring to education and training, given the large number of specialists that will be needed in a short time.

Cluster 3. Describes the fundamental components of LM. And as seen in the Fig. 5, it is strongly related to cluster 1.

Clusters 4, 5 and 6 are of lesser strength, but reflect the objectives of the interaction of the two concepts. Since they unite ICT, product design and manufacturing companies.

4 Conclusions

In relation to the first question posed, it is observed that, in terms of the relationship between these two issues, aspects not contemplated at the beginning are already being introduced, highlighting two important issues, the digital transformation and the application of new TIC, to harnessing the speed of data.

Current research trends are also clearly inclined to the objective of smart factories, with a clear domain of TIC, to generate data and information quickly and efficiently, so that, with the right combination of LM tools, suppose a great saving in maintenance costs, and advance in sustainability.

Improved internal information flows, due to the use of IoT, enable decision making based on LM tools to improve productivity.

When the term IIot appears, he explains that current research tends towards studies of the digital and effective transformation of companies. In addition, this term is being studied by the scientific community, in the research work of the so-called cyber-physical and virtual systems. Progress should be made in future research work on the influences of virtual systems, ways of working in the digital cloud, data processing (big data), and of course the so-called digital twins.

The future development of IoT, with new network technologies, will further modernise operations, generating LM tools compatible with this technology. An example could be the case of JIT, since in order to improve product traceability, the speed and processing of data will be key.

Likewise, it is made clear that the specific training of technical personnel is necessary, with knowledge in both fields in the industrial organization based on LM tools, and the possibilities generated by the IoT.

References

1. Garrido-Hidalgo, C., Teresa-Olivares, F., Ramirez, J., Roda-Sanchez, L.: An end-to-end Internet of Things solution for reverse supply chain management in industry 4.0. Comput. Indus. **112**, 103127 (2019). https://doi.org/10.1016/j.compind.2019.103127
2. Cagliano, R., Canterino, F., Longoni, A., Bartezzaghi, E.: The interaction between smart manufacturing technologies and work organization: the role of technological complexity. Int. J. Oper. Prod. Manage. **39**(6/7/8), 913–934 (2019)
3. Mrugalska, B., Wyrwicka, M.K.: Towards lean manufacturing in industry 4.0. Proc. Ing. **182**, 466–473 (2017)
4. Buer, S.V., Strandhagen, J.O., Chan, F.T.: The link between Industry 4.0 and lean manufacturing: mapping current research and setting a research agenda. Int. J. Prod. Res. **56**(8), 2924–2940 (2018)
5. Frank, A.G., Dalenogare, L.S., Ayala, N.F.: Industry 4.0 technologies: implementation patterns in manufacturing companies. Int. J. Prod. Econ. **210**, 15–26 (2019). https://doi.org/10.1016/j.ijpe.2019.01.004
6. Rüttimann, B.G., Stöckli, M.T.: Lean and industry 4.0: twins, partners or contenders? A due clarification on the alleged clash of two production systems. Serv. J. Sci. Admin. **9**, 485–500 (2016)
7. Sanders, T.O., Elangeswaran, C., Wulfsberg, J.: Industry 4.0 implies lean manufacturing: Research activities in Industry 4.0 work as enablersfor lean manufacturing. J. Ind. Ing. Manage.**9**(3), 811–833 (2016)
8. Thunnnissen, M., Gallardo-gallardo, E.: Rigopr and relevance in empirical TM research: key issues and challenges. BRQ Bus. Res. Q. **22**, 171–180 (2019)
9. Chen, C., Zhu, W., Tomaszewski, B., MacEachren, A.: Monitoring of the conceptual and geospatial diffusion of knowledge. In: Schuler, D. (Ed.), International Conference on Online Communities and Social Computing, pp. 265–274, Springer, Heidelberg, Berlin (2007)
10. Vogel, R., Güttel, W.H.: The vision of dynamic capacity in strategic management: a bibliometric review. Int. Manager. J. Rev. **15**(4), 426–446 (2013)
11. Verbeek, T.O., Debackere, K., Luwel, M., Zimmermann, E.: Measuring progress and evolution in science and technology – I: the multiple uses of bibliometric indicators Int. Manager. J. Rev. **4**(2), 179 (2002)
12. Park, J.Y., Nagy, Z.: Data on the interaction between thermal comfort and building control research. Data Brief. **17**, 529–532 (2018)

13. Fortuny-Santos, J., Ruizde-ArbuloLópez, P., Cuatrecasas-Arbos, L., Fortuny-Profitós, J.: Balancing workload and workforce capacity in lean management: application to multi-model assembly lines. App. Sci. **10**, 8829 (2020). https://doi.org/10.3390/app10248829
14. Legner, C., et al.: Digitalization: opportunity and challenge for the business and information systems engineering community. Bus. Inf. Syst. Eng. **59**(4), 301–308 (2017)

Conceptual Proposal for the Design of a Work Order Prioritization Heuristic in a Workshop

Efraín Pérez-Cubero[1(✉)] and Raúl Poler[2]

[1] Universidad de Costa Rica, Alajuela, Costa Rica
efrain.perezcubero@ucr.ac.cr
[2] Universitat Politècnica de València, Valencia, Spain

Abstract. This article is a proposal for the construction of a work order prioritization heuristic rule through the use of Monte Carlo simulation and structured experimentation. The heuristic to be constructed will have the form of a first order linear equation where the variables frequently used in classical heuristics such as FIFO, SOT and others will be taken into account. The detailed methodology to be followed for the construction of the rule is presented, as well as the design of the necessary experiments to validate the rule. Finally, conclusions and future lines of research are presented.

Keywords: Heuristics · Job shop · Sequencing

1 Job Shop Scheduling Problem

The search for solutions to the job shop sequencing problem (JSSP) is a current subject of study for academics and of importance to business.

A job shop (JS) can be described as a location where there are several general purpose workstations that are used to perform a variety of tasks [1].

The JSSP is given by a finite set of jobs or J of n jobs or parts, and a finite set M of m machines. For each job j ∈ J the list (σ_1^j,…,σ_n^j) of machines with the processing order of job j is provided. Each machine can only process one job at a time. Once a job is started on a machine, it must finish its processing on that machine without any interruption [2].

A heuristic is an algorithm capable of generating solutions to optimisation problems in a reasonable time, these solutions must be "good" but not necessarily optimal [3].

For companies, work sequencing decisions have a direct impact on production costs, facility utilisation and overall shop floor performance.

This work proposes the construction of a heuristic to prioritise pending orders in front of a machine by means of simulation and structured experimentation.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 179–184, 2023.
https://doi.org/10.1007/978-3-031-27915-7_33

2 Heuristic Rules for Job Shop Scheduling

Table 1 shows a compilation of the most frequently used rules, its acronym, name and a description of the rule(Guzman et al., 2022).

Table 1. Heuristic prioritization rules

Acronym	Name	Rule
FIFO	First in, first out	First come, first served
LIFO	Last in, first out	The last to arrive are the first to be served
LOT	Longer processing time	The task with the longest processing time is selected
LRO	Less remaining operations	The priority task is the task with the lowest number of operations remaining to be performed
LROT	Increased remaining operating time	The priority job is the one with the highest sum of processing times for all operations remaining to be performed
LSU	Shorter adjustment time	The jobs with the shortest preparation time are scheduled
MRO	More remaining operations	The priority task is the one with the highest number of operations remaining to be performed
SOT	Shorter processing time	The task with the shortest processing time is selected
SROT	Reduced remaining operating time	The priority job is the one with the smallest sum of processing times for all remaining operations to be performed
DD	Delivery date	The one with the earliest delivery date is selected
SS	Static clearance	The one with the shortest time remaining until the delivery date is selected. It is equivalent to the DD rule
DS	Dynamic clearance	The one with the shortest remaining time to delivery date minus the sum of all remaining operation times is selected
WINQ	Jobs in the next queue	Higher priority is given to the part that would move to the machine with less work
RANDOM	RANDOM	It is not a rule as such, it is used to test the quality of other heuristics. It consists of selecting a job at random from the jobs in the queue

3 Heuristics in the Form of a First-Order Linear Regression Model

3.1 Description

The heuristic rule that we propose to develop is based on the calculation of an indicator provided by a linear function, ywhose variables are characteristics of the jobs in the queue, x_iand that the coefficients β_i of this function will be calculated by means of structured experimentation and Monte Carlo simulation. This will result in an equation such as Eq. (1)

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + \varepsilon \quad (1)$$

Table 1 shows the heuristics that provide a solution to the JSSP. From this table, the variables that are used in the different heuristics mentioned have been identified. These variables are (the rules that make use of these variables are shown in brackets):

- Remaining Route Processing Time (LROT, SROT, DS)
- Time remaining until delivery date (DD, SS, DS)
- Number of remaining operations (LRO, MRO)
- Processing time on current machine (LOT, SOT)
- Time waiting in the queue of the current machine (FIFO, LIFO)
- Number of jobs in the next queue of the route (WINQ)
- Time of jobs in the next queue of the route (WINQ)
- Setting time (LSU)

The new heuristic rule would be:

$$y = +\beta_1 RPT + \beta_2 TTD + \beta_3 NOR + \beta_4 PT + \beta_5 WT + \beta_6 JNQ + \beta_7 TJNQ + \beta_8 ST \quad (2)$$

where:

- RPT = standardised remaining processing time
- TTD = standardised remaining time to delivery date
- NOR = normalised number of remaining operations
- PT = processing time on current machine standardised
- WT = waiting time on current machine standardised
- JNQ = normalised number of jobs in the next queue
- TJNQ = time of jobs in the next normalised queue
- ST = standard setting time

In order to standardise the responses, it is proposed to standardise the coefficients of Eq. (2) by making them satisfy the following properties:

$$\sum\nolimits_{i=0}^{n} \beta_i = 1 \quad (3)$$

$$\beta_n; \beta_n \subset [0, 1] \forall n \in \mathbb{Z} \quad (4)$$

It is also proposed to use all variables in a standardised way. This standardisation will be carried out according to Eq. (5).

$$v_s = \frac{v_i}{\max V}, V = \{v_1, v_2, v_3, \ldots, v_n\} \tag{5}$$

where:

- v_i is the value of the variable v for the job i waiting
- v_s is the standardised variable of v_i
- V: is the set of values for the variable v of the n jobs in queue

3.2 Building Methodology

The methodology proposed consists of 5 milestones:

1. Construction of a general-purpose Job Shop simulation environment.
2. Calculation of the linear function of the heuristic by structured experimentation and Monte Carlo simulation.
3. Comparison of the quality of the rules proposed by the two methods and selection of a rule.
4. Validation by simulation of the functionality of the proposed rule.

With regard to the first milestone, the simulation environment will have the following features:

- n machines
- j works
- for each job there shall be a route r
- the process times of each part at each station shall be deterministic
- the set-up times for each job on each machine shall be deterministic and independent of the sequence

The second milestone seeks to estimate the values of the β indices of Eq. (2), for which two different paths will be followed: structured experimentation and the use of Monte Carlo simulation.

Structured experimentation consists of testing all possible combinations of beta values, between 0 and 1, in predefined jumps. The advantage of this approach is that it allows the entire feasible solution space to be fully analysed. When experimentation identifies a promising region, response surface methodology is used to identify whether a global minimum of the model exists in that area.

The disadvantages of this approach are the time investment required to perform all the necessary experiments. Another disadvantage is the possibility that there are many promising regions, which would make it unfeasible to perform all the necessary analyses.

The second way to construct the heuristic rule is the Monte Carlo simulation, which should be performed after the structured experimentation. The simulation will be run until one of two things happens: a solution as good as the one found with the structured experimentation is found in less time than the time spent in the structured experimentation. This condition would lead to recommend the use of Monte Carlo as a method to find the beta values of Eq. (1). The other alternative is that Monte Carlo simulation becomes as slow as structured experimentation without a clearly better solution, in which case the best solution found (beta values) would have to be identified and the better of the two methods tested by appropriate statistical tests before moving on to the actual validation. In this way, the third milestone would be met.

The advantages of using Monte Carlo simulation are the possibility to find values with higher accuracy. It also has the possibility to find the solution in less time than the proposed structured experimentation.

3.3 Objective Function

[4] show that the objective functions that have been most frequently used to evaluate JSSP solutions are related to time. On the other hand, they [5] list within these objective functions the completion time of all tasks (makespan) and tardiness as functions that are used in 50% of the recently published articles dealing with the topic. For this reason the authors will use both functions as objective functions.

To deal effectively with two different outcome metrics without creating ambiguities in the interpretation of the results, an objective function is proposed to measure the goodness of solution from the relativised makespan and mean tardiness, Eq. (4).

$$s = \alpha * (RAT) + (1 - \alpha) * (RM) \tag{6}$$

where:

$$RM = \frac{Makespan}{Longestroutetime} \tag{7}$$

$$RAT = \frac{AverageMaximumtardiness}{Maximumtardiness} \tag{8}$$

4 Validation of Sequencing Rule

It is of particular interest to be able to categorically demonstrate the quality of the rule generated. To this end, it is proposed to design and carry out sufficient statistical experiments to guarantee the results obtained.

The proposed sequencing rule will be compared with 4 heuristic sequencing rules: RANDOM, FIFO, SOT and SS. This comparison will be performed by means of a single factor ANOVA.

The validation shall start by comparing solutions of the same type of problem and from the same workshop. In case of favourable results, a second validation will be performed by modifying the type of problem and the workshop configuration to determine if the rule found works well for other types of workshops and problems.

5 Conclusions and Future Lines of Research

The use of response surface methodology in combination with simulation are promising optimisation tools to find solutions to JSSP and would be a relevant contribution to the field of knowledge.

The future work to be carried out is the verification of the methodology proposed here, i.e. the performance of experiments with the aim of constructing the proposed novel heuristic.

This proposal will generate a linear formula that takes into account the different variables that are considered by the heuristic priority rules, a natural evolution of this research is to use a neural network that is a universal approximator to find a rule of more general use and better performance. To do this, a full workshop simulator and reinforcement learning would have to be used to determine the weights of the neural network to obtain a higher level algorithm with better solutions than the heuristic proposed here.

Acknowledgments. The research leading to these results received funding from the Regional Department of Innovation, Universities, Science and Digital Society of the Generalitat Valenciana entitled "Industrial Production and Logistics Optimization in Industry 4.0" (i4OPT) (Ref. PROMETEO/2021/065).

References

1. Cunha, B., Madureira, A.M., Fonseca, B., Coelho, D.: Deep reinforcement learning as a job shop scheduling solver: a literature review. Adv. Intell. Syst. Comput. **923**, 350–359 (2020)
2. Guzman, E., Andres, B., Poler, R.: Matheuristic algorithm for job-shop scheduling problem using a disjunctive mathematical model. Computers **11**(1), 1 (2021). https://doi.org/10.3390/computers11010001
3. Ball, M.O.: Heuristics based on mathematical programming. Surv. Oper. Res. Manag. Sci. **16**, 21–38 (2011)
4. Serrano-Ruiz, J.C., Mula, J., Poler, R.: Smart manufacturing scheduling: a literature review. J. Manuf. Syst. **61**, 265–287 (2021)
5. Pérez-Cubero, E., Poler, R.: Aplicación de algoritmos de aprendizaje automático a la programación de órdenes de producción en talleres de trabajo: Una revisión de la literatura reciente. Dir. y Organ. **72**, 82–94 (2021)

Blocking Flowshop Scheduling Problem with Minimum Makespan and Quota Property

Joaquín Bautista-Valhondo(✉) and Rocío Alfaro-Pozo

ETSEIB Universitat, Politècnica de Catalunya Av. Diagonal 647, 08028 Barcelona, Spain
{joaquin.bautista,rocio.alfaro}@upc.edu

Abstract. A problem of sequences in production lines of mixed models is presented, transforming the production line into a blocking flowshop. The Heijunka concept is applied to the sequences, imposing compliance with the Quota property, with the purpose of adapting the workshop to the Just in Time ideology adopted by Lean Manufacturing. The proposed problem is solved by means of MILP using the IBM-CPLEX solver on the set of 23 Nissan-9Eng.I instances. It is concluded that the economic impact due to loss of production is very important when the buffers are removed from the production line (€1,265/day), while the economic impact generated by Heijunka can be considered negligible compared to the advantages it offers (€170 /day).

Keywords: Production assembly lines · Mixed model sequencing problem · Blocking flowshop scheduling problem · Heijunka · Lean manufacturing · Makespan · Mixed integer linear programming · IBM-CPLEX solver

1 Introduction

Flowshop scheduling problems (FSP) have been the subject of special attention by the scientific community in recent decades [1, 2]. This fact is due to the ability of such problems to model a wide variety of situations in the production environments of various industrial and service sectors.

A formalization of the general problem under study is the following. Let J be a set of jobs (or pieces) composed of n types, and let K be a set of machines containing m elements. It is assumed that the machines are arranged in series and that the condition is imposed that all jobs pass through all machines in the same order, starting on the first machine (ie $k = 1$) and ending on the last machine (ie $k = m$). It is further assumed that the processing time of a generic job $j \in J$ when it passes through a generic machine $k \in K$ is deterministic and is denoted by $p_{j,k}$ $(\forall j, \forall k)$. When you add to these conditions that all machines process jobs in the same order, then the problem reduces to finding a permutation of jobs in the flow shop, and is called the *Permutation flowshop scheduling problem* (PFSP).

Considering the availability of space between pairs of consecutive machines (buffers) in order to be able to separate the pieces of the productive flow, this type of problem presents two extreme versions: (v1) problems in which the buffers are supposed to have

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 185–190, 2023.
https://doi.org/10.1007/978-3-031-27915-7_34

a capacity unlimited, and (v2) problems where it is assumed that there are no buffers between pairs of consecutive machines and, therefore, it is not possible to separate the parts of the production flow (BFSP).

Note that the proposed formalization allows establishing a certain similarity between some mixed model sequencing problems in production lines (eg cars, motors, etc.) in which a fixed cycle time (c) is not imposed to process the operations [3], and programming problems in the flow workshop. For this reason, here we will use interchangeably the words work and product, on the one hand, and the words machine and work station, on the other.

In problems with buffers, it is considered that, after completing the operation (j, k) of the generic product $j \in J$ in the generic station $k \in K$ $(k > 1)$, station k is free to process the operation corresponding to the following product according to the manufacturing sequence $\vec{\pi}(T) = (\pi_1, .., \pi_t, .., \pi_T)$, where π_t symbolizes the type of product that occupies position t in the sequence $\vec{\pi}(T)$ whose length is T.

On the other hand, in problems without buffers it turns out that, once the operation of the product $j \in J$ in the workstation $k \in K$ is completed, such product could be blocked by the following station $(k + 1)$, in case this would not have completed the operation corresponding to the previous product according to the manufacturing sequence $\vec{\pi}(T)$.

It is evident that the blocking of products in the stations has a negative impact on the efficiency of the production system, since it generates delays in the continuous flow of manufacturing, prolongs the completion time of all the jobs (C_{max}: makespan), and can increase the stock due to the dilation of the mean flow time ($\overline{F}$) for a specific maximum flow time (F_{max}) and, therefore, it can generate additional production costs that can sometimes be very significant [4].

On the other hand, in many realistic manufacturing systems, such as mixed-model production lines, it happens that the products (jobs) of the set J are not all different from each other, but instead appear copies of the same genre and, therefore, these products can be grouped by types or families in a set that we will note by I (v.gr. Types of motors, frames, etc.); in this case, we associate to each type of product $i \in I$ a demand $d_i > 0 (\forall i)$, constituting a general demand plan that we will denote by $\vec{d} = \left(d_1, .., d_{|I|}\right)$.

In such conditions, the Japanese Heijunka concept (production leveling) can be applied to the sequences, which appears in the Just-in-Time ideology [5], adopted by Lean manufacturing [6].

The Heijunka concept applied to sequences of mixed models can be characterized through an objective function [7] and through restrictions on the production system, imposing, for example, the satisfaction of the Quota property on the pace and progress of production of all product types and in all manufacturing cycles [4].

Some advantages offered by Heijunka are: (i) reduction of the stock level; (ii) adjustment of the required productive capacity (eg labor, machinery, equipment, instruments, materials, etc.) (iii) (3) reduction of delivery times in the following processes and from the previous processes; (iv) simplification of information to manage production operations; and (v) transparent relationship with agents in the supply chain.

In this paper we focus on a programming problem in a flow workshop with minimization of the total completion time C_{max} without buffers between pairs of consecutive stations and imposing on the sequences that satisfy the Quota property on the production rate of the models in all manufacturing cycles.

2 Mathematical Model

The mathematical program proposed in this article, **Q-BFSP** (Blocking flowshop scheduling problem with Quota property), is a natural extension of [4].

MP Q-BFSP:

$$\min \mathcal{F}(\pi(T)) = C_{max} \equiv C_{m,T} \tag{1}$$

$$C_{k,t}(\pi_t) = S_{k,t}(\pi_t) + p_{\pi_t,k} \forall k \in K \forall t = 1, .., T \tag{2}$$

$$S_{k,t}(\pi_t) = max(C_{k,t-1}(\pi_{t-1}), C_{k-1,t}(\pi_t)) \forall k \in K \forall t = 1, .., T \tag{3}$$

$$C_{k-1,t}(\pi_t) \geq C_{k,t-1}(\pi_{t-1}) \forall k \in K \forall t = 1, .., T \tag{4}$$

$$X_{i,t} = |\{\pi_\tau \in \pi(t) \subseteq \pi(T) : \pi_\tau = i \in I\}| \forall i \in I \forall t = 1, .., T \tag{5}$$

$$\lceil \lambda_i t \rceil \leq X_{i,t} \leq \lceil \lambda_i t \rceil \forall i \in I \forall t = 1, .., T \tag{6}$$

$$X_{i,T} = d_i \forall i \in I \tag{7}$$

$$\mathrm{C}_{\mathrm{k},0} = 0 \forall k \in K \tag{8}$$

$$C_{0,t} = 0 \, \forall t = 1, .., T \tag{9}$$

In the **Q-BFSP** model, the objective function (1) expresses the minimization of the completion time of all operations in the workshop (C_{max}). Constraints (2)-(4) allow setting the start times of the operations, $S_{k,t}(\pi_t)$, as well as the completion times, $C_{k,t}(\pi_t)$, of any operation (π_t, k); specifically, constraints (4) correspond to blocking. Formula (5) determines the cumulative production of all types of product $i \in I$ up to every cycle t. Formula (6) imposes the Quota property on the manufacturing sequence $\vec{\pi}(T)$. The equalities (7) force the satisfaction of the demand plan $\vec{d}$ of all product types. Finally, formulas (8)–(9) establish the initial conditions of the problem.

Starting from the **MP Q-BFSP** in this work three models are applied which, in turn, correspond to three classes of flow workshop problems; these are:

- **PFSP** (Permutation flow shop scheduling problem). This model is obtained by removing constraints (4) and (6) in the **Q-BFSP** model. Ideal situation.
- **BFSP** (Blocking flow shop scheduling problem). This model is obtained by removing constraints (6) in the **Q-BFSP** model.
- **Q-BFSP** (Quota-Blocking flow shop scheduling problem). Complete model.

3 Computational Experiment

Table 1 shows the results of the application of the three models on the 23 instances of the Nissan-9Eng.I set [3, 4, 8].

Table 1. Results of the application of three models on the set of instances Nissan-9Eng.I.. Makespan (C_{max}), Lower Bound (*LB*) and Loss of Production (*LoP*).

	PFSP	BFSP			Q-BFSP		
$\varepsilon \in$ E	C_{max}	*LB*	C_{max}	*LoP*	*LB*	C_{max}	*LoP*
1	50091	50091	50699	3.47	50091	50724	3.62
2	50174	50174	50758	3.34	50175	50866	3.95
3	50301	50301	50517	1.23	50301	50572	1.55
4	50167	50166	50873	4.03	50176	50939	4.41
5	50379	50379	50701	1.84	50382	50816	2.50
6	50202	50202	50926	4.14	50203	50988	4.49
7	50395	50395	50598	1.16	50397	50636	1.38
8	50123	50123	50606	2.76	50123	50653	3.03
9	50378	50378	51296	5.25	50388	51433	6.03
10	50619	50618	50666	0.27	50625	50725	0.61
11	50078	50078	50619	3.09	50078	50638	3.20
12	50192	50192	50615	2.42	50192	50675	2.76
13	50123	50123	50811	3.93	50123	50854	4.18
14	50218	50218	50706	2.79	50218	50812	3.39
15	50242	50242	50600	2.05	50242	50645	2.30
16	50118	50118	50668	3.14	50118	50768	3.71
17	50269	50269	50610	1.95	50269	50806	3.07
18	50273	50273	51053	4.46	50278	51105	4.75
19	50475	50475	50595	0.69	50481	50668	1.10
20	50089	50094	50724	3.63	50106	50736	3.70
21	50307	50307	51136	4.74	50313	51266	5.48
22	50539	50539	50608	0.39	50545	50726	1.07
23	50151	50151	50529	2.16	50151	50573	2.41

Each instance in Table 1 corresponds to a demand plan with 270 products (jobs) of 9 different types. The plans are inspired by a case study of a mixed engine assembly line with 21 workstations and a cycle time of 175 s. The computational experiment is carried out with the CPLEX solver, giving each model and each instance a maximum time one hour CPU.

To analyze the results obtained, we will use as reference the values of C_{max} corresponding to the PFSP problem, which is associated with the most efficient production line.

In view of Table 1, we can establish the following sentences:

- The average loss of production of the line (*LoP*) when the buffers between the workstations (**BFSP**) are suppressed is equal to 2.74 engines/day, with a range of values between 0.27 and 5.25, and with a standard deviation equal to 1.37 engines/day.
- The average loss of production of the line (*LoP*) when the satisfaction of the Quota property is imposed on the sequences and, in addition, the buffers between the workstations are suppressed (**Q-BFSP**) is equal to 3.16 engines/day, with a range of values between 0.61 and 6.03, and with a standard deviation equal to 1.40 engines/day.
- The economic loss generated by the simple suppression of buffers in the line is of the order of €1095/day on average.
- On average, the impact produced by the incorporation of the Heijunka technique on the loss of production in the line without buffers between the workstations is equal to 0.42 engines per day, which is equivalent to an additional cost valued at €170/day.
- Heijunka favors the reduction of stocks, the adjustment of production capacity, the reduction of delivery times, the simplification of information on production control, and the transparent relationship between productive agents, without requiring any additional cost for its implementation in a production line with or without buffers between workstations, except for the determination of product sequences that satisfy the Quota property.

4 Conclusions

In this paper, the C_{max} values offered by the three models for the 23 Nissan-9Eng.I demand plans are compared, and the costs due to loss of production are evaluated with respect to the most efficient flow workshop (PFSP). The results are: (i) the average production loss due to blockage in the machines is 2.74 and 3.16 motors/day in the **BFSP** and **Q-BFSP** cases, respectively; (ii) the economic impact per block is equal to €1095/day (BFSP) and €1265/day (Q-BFSP); and (iii) the Heijunka impact in the flow workshop without buffers is equal to €170/day.

Taking into account the realistic case study analyzed in this work, it can be concluded that production lines with closed stations could be more efficient by installing buffers (lateral or aerial) that would allow some units to be separated from the production flow, thus avoiding loss of production.

Heijunka is very easy to incorporate into the production lines of mixed models, having significant advantages when, having a diversity of models, this does not reach the point where all the units of the product are different from each other, this being a case that does not have much sense in the automotive industry.

Acknowledgements. This work has been funded by the Ministry of Economy and Competitiveness of the Government of Spain through project OPTHEUS (ref. PGC2018-095080-B-I00), including European Regional Development Funds (ERDF).

References

1. Pinedo, M.L.: Scheduling. Springer International Publishing, Cham (2016). https://doi.org/10.1007/978-3-319-26580-3
2. Conway, R.W., Maxwell, W.L., Miller, L.W.: Theory of Scheduling. Dover Publication, Inc., Mineola (2003)
3. BautistaValhondo, J., Alfaro, R.: Transformación de una línea de montaje de modelos mixtos en un taller de flujo regular: Caso de estudio en la factoría Nissan de Barcelona. Dirección y Organización **69**, 82–98 (2019). https://doi.org/10.37610/dyo.v0i69.562
4. BautistaValhondo, J.: Exact and heuristic procedures for the Heijunka-flow shop scheduling problem with minimum makespan and job replicas. Progr. Artif. Intell. **10**(4), 465–488 (2021). https://doi.org/10.1007/s13748-021-00249-z
5. Monden, Y.: Toyota Production System: An Integrated Approach to Just-In-Time, 4th edn. Productivity Press, New York (2011)
6. Shahin, M., Chen, F.F., Bouzary, H., Krishnaiyer, K.: Integration of lean practices and Industry 4.0 technologies: smart manufacturing for next-generation enterprises. Int. J. Adv. Manuf. Technol. **107**(5–6), 2927–2936 (2020). https://doi.org/10.1007/s00170-020-05124-0
7. Bautista-Valhondo, J.: Heijunka-inspired planning and sequencing methods in the apportionment problem in electoral systems (in Spanish). Dirección y Organización **73**, 18–38 (2021). https://doi.org/10.37610/dyo.v0i73.590
8. BautistaValhondo, J., AlfaroPozo, R.: Mixed integer linear programming models for flow shop scheduling with a demand plan of job types. CEJOR **28**(1), 5–23 (2018). https://doi.org/10.1007/s10100-018-0553-8

Barriers to the Integration of IoT Safety Devices in Construction Environments

María del Carmen Rey-Merchán[1], Vicente-Joaquín Delgado-Fernández[2], and Antonio López-Arquillos[2](✉)

[1] Consejería de Educación y Deporte, Junta de Andalucía, Granada, Spain
mcrey@uma.es
[2] Escuela de Ingenierías Industriales, Universidad de Málaga, 29071 Málaga, Spain
alopezarquillos@uma.es

Abstract. The construction industry is one of the most dangerous sectors. Improving safety conditions on the construction site is very important to reduce accidents and mitigate their effects. The use of IoT devices for safety is an effective preventive strategy but its adoption by construction companies is limited. The objective of this research is to identify the main barriers to the adoption and learning of IoT technologies, for the improvement of safety conditions in the construction sector. The methodology used was the adaptation and distribution of a previous questionnaire. The results showed that the peculiarities of such a traditional sector act as a barrier in terms of adoption and learning of the use of IoT. The large investment required, concerns about the availability of technical support, and lack of information on the effectiveness of health and safety technology obtained the highest scores, based on the opinion of the workers. In contrast doubts about the reliability of these technologies, and limited attributes and features obtained the lowest values. Greater knowledge about the advantages of its adoption and an adaptation of training programs can help a greater integration of IoT safety systems.

Keywords: Internet of Things · IoT · Safety · Construction · Management

1 Introduction

Occupational accidents are a cause of concern in the construction industry [1, 2]. Several causes are linked to these accidents like falls from heights [3], or poor safety training [4]. Different preventive strategies can be implemented to reduce the number of accidents and mitigate their effects as Prevention through Design (PtD) [5], safety training [6], or Building Information Modelling (BIM) [7]. One of the most effective is the use of IoT devices [8]. Nowadays, the use of the Internet of Things IoT has increased significantly in the last few years. Specific applications based on the IoT paradigm have been developed in many different sectors such as a logistic, manufacturing, smart cities, and waste management. The majority of them are focused on the improvement of productivity, however, the use of IoT is extending to other issues such as health and safety management at the workplace [9]. Some examples of IoT systems for construction

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 191–196, 2023.
https://doi.org/10.1007/978-3-031-27915-7_35

safety can be found in the literature. For instance, Yang et al. proposed an identification proactive system to prevent construction accidents [10]. Other authors fussed BIM and RFID for increased accuracy in construction locations [11]. More recently an IoT smart system was proposed to check the appropriate use of PPE y workers in construction environments [12]. Similarly, other researchers developed IoT safety systems to Monitor Health and Safety of construction workers [13], and mining workers [14].

The construction sector is characterized by higher rates of accidents and safety risks, then the adoption of IoT systems for safety management could improve construction safety conditions [15]. However, its adoption, learning, and integration are slower compared to other industries. Several authors have identified different barriers to the adoption of IoT, such as lack of integration between technologies [16, 17], false alarm [18], or data privacy issues [19], but few authors have analyzed cited barriers in the same research [20, 21]. Based on the reviewed literature, the purpose of the current research is to identify the main barriers to the adoption and learning of IoT technologies, for the improvement of safety conditions in the construction sector.

2 Methodology

The current research is based on a previous questionnaire developed and validated in the USA [21]. The questionnaire (Table 1) was previously translated to Spanish and then, delivered to between one hundred workers from construction companies in Spain.

Table 1. The questionnaire was developed and validated by Nnaji and Karakhan [21]

Item	Barriers
1	Large initial investment required
2	Need for extensive training before achieving optimal performance
3	Concerns about the availability of technical support
4	Doubts about the reliability of these technologies
5	The client rarely requires its use
6	The difficulty associated with interoperability
7	Limited technology lifespan
8	Need for extensive technical support to achieve optimal performance
9	Limited attributes and features
10	Technologies tend to be complex to use
11	The organization prefers to use existing processes to manage security
12	Lack of information on the effectiveness of health and safety technology
13	Limited opportunities to observe and test health and safety technologies

A total number of 78 answered questionnaires were collected. 76 participants were male workers, and only 2 workers were female. This was motivated by the high presence of men in the construction sector. The distribution of the participants is shown in Table 2.

Table 2. Distribution of participants in the survey

Occupation	Number
Construction Safety Manager	5
Occupational Health and Safety coordinator	6
Foreman	40
Construction workers (Bricklayers, plumbers, electricians, etc.)	25

The participants were asked to evaluate the importance of the following statements (Table1) regarding the adoption of IoT technologies (sensors, software, and other technologies to connect and exchange data with other systems through the Internet) in the construction sector from 1 to 5. (1 being not important, and 5 very important).

3 Results

The results showed that the peculiarities of such a traditional sector act as a barrier in terms of the adoption and learning of the use of IoT. A large initial investment in the development and integration of the IoT system was pointed to as a potentially important barrier, however, IoT systems are low cost and especially cheap if they are compared with the total budget of a construction project [22].

Construction workers often associate new technologies with high investment but this perception is not true for many sensors and monitoring devices [23]. Another important barrier is the management of the new devices The lack of personnel trained in the use of IoT systems for safety is a key factor in construction environments, and this problem has been identified by previous authors [24, 25]. Additionally, concerns about the availability of technical support were identified as an important or very important barrier by 70% of the participants. In contrast, doubts about the reliability of these technologies obtained lower scores. In consequence, the construction managers trust in the technology applicability but they do not trust in the technical skills of the construction workers. Aligned with these results, the participants pointed out the need for extensive technical support to achieve optimal performance, as another relevant barrier to the implementation of IoT for safety in construction projects (Fig. 1).

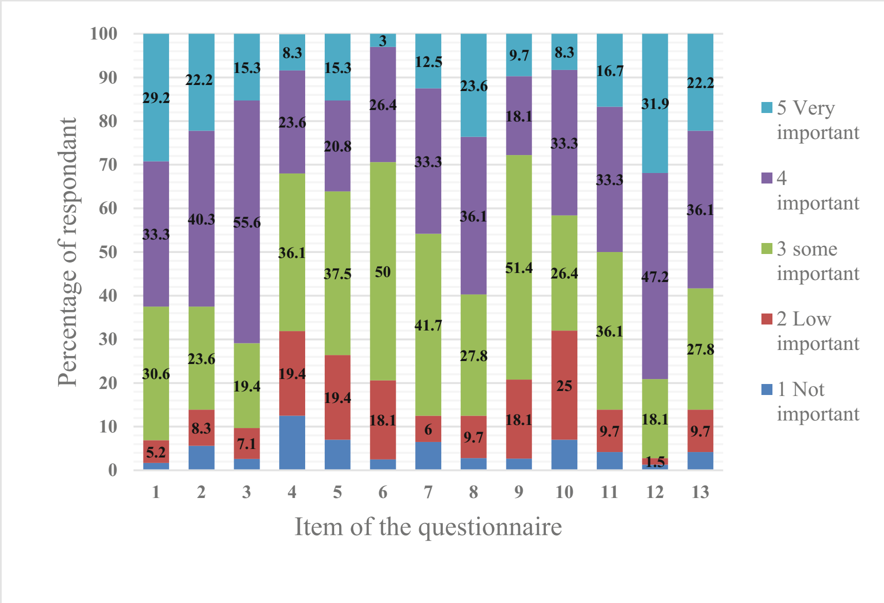


Fig. 1. Identification of main barriers to the adoption of IoT for Safety in construction

4 Conclusions

Greater knowledge about the advantages of its adoption and an adaptation of the training programs, in which these programs are oriented towards a greater presence of IoT technologies, can help greater integration and more effective learning. Clear information about the cost of the devices, and their advantages to improve the safety conditions in the construction sites, is a key factor to promote the use and adoption of the IoT for safety. In addition, an update of the existing legal framework on safety where new existing technologies are considered would favor their dissemination and applicability.

Acknowledgements. This research was funded by the University of Málaga thorugh the Plan Propio. Project Title *"Integración de dispositivos basados en el paradigma loT para la mejora de seguridad laboral en proyectos de contrucción (IoTcons)"*.

References

1. LópezArquillos, A., RubioRomero, J.C., Gibb, A.G.F., Gambatese, J.A.: Safety risk assessment for vertical concrete formwork activities in civil engineering construction. Work **49**(2), 183–192 (2014). https://doi.org/10.3233/WOR-131724
2. LópezArquillos, A., RubioRomero, J.C., Gibb, A.: Accident data study of concrete construction companies' similarities and differences between qualified and non-qualified workers in Spain. Int. J. Occup. Saf. Ergon. **21**(4), 486–492 (2015). https://doi.org/10.1080/10803548.2015.1085750

3. del Carmen, M., ReyMerchán, J.M., GómezdeGabriel, A.L.-A., Choi, S.D.: Analysis of falls from height variables in occupational accidents. Int. J. Environ. Res. Publ. Health **18**(24), 13417 (2021). https://doi.org/10.3390/ijerph182413417
4. Arquillos, A.L., Romero, J.C.R., Gibb, A.: Analysis of construction accidents in Spain, 2003-2008. J. Saf. Res. **43**(5–6), 381–388 (2012). https://doi.org/10.1016/j.jsr.2012.07.005
5. LópezArquillos, A., RubioRomero, J.C.: Proposed indicators of prevention through design in construction projects. Revista de la construcción **14**(2), 58–64 (2015). https://doi.org/10.4067/S0718-915X2015000200008
6. Sacks, R., Perlman, A., Barak, R.: Construction safety training using immersive virtual reality. Constr. Manag. Econ. **31**, 1005–1017 (2013). https://doi.org/10.1080/01446193.2013.828844
7. Zhang, S., Teizer, J., Lee, J.K., Eastman, C.M., Venugopal, M.: Building information modeling (BIM) and safety: automatic safety checking of construction models and schedules. Autom. Constr. **29**, 183–195 (2013)
8. del Carmen, M., ReyMerchán, J.M., GómezdeGabriel, J.-A.F.-M., LópezArquillos, A.: Improving the prevention of fall from height on construction sites through the combination of technologies. Int. J. Occup. Saf. Ergon. **28**(1), 590–599 (2020). https://doi.org/10.1080/10803548.2020.1815393
9. GomezdeGabriel, J.M., FernándezMadrigal, J.A., LopezArquillos, A., RubioRomero, J.C.: Monitoring harness use in construction with BLE beacons. Measurement **131**, 329–340 (2019)
10. Yang, H., Chew, D.A.S., Wu, W., Zhou, Z., Li, Q.: Design and implementation of an identification system in construction site safety for proactive accident prevention. Accid. Anal. Prev. **48**, 193–203 (2012). https://doi.org/10.1016/j.aap.2011.06.017
11. Costin, A.M., Teizer, J.: Fusing passive RFID and BIM for increased accuracy in indoor localization. Visual. Eng. **3**(1), 1–20 (2015). https://doi.org/10.1186/s40327-015-0030-6
12. Yang, X., Yu, Y., Shirowzhan, S., Sepasgozer, S., Li, H.: Automated PPE-Tool pair check system for construction safety using smart IoT. J. Build. Eng. **32**, 101721 (2020). https://doi.org/10.1016/j.jobe.2020.101721
13. Mehata, K.M., Shankar, S.K., Karthikeyan, N., Nandhinee, K., Hedwig, P.R.: IoT based safety and health monitoring for construction workers. In: 2019 1st International Conference on Innovations in Information and Communication Technology (ICIICT), pp. 1–7. IEEE (2019). https://doi.org/10.1109/ICIICT1.2019.8741478
14. Devi, D.N., Zahoor-Ul-Huq, S., Ahamed, K.I.: Real time monitoring of integrated coalmine mashup middleware system using WSN. Int. J. Recent Technol. Eng. **7**, 1–3 (2019)
15. Del Carmen Rey-Merchan, M., Arquillos, A.L., Soto-Hidalgo, J.M.: A Fall from Height prevention proposal for construction sites based on Fuzzy Markup Language, JFML and IoT solutions. In: IEEE International Conference on Fuzzy Systems (2021). https://doi.org/10.1109/FUZZ45933.2021.9494548
16. Asadzadeh, A., Arashpour, M., Li, H., Ngo, T., BabHadiashar, A., Rashidi, A.: Sensor-based safety management. Autom. Constr. **113**, 103128 (2020). https://doi.org/10.1016/j.autcon.2020.103128
17. Sigcha, L., Pavón, I., Arezes, P., Costa, N., De Arcas, G., López, J.M.: Occupational risk prevention through smartwatches: Precision and uncertainty effects of the built-in accelerometer. Sensors **18**(11), 3805 (2018). https://doi.org/10.3390/s18113805
18. Zhou, C., Ding, L.Y.: Safety barrier warning system for underground construction sites using Internet-of-Things technologies. Autom. Constr. **83**, 372–389 (2017). https://doi.org/10.1016/j.autcon.2017.07.005
19. Häikiö, J., Kallio, J., Mäkelä, S.-M., Keränen, J.: IoT-based safety monitoring from the perspective of construction site workers. Int. J. Occup. Environ. Saf. **4**(1), 1–14 (2020). https://doi.org/10.24840/2184-0954_004.001_0001

20. Tabatabaee, S., et al.: Investigating the barriers to applying the internet-of-things-based technologies to construction site safety management. Int. J. Environ. Res. Public Health. **19**, 868 (2022)
21. Nnaji, C., Gambatese, J., Karakhan, A., OseiKyei, R.: Development and application of safety technology adoption decision-making tool. J. Constr. Eng. Manag. **146**, 04020028 (2020). https://doi.org/10.1061/(asce)co.1943-7862.0001808
22. Awolusi, I., Marks, E., Hallowell, M.: Wearable technology for personalized construction safety monitoring and trending: review of applicable devices. Autom. Constr. **85**, 96–106 (2018)
23. Nnaji, C., Karakhan, A.A.: Technologies for safety and health management in construction: current use, implementation benefits and limitations, and adoption barriers. J. Build. Eng. **29**, 101212 (2020). https://doi.org/10.1016/j.jobe.2020.101212
24. Alam, M.F., Katsikas, S., Beltramello, O., Hadjiefthymiades, S.: Augmented and virtual reality based monitoring and safety system: a prototype IoT platform. J. Netw. Comput. Appl. **89**, 109–119 (2017). https://doi.org/10.1016/j.jnca.2017.03.022
25. Chung, W.W.S., Tariq, S., Mohandes, S.R., Zayed, T.: IoT-based application for construction site safety monitoring. Int. J. Constr. Manag. (2020). https://doi.org/10.1080/15623599.2020.1847405
26. Wilkins, J.R.: Construction workers' perceptions of health and safety training programmes. Constr. Manage. Econom. **29**, 1017–1026 (2011). https://doi.org/10.1080/01446193.2011.633538

Multiple Trip Drones-Truck Combined Operations for Last-Mile Delivery Applications. A Literature Review

David Sanchez-Wells[1,2](✉), Pedro L. Gonzalez-R[1](✉), and Jose Luis Andrade-Pineda[1]

[1] Department of Industrial Engineering and Management Science, School of Engineering, University of Seville, Seville, Spain
davsanwel@alum.us.es, {pedroluis,jandrade}@us.es
[2] Indaero Emergy Group, Seville, Spain

Abstract. The cooperative use of a fleet of drones and one or more trucks to perform logistics and transport operations, especially for last-mile applications, has been growing in popularity as one of the most attractive approaches for a future implementation in real environments, gaining interest both among research groups and companies around the globe. In this brief review, an attempt is made to introduce the lay reader to the scientific literature most directly related to this type of combined logistics operations.

Keywords: Literature review · Drone-truck combined operations · UAV

1 Introduction

It has been a while since major companies using or providing massive last-mile logistics services began to envision an, at that time, futuristic and innovative delivery system in which autonomous drones would be the last link in the delivery chain. This vision, given its economic and environmental implications, inspired entrepreneurs and researchers around the world, who immediately began working in their respective circles of influence to build this future (see [1–3]).

While some of the most recent papers focus on a single-drone setting (see [4–6]), one of the most promising proposals of this logistics model, which has already been analyzed and studied in the literature, is defined by the use of a fleet of drones and one or more trucks. This has been corroborated by statements from the main players in the sector. That is why it is considered appropriate to carry out a state-of-the-art study that analyzes this specific configuration, which will be especially synthetic with the objective of bringing the reader closer to these logistic systems. We aim at identifying if the purchased objectives present in the relevant literature are realistic both in the current and future drone-related technologic ecosystem, where real circumstances lead to considerate multiple objectives simultaneously and the last environment-focused developments towards using H2-propelled UAVs are, every day, closer to become a cost-effective and cleaner solution.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 197–201, 2023.
https://doi.org/10.1007/978-3-031-27915-7_36

This literature review is structured as follows: Sect. 2 will introduce and justify the scope of the review itself; Sect. 3 will establish the applicable concepts and definitions; Sect. 4 will present the most important aspects found in the literature; and finally, Sect. 5 will propose future directions of development on this topic.

2 Scope of Review

As pointed out by recent literature reviews (Fig. 1) about last-mile logistics [7], this last step of the delivery process is nowadays a highly relevant topic due to global trends, such as 1. Increasing urbanization and growing e-commerce turnover, 2. Expanding role that sustainability aspects play in our daily lives, 3. Great potential for cost reduction in an activity extensive in human labor force, 4. Competition in terms of delivery speed between different companies and 5. Aging of the population and subsequent reduction of the available labor force in societies with higher GDP.

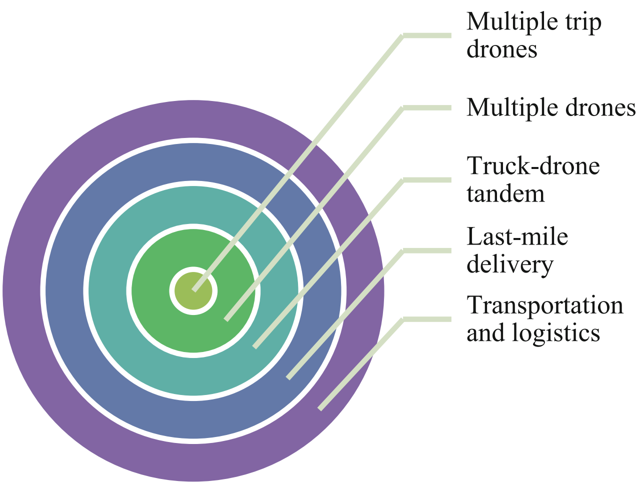


Fig. 1. Literature review context (Source: own elaboration)

On the other side, a specific literature review [8] surveys the state-of-the-art for civil drone and drone-truck combined operations, including the applications for the transport and logistics sector. An analysis of this work reveals that most of the literature studying the drone-truck combined operations (henceforth, DTCO) focuses on transport and logistics applications (see Fig. 2). On the other hand, a more in-depth analysis shows that only 4 transport and logistics research papers study the multiple trips drone operations. This number is reduced to 3 if we account the possibility of using multiple drones (see [5, 9, 10]).

As a conclusion, we can state that the multiple trip drones-truck combined operations for last-mile delivery applications research field is underdeveloped, despite its interest and potential. A specific study of this topic is therefore justified, to serve as a basis for future developments that both experienced researchers and newcomers can use as a starting point for their work.

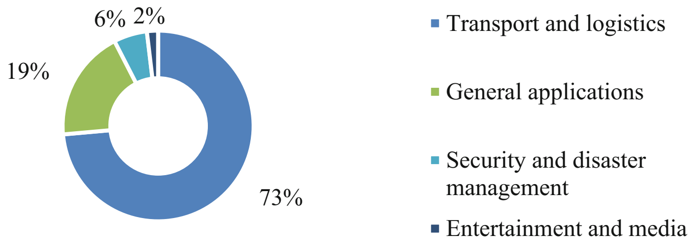


Fig. 2. Applications of DTCO routing [8] (Source: own elaboration)

3 Literature Analysis

A systematic review was undertaken, finally leading us to perform an in-depth analysis from Table 10 in [8], where the surveyed DTCO papers related to routing problems are summarized. This table has been extended with more recent papers from some of the listed authors ([11–13]). All these papers contribute with a mathematic model, a heuristic and experimentation: only [9] performs a deep theoretical study. From the truck point of view, only [9] and [10] consider the possibility of using multiple, capacitated trucks with no synchronization (rendezvous with the drones), while the remaining use a single truck with synchronization. At last, in [9] the truck has the delivery role with drone support, while in [5] and [10] the drone has this role, with truck support (Table 1).

Table 1. Infrastructure configuration and roles in the relevant state of the art.

Reference	Model	Heuristic	Truck	Sync (Limitation)	Delivery	Size of Instances
[5]	Yes	B&B	Single	Yes (Autonomy)	Drone	S + M + L
[9]	Yes	IG	Multiple	No	Truck	S + M
[10]	Yes	B&P	Multiple	No	Drone	S + M
[11]	Yes	GRASP + ALNS	Single	Yes (Autonomy)	Both	S + M
[12]	Yes	TS + SA	Single	Yes (Capacity)	Both	S + M
[13]	Yes	MAS	Single	Yes (Autonomy)	Both	L

From the system configuration point of view, [5] is centered on a problem where a mothership (truck) and multiple drones act as a tandem where only the last have the delivery role, looking after minimizing the total service time; [9] considers a delivery problem with time windows where the drones resupply the trucks as they execute the delivery work and where the objective is to maximize the number of served clients and, in a second step, the truck time; in [10] a set of trucks and drones with previously defined synchronization places (called “docking hubs”) work collaboratively for the delivery and where the total mission cost is minimized.

They referred to the TSP-D with multiple drones with consideration of adjustable speeds and battery consumption rate as a function of the payload, although they assumed the truck serves solely as a mobile depot (drone primary) which does not deliver packages to customers. [12] also includes the fact that the battery endurance depends not only on the flight time, but on the self-weight of the drone and the total weight of the carried packages. They solve their model using a heuristic approach and report its performance only for a small fleet of two drones cooperating with the truck. In contrast, [13] addressed a truck-multiple drones system for serving a big number of targeted points, assuming that for minimization of the total service time a drone is not allowed to come back to its launch node. [11] also faced the synchronized deployment of a truck with multiple UAVs, although they only allow the drones to be retrieved one-at-a-time and at a position different of that from which the drone was launched.

4 Managerial Implications

From a managerial point of view, the main conclusion that may be extracted from our research is clear: one of the most promising applications of the combined use of trucks and drones for last mile logistics has still a lack of scientific research aimed at generating solutions that may fit real situations or, at least, serve as a basis for it. On the other hand, this work can be used as basis for developing last mile logistics systems since it highlights the existing opportunities and approaches in this field.

5 Future Research

For future research, an important aspect would be to account for the importance of the environment and sustainability aspect, as no one of the relevant papers consider the pollution factor for the internal combustion engine trucks or the energy source for any of the vehicles that may contribute to the delivery mission.

Additionally, and due to the increasing interest of the mobility industry in H2-based propulsion, it is considered as a new factor that may positively affect to the energetic efficiency and pollution factor of the vehicles, as the technology gradually will allow for it as this type of propulsion systems are democratized.

At last, it has been observed that, in general, the whole literature focus on a specific and very generic objective (delivery time or mission cost), while most of the real-world problems face with multiple challenges at the same time and do have, subsequently, a multi-objective nature.

References

1. Olivares, V., Cordova, F., Sepúlveda, J.M., Derpich, I.: Modeling internal logistics by using drones on the stage of assembly of products. Proc. Comput. Sci. **55**, 1240–1249 (2015)

2. Macrina, G., Pugliese, L.D.P., Guerriero, F., Laporte, G.: The green mixed fleet vehicle routing problem with partial battery recharging and time windows. Comput. Oper. Res. **101**, 183–199 (2019)
3. Murray, C.C., Chu, A.G.: The flying sidekick traveling salesman problem: Optimization of drone-assisted parcel delivery. Transp. Res. Part C Emerg. Technol. **54**, 86–109 (2015). https://doi.org/10.1016/j.trc.2015.03.005
4. GonzalezR, P.L., Canca, D., AndradePineda, J.L., Calle, M., LeonBlanco, J.M.: Truck-drone team logistics: a heuristic approach to multi-drop route planning. Transp. Res. Part C Emerg. Technol. **114**, 657–680 (2020). https://doi.org/10.1016/j.trc.2020.02.030
5. Poikonen, S., Golden, B.: Multi-visit drone routing problem. Comput. Oper. Res. **113**, 104802 (2020)
6. Tavana, M., KhaliliDamghani, K., SantosArteaga, F.J., Zandi, M.-H.: Drone shipping versus truck delivery in a cross-docking system with multiple fleets and products. Expert Syst. Appl. **72**, 93–107 (2017). https://doi.org/10.1016/j.eswa.2016.12.014
7. Boysen, N., Fedtke, S., Schwerdfeger, S.: Last mile delivery concepts: a survey from an operational research perspective. OR Spect. **43**, 1–58 (2021)
8. Chung, S.H., Sah, B., Lee, J.: Optimization for drone and drone-truck combined operations: a review of the state of the art and future directions. Comput. Oper. Res. **123**, 105004 (2020)
9. Dayarian, I., Saverlsbergh, M., Clarke, J.-P.: Same-day delivery with drone resupply. Transp. Sci. **54**(1), 229–249 (2020)
10. Wang, Z., Sheu, J.-B.: Vehicle routing problem with drones. Transp. Res. Part B Methodol. **122**, 350–364 (2019). https://doi.org/10.1016/j.trb.2019.03.005
11. Kitjacharoenchai, P., Min, B.-C., Lee, S.: Two echelon vehicle routing problem with drones in last mile delivery. Int. J. Prod. Econom. **225**, 107598 (2020)
12. Luo, Z., Poon, M., Zhang, Z., Liu, Z., Limde, A.: The multi-visit traveling salesman problem with multi-drones. Transp. Res. Part C. Emerg. Technol. **128**, 103172 (2021)
13. Leon-Blanco, J.M., Gonzalez-R, P.L., Andrade-Pineda, J.L., Canca, D., Calle, M.: A multi-agent approach to the truck multi-drone routing problem. Expert Syst. Appl. **195**, 116604 (2022)

How COVID-19 Pandemic Drives Digital Transformation of the Workplace: A Case Study of an Industrial SME

J. M. González-Varona(✉), F. Acebes, N. Martín-Cruz, and J. Pajares

INSISOC – Universidad de Valladolid, Paseo del Cauce 59, 47011 Valladolid, Spain
Josemanuel.gonzalez.varona@uva.es

Abstract. The digital transformation of SMEs is unstoppable and one of its consequences will be the change of the workplace, which implies advantages but also disadvantages for companies and employees. The COVID-19 pandemic and the related lockdown made remote work, facilitated by digital technologies, a necessity. Based on a case study in an industrial SME, through semi-structured interviews, we obtained relevant information on the response given to this new situation. As a result, we propose three issues to be addressed to advance in the digital transformation of the workplace: firstly, SMEs must address needs at the operational level; secondly, professional relationships and, finally, new requirements derived from the very nature of digital work.

Keywords: Digital transformation · SME · COVID-19 · Digital work · Workplace · Remote work

1 Introduction

The digital transformation of SMEs is unstoppable and one of its consequences will be the increase of remote work, which has many advantages for companies and employees, but also has some disadvantages, as described by several authors [1–3].

We understand "digital workplace" as a set of technologies and practices that are involved in the employee experience in the digital workplace, regardless of physical location [2].

As indicated by [4], in the future, work will be about what to do and how to do it, not where and when to do it. Therefore, SMEs increasingly provide new digital technologies to their employees to facilitate digital work and achieve greater flexibility.

But employees also require balance and stability between private and professional life. Enabling employees to be independent, responsible and connected in the workplace will be essential for their future performance in digital work and also for achieving the expected well-being [5]. As pointed out by [6], SMEs need to develop a digital capability related to the workplace that will enable them to advance in digital maturity.

The confinement situation that occurred with the COVID-19 pandemic made it possible to observe all this within a special situation, when many employees were suddenly forced to work from home.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 202–207, 2023.
https://doi.org/10.1007/978-3-031-27915-7_37

The COVID-19 emergency changed the way of working in many SMEs, where employees were forced to work from home, what we know as "remote work". The new digital technologies enabled employees to work from home and an advance in the digitalization of the workplace, and the digital maturity of SMEs. Although initially advantages were observed since it favored the conciliation of work and family life, disadvantages were also soon revealed, as it increased work stress and posed problems with work-life balance [1, 7, 8].

Studies are still needed to investigate how this special situation has affected employees [9], this paper aims to address this gap by investigating, through a case study, the advantages and disadvantages experienced by employees of an SME in the industrial sector, who had a face-to-face work and are forced by confinement to work from home.

2 Methodology

For our research we used a case study approach. We selected an R&D project wich we called "HIP"[1] and wich was being executed by an industrial SME when the "lock-down" occurred, that we called "Compression". The project was co-funded by the European Regional Development Fund (ERDF) and had a budget of approximately 2 million euros.

Compression is an international reference in the design, manufacture and commercialization of industrial processing equipment for the food sector. It has a turnover of more than 50 million euros and more than 120 technical professionals and engineers, some of them with PhDs.

Currently, it dedicates 10% of its profits to R&D, with the participation of 20% of the workforce. In addition, it has delegations in the United States of America and Mexico. The aim was to develop a prototype of a machine using a new technology for SME, test it and carry out the necessary commercial work to bring it to market.

When the COVID-19 pandemic emerged, we conducted semi-structured interviews with the project team to obtain information on the complexity of working remotely on a project of this nature. In the interviews, questions were asked regarding the way to coordinate on the project, work-life balance, technological requirements, viability of working remotely and satisfaction with the new way of working. In total, semi-structured interviews were conducted with 16 employees (Fig. 1) and textual quotes were included in the results obtained to convey in more detail [10].

Finally, we obtained a relevant dataset and conducted a qualitative analysis using NVivo data analysis software. These data allowed us to know what the main advantages and disadvantages were and to compare the situation before and after the start of the COVID-19 pandemic.

[1] The name of the project and the company have been replaced by fictitious ones to ensure confidentiality.

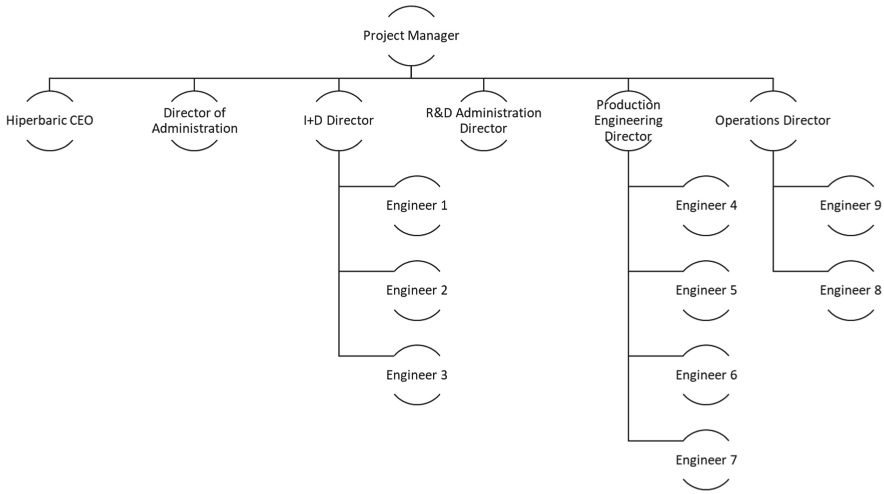


Fig. 1. Interviewed work team in project HIP. Source: Own elaboration

3 Results

It is important to note that the results obtained are related to the exceptional situation of lockdown, and that they serve as an orientation of what a situation in which remote working is widespread would be like. From the information obtained from the semi-structured interviews, we can differentiate between the data provided by management and those provided by employees.

On the one hand, CEO of Compression is quite critical of working from home, he prefers face-to-face work. He gave employees the freedom to choose to work from home or in the office, but remote work requires commitment from the employee and he is fully convinced that there is a loss of efficiency when working remotely.

They made the company "transparent" without walls, diaphanous, so that everyone could see everything and improve teamwork. Now, people are hard to reach, over-meeting is generated, and valuable people are sometimes left behind because of lower performance working from home.

On the positive side, losing the fear of videoconferencing, which will allow us to be more efficient in the future, with regard to clients. Although they will not replace face-to-face meetings, contact and personal relationships that generate trust, but they will avoid many of the routine meetings.

On the other hand, employees have indicated the need to adapt to the new situation in order to move forward. Working from home means a greater workload and mental overload, they are more stressed. The number of online meetings is excessive, and tensions are generated with colleagues and other departments.

Although it makes it possible to reconcile work and family life, it is also stressful to show that you have been working, that you have not been out of work. On the other hand, when manufacturing customised machines, to fine-tune them and make modifications prior to commissioning, there is a lack of coordination with customers.

Table 1 summarizes the main disadvantages identified in the semi-structured interviews conducted with the HIP project team.

Table 1. Disadvantages of remote work in lockdown. Source: Own elaboration.

Operational needs	• Lack of "on-site" staff • Coordination between project staff and other areas • Relationship problems with suppliers and customers
Professional relationships	• Tensions between departments • Impossibility of informal meetings • Impossibility of face-to-face meetings • Difficulties in establishing trusting relationships with new customers
New requirements	• Need for training in new technologies • Technical problems in "fine-tuning" customized machine requirements • Work planning and organization in order not to lose efficiency

4 Discussions

4.1 Conclusions

Although initially, remote working, family reconciliation and flexible working hours allowed the workplace to survive, drawbacks soon emerged that call remote working into question and make both the employees and Compression´s CEO doubtful.

The CEO of "Compression" has detected a loss of efficiency in the work of his employees that needs to be corrected. On the other hand, although working from home was an immediate necessity, it would require planning and organization to be adopted as an improvement.

Both the CEO and the employees think that remote working is temporary, although Compression has developed new digital capabilities, and it is foreseeable that once the pandemic is over, it will not return to the previous situation. Instead, it is more likely to use its hard-won new digital capabilities to launch a new phase of innovation and competition. As indicated by [11], there is a need to rethink the way employees work and the expectations of customers in order to develop a new vision for the future.

The results are intended to help SMEs cope with the new situation they face with the end of the pandemic and the removal of restrictions.

4.2 Limitations and Future Research

The results obtained are not fully generalizable due to practical limitations. The application of the results obtained in other SMEs in other sectors of activity should be further investigated. We believe that future interviews and longitudinal studies are necessary to advance in the development of the necessary knowledge of the impact of remote work on the management of SMEs.

Further research on the impact on SMEs of having worked remotely for several months, would be worthwhile. Is it necessary to return to face-to-face working or is remote working here to stay? If remote working can become the normal way of working, what adaptations will SMEs have to face.

Finally, future studies should be aimed at establishing the quantifiable benefits derived from the total or partial implementation of remote work in the daily operations of SMEs.

Acknowledgements. This research has been partially financed by the Regional Government of Castile and Leon (Spain) and the European Regional Development Fund (ERDF, FEDER) with grant VA180P20.

References

1. Richter, A.: Locked-down digital work. Int. J. Inf. Manage. **55**, 102157 (2020). https://doi.org/10.1016/j.ijinfomgt.2020.102157
2. Marsh, E., Vallejos, E.P., Spence, A.: The digital workplace and its dark side: an integrative review. Comput. Human Behav. **128**, 107118 (2022). https://doi.org/10.1016/j.chb.2021.107118
3. Kudyba, S.: COVID-19 and the acceleration of digital transformation and the future of work. Inf. Syst. Manage. **37**, 284–287 (2020). https://doi.org/10.1080/10580530.2020.1818903
4. Dittes, S., Richter, S., Richter, A., Smolnik, S.: Toward the workplace of the future: how organizations can facilitate digital work. Bus Horiz. **62**, 649–661 (2019). https://doi.org/10.1016/j.bushor.2019.05.004
5. Meske, C., Junglas, I.: Investigating the elicitation of employees' support towards digital workplace transformation. Behav. Inf. Technol. **39**, 1–17 (2020). https://doi.org/10.1080/0144929X.2020.1742382
6. GonzálezVarona, J., LópezParedes, A., Poza, D., Acebes, F.: Building and development of an organizational competence for digital transformation in SMEs. J. Ind. Eng. Manage. **14**, 15–24 (2021). https://doi.org/10.3926/jiem.3279
7. Lonska, J., Mietule, I., Litavniece, L., et al.: Work-life balance of the employed population during the emergency situation of COVID-19 in Latvia. Front. Psychol. **12**, 3398 (2021). https://doi.org/10.3389/FPSYG.2021.682459/BIBTEX
8. Subramaniam, R., Singh, S.P., Padmanabhan, P., et al.: Positive and negative impacts of COVID-19 in digital transformation. Sustainability **13**, 9470 (2021). https://doi.org/10.3390/su13169470
9. Tønnessen, Ø., Dhir, A., Flåten, B.T.: Digital knowledge sharing and creative performance: work from home during the COVID-19 pandemic. Technol. Forecast. Soc. Change **170**, 120866 (2021). https://doi.org/10.1016/J.TECHFORE.2021.120866

10. Saunders, M., Lewis, P., Thornhill, A.: Research Methods for Business Students. Financial Times/Prentice Hall (2009)
11. Kane, G.C., Nanda, R., Phillips, A., Copulsky, J.: Redesigning the post-pandemic workplace. MIT Sloan Manag. Rev. **62**, 12–14 (2021)

Two Solution Approaches for an Enriched Multi-depot Vehicle Routing Problem

T. Granados-Romero[1], A. García-Sánchez[2,3](✉), H. Larzábal[3], and R. Nait-Abdallah[4]

[1] Pontificia Universidad Javeriana, Bogotá, Colombia
granados_tania@javeriana.edu.co

[2] Departamento de Ingeniería de Organización, Administración de Empresas y Estadística, Universidad Politécnica de Madrid, Madrid, Spain
alvaro.garcia@upm.es, alvaro.garcia@baobabsoluciones.es

[3] Baobab Soluciones, SL. Calle José Abascal 55, Entreplanta Izquierda, Madrid, Spain
hugo.larzabal@baobabsoluciones.es

[4] Departamento de Ingeniería Industrial, Pontificia Universidad Javeriana, Bogotá, Colombia
rnait-abdallah@javeriana.edu.co

Abstract. This paper analyzes a routing problem for a telecommunications company. Two different approaches were tested: a Particle Swarm Optimization (PSO) and a biased randomization approach. The results show that the two approaches are comparable. The general conclusion is that PSO is slightly better than the biased randomization approach but in the biggest instance the biased randomization approach finds a good solution sooner.

Keywords: Biased- randomized heuristics · MDVRP · Particle swarm optimization · Vehicle routing problem

1 Introduction

This paper addresses a variation of the Vehicle Routing Problem for a major telecommunication company in Europe. Two approaches are tested: Particular Swarm Optimization (PSO) and biased randomization.

The remainder of this document is structured as follows: Sect. 2 describes the problem to be solved. Section 3 presents the resolution approaches. And finally, we compare the computational results.

2 Problem Description

One of the most important telecommunications operators in Europe must audit its stores every three months. The problem consists in determining the routes of the auditors to visit all the stores in Spain (more than 2000 stores). All stores must be visited within a maximum period of 3 months and the objective is to minimize costs.

This problem can be viewed as a variation of a multi-depot vehicle routing problem. Multi-Depot VRP (MDVRP) aims at generating optimal routes for vehicles having as

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 208–212, 2023.
https://doi.org/10.1007/978-3-031-27915-7_38

a characteristic that more than one depot is considered from which customers can be served. The solution procedures used for this type of problem are mainly classified into exact methods, heuristics, or metaheuristics [2].

For this problem the vehicles are the store auditors and have a capacity to visit maximum 2 clients per day. Auditors work from Monday to Friday. The deposits are the auditors' homes. Auditors leave their homes on Mondays and have to be back on Fridays. Auditors can visit stores in their own municipality or travel to other municipalities and visit a maximum of two stores in a day, one in the morning and one in the afternoon. During the week, the auditor spend the night in the municipality he/she visited in the afternoon, travel to another municipality and spend the night there, or return to his/her residence.

The problem comes with other specific constraints such us:

– the existence of coordinators which are location dependent and must be present during the auditions,
– regional holidays in Spain: a store cannot be visited if it is holiday, and an auditor doesn't work if his municipality is on holiday,
– constraints related to maximum travel distances and maximum travel times.

The cost is composed of: wages (proportional to the number of worked days), overnight stays, and travel distances.

These constraints make our MDVRP very specific. And the resolution techniques available in the literature don't grasp all its specificities. Thus, we decided to design our own approach for this enriched MDVRP.

3 Two Different Approaches to Solve the Problem

We developed two approaches to solve the problem: a Particle Swarm Optimization metaheuristic and a biased randomization approach. These two approaches rely on routing algorithm that we developed.

This routing algorithm is integrated into our two different approaches: PSO and biased randomization as shown in Fig. 1.

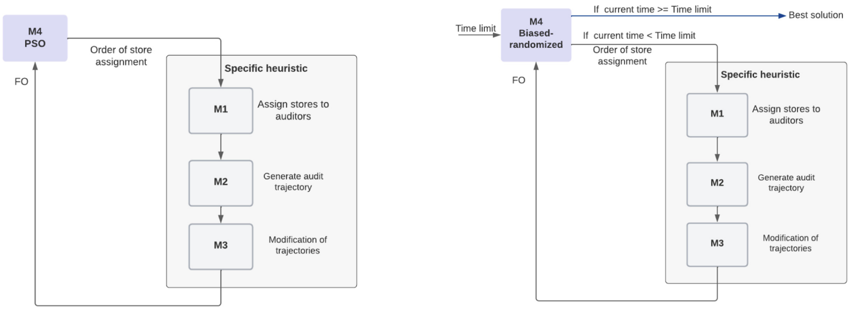


Fig. 1. Hybridization diagram of our routing algorithm with the two other approaches

In the following, we describe the PSO approach and the biased randomization approach. But first, we will detail our routing algorithm on which both other approaches are based.

3.1 Description of Our Routing Algorithm

This heuristic is decomposed in three phases: first assign stores to auditors, then determine the route of each auditor and finally, modify the routes to reduce costs.

Phase 1: Assignment of Stores to Auditors
This phase determines the number of auditors to be hired and the stores that they will visit. All stores end up being assigned to auditors and we assign the closest stores first to minimize distances. Additionally, we make sure that the maximum number of stores per auditor is less than $\frac{\text{numstores}+1}{12}$. This rule of thumb prevents overloading auditors. The denominator of this rule of thumb was determined experimentally by making many trial/error tests to find the best value.

Phase 2: Generation of Routes
Once all the stores are assigned to auditors, the next phase is to generate each auditor's route. The routes are generated using a nearest neighbor algorithm considering the constraints of maximum traveling distance, holidays and the availability of a coordinator in the visited municipalities. The decision of where to spend the night (at home or in another municipality) is made choosing the lowest cost alternative.

Phase 3: Modification of the Routes
The first two phases create a solution that is complete and feasible. This last phase identifies opportunities of combining routes of the same auditors when it allows to reduce costs.

3.2 Particle Swarm Optimization Approach

The particles in the PSO consist in the order of the stores to be assigned. This order is then used as an input to our routing algorithm where it replaces the rule of assigning the closest stores in phase 1. This hybridization is shown in Fig. 1. The algorithm is run with 10 particles.

3.3 Biased Randomization Approach

Similarly to the PSO, this approach creates an order of the stores to be used as an input for our routing algorithm as shown in Fig. 1. A random order is generated instead of using the rule of the closest store first.

The approach consists in generating and evaluating many random sequences, and the final solution is the one that gives the best objective function. The number of random sequences is not fixed but we keep on generating them until we reach the time limit equivalent to the PSO execution time. This allows the two approaches to be comparable.

The biased randomization approach was implemented using two variations to generate the random sequence: triangular and geometrical [4]. At the end, triangular randomization showed systematically better results (0.04%–0.40% improvement) and it is the one that is kept in the remaining of the document.

4 Computational Results

In the following we compare the results of the two approaches. We evaluated the value of the objective function as we increase execution time. The results are shown in Fig. 2. The two approaches were tested on four instances of different sizes: 300 stores, 500 stores, 1000 stores, and 2470 stores (Instance of the real problem).

Fig. 2. Comparison of the two approaches with different instances

5 Analysis and Conclusions

The main conclusions from the computations can be summarized as follows:

- The performance of the PSO and biased triangular randomization are comparable, although the PSO gives slightly better results
- In the biggest instance we can see that the PSO takes much more time to find a first solution. While the biased randomization finds a good solution faster

As a general conclusion we can say that the two approaches are comparable. The PSO is slightly better for this problem (0.02%–0.21%). The use case in favor of the biased randomization would be bigger instances with a short amount of execution time.

References

1. Hesam Sadati, M.E., Çatay, B., Aksen, D.: An efficient variable neighborhood search with tabu shaking for a class of multi-depot vehicle routing problems. Comput. Oper. Res. **133**, 105269 (2021). https://doi.org/10.1016/j.cor.2021.105269
2. Montoya-Torres, J.R., López Franco, J., Nieto Isaza, S., Felizzola Jiménez, H., Herazo-Padilla, N.: A literature review on the vehicle routing problem with multiple depots. Comput. Indus. Eng. **79**, 115–129 (2015). https://doi.org/10.1016/j.cie.2014.10.029
3. Braekers, K., Ramaekers, K., van Nieuwenhuyse, I.: The vehicle routing problem: state of the art classification and review. Comput. Ind. Eng. **99**, 300–313 (2016). https://doi.org/10.1016/j.cie.2015.12.007
4. Grasas, A., Juan, A.A., Faulin, J., de Armas, J., Ramalhinho, H.: Biased randomization of heuristics using skewed probability distributions: a survey and some applications. Comput. Ind. Eng. **110**, 216–228 (2017). https://doi.org/10.1016/j.cie.2017.06.019

Frames of Industry 4.0: Comparing Companies and Labor Unions in Brazil and Spain

Diego Rorato Fogaça[1,2,3](✉), Mercedes Grijalvo[1], and Mario Sacomano Neto[2]

[1] Universidad Politécnica de Madrid (UPM), Madrid, Spain
diego.fogaca@ufms.br
[2] Federal University of São Carlos (UFSCar), São Carlos, SP, Brazil
[3] Federal University of Mato Grosso Do Sul (UFMS), Campo Grande, MS, Brazil

Abstract. This work aims to analyze how companies and unions frame Industry 4.0. For this, we performed an inductive and deductive discourse analysis based on publicly available documents. Companies frame Industry 4.0 from a perspective of increasing productivity and sustainability. Unions focus on employment issues and working conditions. The Brazilian union has a more negative view of the I4.0, which can be explained by the country's institutional relations.

Keywords: Industry 4.0 · Neo-institutional theory · Framing

1 Introduction

Industry 4.0 (I4.0) is claimed to have a significant influence on global competition, labor market, socioenvironmental standards and even educational priorities [1]. Although there is a lack of an agreed-upon definition [2], attempts to define it are usually technology-oriented, like "Industry 4.0 is the implementation of Cyber Physical Systems for creating Smart Factories by using the Internet of Things, Big Data, Cloud Computing, Artificial Intelligence and Communication Technologies for Information and Communication in Real Time over the Value Chain" [3]. However, some authors [4–6] present challenging perspectives for Industry 4.0 by adopting a neo-institutional approach as one of the ways to explain this phenomenon. The new institutional theory asserts that organizational structure not only reflects technical demands but is also shaped by institutional forces. Organizations are embedded in social and political environments, so their practices frequently reflect or respond to rules, beliefs, and conventions constructed into the wider environment [7].

For Phillips and Malhotra [8] the definition of institutions as having a rule-like status in thought is fundamentally cognitive and socially constructed. Similarly, Zilber [9] stresses the importance of studying the dynamics of meanings in the institutionalization process because this highlights particular and contextual issues. Language provides meaning and legitimacy to practices and builds structures that support institutions [8].

Frames are pivotal to the cultural-cognitive aspect of institutions which "involves the creation of shared conceptions that constitute the nature of social reality and the frames

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 213–218, 2023.
https://doi.org/10.1007/978-3-031-27915-7_39

through which meaning is made" [10]. When the concept of framing is operationalized to analyze the discourse, the idea is to analyze utterances of a varied nature, capturing the way in which they frame reality. At the heart of this type of operationalization is a concern with understanding how discourses establish frames of meaning, framing the world from specific perspectives. It seeks to think about how the discursive content itself creates a context of meaning, calling the interlocutors to follow a particular interpretative path. Frames can define problems, diagnose causes, make moral judgments and suggest solutions [11].

This work aims to analyze how Industry 4.0 is framed by companies and unions through discourse analysis of these organizations in Brazil and Spain.

2 Methods

Discourse analysis has significant potential for theory development and empirical research in institutional theory [12]. It is typically constructionist since it views language as productive rather than reflective. The analytic focus is on understanding, in various ways, what language does, what realities are constructed through language, and how this happens [13]. Discourse analysis examines the communication exchange and its social context; thus, it requires an appreciation of where texts originate, how organizational actors employ them, and the cultural circumstances [12, 14]. Similarly to [15] we used text only to analyze frames utilized in discourse.

We picked the 20 publicly listed companies with the highest market capitalization in Spain and Brazil according to [16] as of February 2022. Market capitalization is calculated by multiplying the share price by the number of outstanding shares. Next, we accessed the websites of these companies and downloaded all the reports available to investors up to the year 2018. This document with consolidated information is usually called an "annual report". It is often regarded as an informative instrument whose primary goal is to communicate reliable and relevant information about an organization's past, present, and future activities [17]. However, there are variations in its denomination or the creation of separate reports such as "integrated report", "sustainability report", "corporate governance report", "economic and financial statements", and "management report". Regarding unions, we chose the largest federation of unions in Brazil, the Central Única dos Trabalhadores (CUT), and the largest in Spain, the Unión General de Trabajadores (UGT). All articles and reports on these entities' websites that mentioned Industry 4.0 were downloaded. We retrieved 34 documents from CUT and 24 from UGT. The files of the analyzed companies and unions were uploaded at https://tinyurl.com/CIO2022paper046.

In all company and union documents, we searched for the expression "Industry 4.0" or neologisms [18] (such as work 4.0 or economy 4.0) and identified instances of the use of the terms [19]. Adapting the qualitative analysis of institutional logics by [20], we used an inductive and deductive method. Pattern inducing is an interpretivist approach that assumes meaning is tightly intertwined with context. From a bottom-up analysis, text segments are clustered into meaningful categories. Pattern deducing converts the data to countable occurrences for standardized comparison. Our coding scheme was based on studies that had already analyzed the discourse in Industry 4.0

[6] and on the sensemaking process of the actors involved [5]. Furthermore, for a more macro analysis, we adapted Boltanski's "orders of worth", also called "economies of worth" (EW), "justification regimes" or simply "worlds": inspired, domestic, fame, civic, market, industrial, connectionist/network and green [21, 22].

First, the documents were independently analyzed by two researchers, who noted the main themes that emerged. They compared the results and defined common categories of analysis. Then, they individually performed the category count, comparing the results again and discussing when there were significant divergences.

3 Results

Half of the 20 most valuable publicly traded companies in Spain mentioned Industry 4.0 or related concepts (e.g., energy 4.0, utilities 4.0, airport 4.0 or agriculture 4.0). Of the Brazilian organizations, there were eight. This difference can be explained by the companies in the banking sector that did not mention Industry 4.0 in any of the countries. In Brazil, six companies are from this sector, while there are only three in Spain. Organizations from different sectors brought the concept of Industry 4.0 into their reports, such as telecommunications, energy, infrastructure and construction. On the other hand, important manufacturing companies did not, such as Inditex (clothing) and Ambev (beverage).

Considering Boltanski's EW to analyze the frames related to Industry 4.0 in companies, Spanish and Brazilian organizations presented surprisingly close results. Approximately 90% of them cited the industrial world, 70% the green, half the market and 40% the connectionist. The industrial justification regime relates to technical efficiency, the green to sustainability, the market to the customer and monetary issues, and the network to connections. Table 1 presents terms taken from the annual reports related to each EW.

Table 1. Expressions related to Economies of Worth (EW).

EW	Expressions
Industrial	Process/industrial optimization; Reliability in operations; Avoid unnecessary spending; Improve performance; Service efficiency
Green	Ecologically correct; Less natural resources; Low water consumption; Emission reduction; Energy and climate transition
Market	Performance indicators (EBTIDA); Financial capital; Demand of customers; Improved customer experience; Supporting competitiveness
Network	Control anytime and anywhere; Real-time information; Remote monitoring; Superconnectivity

Although the value chain-oriented definition of Industry 4.0 has recently become dominant in published articles [1], it was not observed in the analyzed reports. Only approximately 10% of them associated this concept with the value chain. Another issue that came up in several reports was the increase in employee safety by implementing 4.0

initiatives. The Brazilian company Gerdau, for example, uses the expression "Security 4.0". The position adopted in all reports was positive, i.e., Industry 4.0 was always linked to benefits. This would be expected since betterment is at the heart of such reports [17].

The main EW mobilized by unions to frame Industry 4.0 is civic. In this justification regime, collective welfare, fundamental rights, equality and solidarity are valued. The themes that emerged in the analysis were related to employment, working conditions, industrialization and participation in the discussion about Industry 4.0. Although CUT and UGT share common themes, important differences need to be pointed out.

Table 2 summarizes the top 3 topics most cited by unions. In Brazil, the most mentioned issue was unemployment, followed by concern with the industrialization of the economy and the demand for participation in public debate and decision-making in I4.0. In Spain, the main question was the sharing of benefits generated by the I4.0 and the guarantee of workers' rights, followed by employment and the need for training of workers.

Table 2. Issues most often mentioned in union documents.

Country	Theme	Documents citing the theme (%)
Brazil	Employment	68
	Industrialization	35
	Participation in debate	35
Spain	Worker's right	65
	Employment	61
	Training	56

The framing of I4.0 by the CUT was mostly negative, while the UGT was primarily neutral. For example, the employment issue, which is prominent in both countries, is portrayed in this way by the Brazilian union: "Industry 4.0 will unemploy, that is, exclude a substantial portion of the working population" and thus by the Spanish confederation: "need to promote changes in the sectoral composition of economic activity and employment, promoting the modernization of traditional sectors […] incorporating Industry 4.0 into our productive fabric".

4 Conclusion

The framing of I4.0 by Spanish and Brazilian companies was quite similar. The same was not observed in the unions. Some of these differences can be explained by the discrepancy between the institutions of the two countries. Spain, as a Coordinated Market Economy (CME), has a balance between companies, unions and government in defining policies and regulating the labor market [23]. Therefore, the Spanish unions frame the I4.0 in a less fearful way than the Brazilians, highlighting the need to qualify workers so that they are integrated into this process. On the other hand, as a Hierarchical Market

Economy (HME), Brazil has atomistic labor relations dominated by MNCs and business groups [24]. In this way, the CUT demands greater participation of workers in the discussion of the I4.0, emphasizing the problem of little industrialization in the country and highlighting the negative impact of the I4.0 on employment.

For future studies, we suggest including the analysis of governments since they play an important role in the implementation of Industry 4.0 and in the mediation of conflicts. Investigating professional and business associations can provide an even more complete picture. In addition, the study of more countries with a CME and a HME can show whether the results obtained here can be generalized.

Acknowledgment. The authors would like to acknowledge the project Biomimicry and carbon adsorbent eco-materials for a climate-neutral economy. P101086302, HORIZON MSCA-2021-SE-01 for the support.

References

1. Ghobakhloo, M., Fathi, M., Iranmanesh, M., Maroufkhani, P., Morales, M.E.: Industry 4.0 ten years on: a bibliometric and systematic review of concepts, sustainability value drivers, and success determinants. J. Clean. Prod. **302**, 127052 (2021). https://doi.org/10.1016/j.jclepro.2021.127052
2. Culot, G., Nassimbeni, G., Orzes, G., Sartor, M.: Behind the definition of Industry 4.0: analysis and open questions. Int. J. Prod. Econom. **226**, 107617 (2020). https://doi.org/10.1016/j.ijpe.2020.107617
3. Rupp, M., Schneckenburger, M., Merkel, M., Börret, R., Harrison, D.K.: Industry 4.0: a technological-oriented definition based on bibliometric analysis and literature review. J. Open Innov. Technol. Market. Compl. **7**(1), 68 (2021). https://doi.org/10.3390/joitmc7010068
4. Reischauer, G.: Industry 4.0 as policy-driven discourse to institutionalize innovation systems in manufacturing. Technol. Forecast. Soc. Change **132**, 26–33 (2018). https://doi.org/10.1016/j.techfore.2018.02.012
5. Meyer, U.: The emergence of an envisioned future. Sensemaking in the case of "Industrie 4.0" in Germany. Futures **109**, 130–141 (2019). https://doi.org/10.1016/j.futures.2019.03.001
6. Oesterreich, T.D., Schuir, J., Teuteberg, F.: The emperor's new clothes or an enduring IT fashion? Analyzing the lifecycle of industry 4.0 through the lens of management fashion theory. Sustainability **12**(21), 8828 (2020). https://doi.org/10.3390/su12218828
7. Powell, W.W., Colyvas, J.A.: New institutionalism. In: International Encyclopedia of Organization Studies. SAGE Publications, Inc., Thousand Oaks, California (2008). https://doi.org/10.4135/9781412956246.n336
8. Phillips, N., Malhotra, N.: Language, cognition and institutions: studying institutionalization using linguistic methods. In: Greenwood, R., Oliver, C., Lawrence, T., Meyer, R. (eds.) The SAGE Handbook of Organizational Institutionalism, pp. 392–417. SAGE Publications Ltd, London (2017). https://doi.org/10.4135/9781446280669.n16
9. Zilber, T.B.: The evolving role of meaning in theorizing institutions. In: The SAGE Handbook of Organizational Institutionalism, pp. 418–445. SAGE Publications, London (2017). https://doi.org/10.4135/9781446280669.n17
10. Scott, W.R.: Institutional carriers: reviewing modes of transporting ideas over time and space and considering their consequences. Ind. Corp. Change. **12**, 879–894 (2003). https://doi.org/10.1093/icc/12.4.879

11. Mendonça, R.F., Simões, P.G.: Enquadramento: diferentes operacionalizações analíticas de um conceito. Rev. Bras. Ciênc. Sociais. **27**, 187–201 (2012). https://doi.org/10.1590/S0102-69092012000200012
12. Phillips, N., Lawrence, T.B., Hardy, C.: Discourse and Institutions. Acad. Manage. Rev. **29**, 635–652 (2004). https://doi.org/10.5465/amr.2004.14497617
13. Braun, V., Clarke, V.: Successful Qualitative Research: A Practical Guide for Beginners. SAGE, Los Angeles (2013)
14. Lune, H., Berg, B.L.: Qualitative Research Methods for the Social Sciences. Pearson, Harlow, England Munich (2017)
15. Jones, C., Livne-Tarandach, R.: Designing a frame: rhetorical strategies of architects. J. Organ. Behav. **29**, 1075–1099 (2008). https://doi.org/10.1002/job.556
16. Companies Market Cap. http://www.companiesmarketcap.com
17. Breton, G.: From folk-tales to shareholder-tales: semiotics analysis of the annual report. Soc. Bus. Rev. **4**, 187–201 (2009). https://doi.org/10.1108/17465680910994191
18. Madsen, D.O.: The emergence and rise of industry 4.0 viewed through the lens of management fashion theory. Admin. Sci. **9**(3), 71 (2019). https://doi.org/10.3390/admsci9030071
19. Bujaki, M., Durocher, S., Brouard, F., Neilson, L., Pyper, R.: Protect, profit, profess, promote: establishing legitimacy through logics of diversity in Canadian accounting firm recruitment documents: protect, profit, profess, promote: establishing legitimacy through logics of "Diversity." Can. J. Adm. Sci. Rev. Can. Sci. Adm. **35**, 162–178 (2018). https://doi.org/10.1002/cjas.1392
20. Reay, T., Jones, C.: Qualitatively capturing institutional logics. Strateg. Organ. **14**, 441–454 (2016). https://doi.org/10.1177/1476127015589981
21. Boltanski, L., Thévenot, L.: The sociology of critical capacity. Eur. J. Soc. Theory. **2**, 359–377 (1999). https://doi.org/10.1177/136843199002003010
22. Boltanski, L., Chiapello, E.: The new spirit of capitalism. Int. J. Polit. Cult. Soc. **18**, 161–188 (2005). https://doi.org/10.1007/s10767-006-9006-9
23. Royo, S.: Varieties of capitalism in spain: business and the politics of coordination. Eur. J. Ind. Relat. **13**, 47–65 (2007). https://doi.org/10.1177/0959680107073967
24. Schneider, B.R.: Hierarchical market economies and varieties of capitalism in Latin America. J. Lat. Am. Stud. **41**, 553–575 (2009). https://doi.org/10.1017/S0022216X09990186

Analyzing the Behavior of Spanish Company Managers from a Gender Perspective

Sofía Estelles-Miguel(✉), Manuel Exposito-Langa, and Gabriela Ribes-Giner

Departamento de Organización de Empresas, Universitat Politècnica de València, 46022 Valencia, Spain
{soesmi,gabrigi}@omp.upv.es, maexlan@doe.upv.es

Abstract. Despite the various studies carried out to date related to female entrepreneurship, the debate remains open about what factors are managed differently from a gender perspective. The aim of this paper is to provide empirical evidence on the differences in a gender perspective in several competitive factors of firms. To do this, competitive factors such as financing, innovation, internationalization and others have been analysed. To address these research questions, and based on the survey carried out in 2021 at the "Observatorio Iberoamericano de la Mipyme" (FAEDPYME), a sample of 1,532 Spanish companies has been analysed. Through a multivariate analysis, and applying the SPSS statistical software to delve into the hypothesis of gender independence with respect to the behavior of company managers, identifying if there are significant differences in the variables proposed in the research.

Keywords: Gender · Financing · Internationalization · Business administration and management · FAEDPYME

1 Introduction

In recent years, we find abundant literature on female entrepreneurship, employment and self-employment [1, 2] and [3], together with the financing of women entrepreneurs [4] and [5] and sustainable finance [6] and [7]. However, despite the various studies carried out to date, the debate on which factor are managed differently from a gender perspective is still open. Thus, and taking these premises into consideration, it is of interest to continue delving into these lines of research.

The aim of this paper is to provide empirical evidence on the differences in a gender perspective in organizational variables. In this way, competitive factors such as financing, innovation, size and internationalization have been analysed. To address these research questions, and based on the survey carried out in 2021 at the "Observatorio Iberoameticano de la Mipyme" (FAEDPYME), a sample of 1,532 Spanish companies has been analysed. This observatory is a permanent research center that contributes to the process of centralization, production and analysis of information related to the historical evolution, current situation and future prospects of the regional productive sector with

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 219–224, 2023.
https://doi.org/10.1007/978-3-031-27915-7_40

an emphasis on SMEs. The observatory was created with the idea of offering information on the productive structure of Ibero-America, and aims to be useful to companies and the different economic and social agents. Its main objective is to provide continous information on the strategies and expectation of the Iberoamerican SMEs in order to facilitate and support decision-making, in scientific terms, to obtain useful solutions for the different sectors of economic activity. Knowing the problems of the company in its multiple aspects allows, undoubtedly to facilitate its competitiviness.

The main results obtained show that, although there are no gender differences between requesting, or not, financing, there are differences in the reasons why women do not seek financing from others. This would be related to the fact that women have more security when they contribute all the capital themselves, maintaining greater autonomy in managing their business, rather than resorting to other sources of financing that may be more complex. It would also be related to the restrictions that women face in accesing financial resources, especially in times of crisis, where financial exclusion is more marked in female entrepreneurship [8]. In turn, the study makes it possible to verify that women are more educated at the university level, in addition to gender being significant in relation to exports and the size of the company.

Finally, we consider that this paper can present interesting contributions to the open debate on the gender perspective and business management.

2 Methodology

To address these research questions, and based on the survey carried out in 2021 at the "Observatorio Iberoameticano de la Mipyme" (FAEDPYME), a sample of 1,532 Spanish companies has been analysed. Through a multivariable analysis, and applying the SPPS statistical sofware, Chi-square and non-parametric statistics are observed, deepen the hypothesis of gender independence with respect to the behaviour of company managers, identifying if there are sisgnificant differences in the variables proposed in the research.

In order to assess whether the gender perspective can influence the different variables considered in the study, a contingency table analysis was carried out to observe the association with categorical variables [9] and [10], such as studies, financing, size and type of company. In this contingency tables, the possible association between the categories represented in rows and colums is observed by comparing the proportions. Using Pearson's Chi-squeare statistic, an independent hypothesis test is established, so that, for a p-value less than 0.05 and considering a confidence level of 95%, it is accepted that there is an association between the variables. Otherwise, it is assumed that the difference between the observed values may be due to chance.

On the other hand, to observe the association of the gender perspective with the numerical variables (age of the manager, age of the company, exports and number of employees), a T-test for independent samples was performed [11]. This test allows us to test the hypothesis of the difference between two independent means. Thus, the homogeneity of variances is first tested using the F-statistic to subsequently estimate the T-statistic, where it is assumed that if the critical level, or p-value, is less than 0.05, the data from both samples reject the null hypothesis of equality of means, so they can be considered different.

The sample used is shown below in Table 1.

Table 1. Descriptive data of the sample used for the study.

Variables	Women	Men	Total
Average age (years)	50.41	51.92	51.67
With university degree	134 (63.07%)	627 (49.29%)	791 (51.63%)
Average company age (years)	29.96	28.96	29.13
The company has recently applied for financing	138 (53.08%)	687 (54.01%)	825 (53.85%)
Average weight of export in your company	6.06%	9.53%	8.93%
Average size (employees)	18.36	25.77	24.51
It is a family business	204 (78.4%)	311 (72%)	1,115 (72,78%)
Sample size	260 (16.97%)	1,272 (83.03)	1,532 (100%)

3 Results

Below we present the results obtained in this study using Pearson's Chi-square test for categorical variables.

Table 2. CEOs with an university degree.

Variables		Women	Men	Total
With university degree	Yes	164 (63.07%)	627 (49.29%)	791 (51.63%)
	No	96 (36.92%)	645 (50.7%)	741 (48.36%)
Sample size		260 (16.97%)	1,272 (83.03)	1,532 (100%)
Pearson's Ch-Square (p-value)			17.407(*) (0.00)	

(*) Indicates that the test is significant ($p < 0.01$)

Table 2 shows that female managers have a higher level of university education than male managers.

Table 3. Access to funding lines and reason for not to doing so in this case.

Variables		Women	Men	Total
Access to funding lines	Yes	138 (53.08%)	687 (54%)	825 (53.85%)
	No, because my company does not need it as it doesn not make investments	32 (12.31%)	104 (8.18%)	136 (8.88%)
	No, because my company does not need it as it is self-financing	76 (29.23%)	455 (35.77%)	531 (34.66%)
	No, because, despite needing it, I think I would not get the financing	14 (5.38%)	26 (2.04%)	40 (2.61%)
Sample size		260 (16.97%)	1,272 (83.03)	1,532 (100%)
Pearson's Ch-Square (p-value)			15.060(*) (0.002)	

(*) Indicates that the test is significant ($p < 0.01$).

Table 3 shows that although there are no differences to apply for financial aid, the reason why women do not request it are different from those mentioned by men.

Table 4. Size of the company.

Variables		Women	Men	Total
Size of the company	6–9 employees	135 (51.92%)	422 (33.18%)	557 (36.36%)
	10–40 employees	109 (41.92%)	697 (54.80%)	806 (52.61%)
	More than 50 employees	16 (6.15%)	153 (12.03%)	169 (11.03%)
Sample size		260 (16.97%)	1,272 (83.03)	1,532 (100%)
Pearson's Ch-Square (p-value)			33.691(*) (0.00)	

(*) Indicates that the test is significant ($p < 0.01$)

In Table 4 we can see that men run larger companies than those run by women.

Next, we present the Contrast T test of means for numerical variables. The size is checked here as well, since the number of employees is available (Table 5).

Table 5. T-test of means for numerical variables

Variables	F-statistic (Levene's test for equality of variance)	t-statistic	Female average group	Male average group
CEO age	.614 (.433)	−2.246* (0.025)	50.41	51.92
Company age	4.502* (.00)	.622 (.008)	29.96	28.96
Weight of export (%)	14.702* (.034)	−2.649* (.534)	6.06	9.53
Number of employes	5.274* (0.022)	−3.013* (0.003)	18.36	25.77
Sample size			260 (16.97%)	1,272 (83.03%)

(*) Indicates that the test is significant ($p < 0.01$)

It is observed that female managers are, on average, slighly younger than tehir male counterparts. Male-led firms are older, but this variable is not significant. Exports and firm size are also higher for male-led firms, in which case the variable is significant.

4 Conclusions

The aim of this paper is to provide empierical evidence on what competitive factors influence business management from a gender perspective. In it, competitive factors have been analyzed, financing and internationalization of the companies studied, disaggregating by gender, age of the companies and their CEOs. For this, the data extracted from the survey carried out in 2021 by the "Observatorio Iberoamericano de la Mipyme (FAEDPYME)" has been used, and a sample of 1,532 Spanish companies has been analyzed.

Female managers were found to have a higher university education than male managers (significant variable). It was also shown that women managers are slighly younger than men managers on average. And althought male-led companies are slightly older, this variable is not significant. The size of the firms and the amount of exports are higher in companies run by men (these variables being significant).

There are no differences in applying for financial support (by men and women), but the reasons why women do not apply for financial support when they do not apply are different from those given by men. Women managers are more risk averse. They are also more likely than men to believe that they will not be granted financial support, it is mainly because they consider that they do not need it because they can finance themselves.

The information extracted from this study is very interesting and is in line with previous studies [3–6, 8, 12, 13, 14] and [15]. Future studies will further explore the issue of financing and the reasons for r women's risk aversion.

Acknowledgements. We would like to thank FAEDPYME with whom we have participated in the "Observatorio Iberoamericano de la Mipyme (FAEDPIME)", in the passage of the survey carried out in 2021.

References

1. Berner, E., Gomez, G., Knorringa, P.: Helping a large number of people become a little less poor: the logic of survival entrepreneurs. Eur. J. Dev. Res. **24**, 382–396 (2012). https://doi.org/10.1057/ejdr.2011.61Ligthelm(2005)
2. Neck, H., Brush, C., Allen, E.: The landscape of social entrepreneurship. Bus. Horiz. **52**(1), 13–19 (2009)
3. Pathak, H.P., Gyawali, M.: Role of microfinance in employment generation: a case study of microfinance program of Paschimanchal Grameen Bikash Bank. J. Nepalese Bus. Stud. **7**(1), 31 (2012). https://doi.org/10.3126/jnbs.v7i1.6401
4. Weber, O., Ahmad, A.: Empowerment through microfinance: the relation between loan cycle and level of empowerment. World Dev. **62**, 75–87 (2014)
5. Purushothaman, S., Varma, R., Puhorit, S.: Women's access to and control over financial resources: towards development and redesigning policy. Policy document commissioned by the Dept of Women and Child Development Govermment of Kamataka, on self help groups (2000)
6. Bartual-Sanfeliu, C.B., Cervelló-Royo, R.C., Moya-Clemente, I.: Measuring performance of social and non-profit microfinance institutions (MFIs): an application of multicriterion methodology. Math. Comput. Model. **57**(7–8), 1671–1678 (2013)
7. Garikipati, S.: The impact of lending to women on household vulnerability and women's empowerment: evidence from India. World Dev. **36**(12), 2620–2642 (2008)
8. Cervelló-Royo, R.C., Moya-Clemente, I., Perelló-Marín, R., Ribes-Giner, G.: Differences in the financial approach to entrepreneurship from a gender perspective. Int. J. Globalisation Small Bus. **12**(1), 46–58 (2021)
9. Everitt, B.S.: The Analysis of Contingency Tables. Chapman & Hall, London (1977)
10. Reynolds, H.T.: Analysis of Nominal Data, 2nd edn. Sage Publications, Beverly Hills and London (1984)
11. Newbold, P., Carlson, W.L., Thorne, B.M.: Statistics of Business and Economic, 5th edn. Prentice Hall, New York (2002)
12. Hosseini, J.F., Bakhtiari, M., Lashgarara, F.: The role of micro credit funds in developing entrepreneurship among rural women in Iran. Am. J. Sci. Res. **44**, 38–43 (2012)
13. Goetz, A.M., Gupta, R.S.: Who takes the credit? Gender, power, and control over loan use in rural credit programs in Bangladesh. World Dev. **24**(1), 45–63 (1996)
14. Bocci, C., Mishra, K.: Forest power: the impact of community forest management on female empowerment. Ecol. Econ. **187**, 107105 (2021). https://doi.org/10.1016/j.ecolecon.2021.107105
15. Purohit, T., Kumar, S.: A study on India's new generation women entrepreneurs: propelling community empowerment though transformative relationships. J. Bus. Manag. **22**(9), 36–47 (2020)

Urban Ecosystem Sustainability Impacts of Air Quality

Salma El Bied[1], Maria Victoria de-la-Fuente-Aragon[1](✉), Lorenzo Ros-McDonnell[1], and Diego Ros-McDonnell[2]

[1] Research Group "Industrial Engineering", ETSII, Technical University of Cartagena, Dr. Fleming S/N, 30201 Cartagena, Spain
{marivi.fuente,lorenzo.ros}@upct.es

[2] Research Group "Project+City", ETSAE, Technical University of Cartagena, C/Real, 3, 30201 Cartagena, Spain
diego.ros@upct.es

Abstract. When considering a problem as vast as the consequences of atmospheric air pollution, it is necessary to take into account many aspects which in turn have various economic and social effects beyond its physiological and environmental effects. It can harm economic competitiveness and limit the ability to attract desirable economic activity. In simple terminology, we can say that air pollution effects can be both direct and indirect. We have studied the relationship between the air quality and the environmental, social and economic consequences, such as the property values in the city, the employee´s productivity and their ability to work; developing a study pilot in Cartagena, a city located in the Region of Murcia, Spain.

Keywords: Sustainability · Air quality · Urban mobility · Sustainable development

1 Introduction

Since the work of the Club of Rome on the impact of growth on the environment in 1973 and the report "Our Common Future" commonly called the Brundtland report in 1987, the economic literature has been interested in sustainable development, the impact of human activity on future generations and the indicators of wealth that are supposed to go beyond the sole economic and financial dimension.

Sustainable development is defined as development that aims to meet the needs of current generations without compromising those of future generations [1]. This concept broadens the economic analysis to take into consideration the social, and environmental dimensions. In fact, the sustainability of our society is compromised when air quality poses a significant risk of health damage to the general or susceptible populations or causes significant degradation of natural resources or the built environment [2].

One of the major's contributors to air pollution beside the agricultural and the industrial activities is urban mobility which has led to a significant increase due to the continuous growth of urbanization [3]. Thus, urban mobility has a major influence on the

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 225–232, 2023.
https://doi.org/10.1007/978-3-031-27915-7_41

sustainability and quality of life in cities which are above all confronted with air pollution, noise, congestion, occupation of public space by traffic [4].

There are numerous implications of air pollution on the ecosystem, among which the affection of crop yields and the environment and impacts on biodiversity and ecosystems, these impacts have significant economic consequences. Which will affect economic growth as well as welfare [5].

After an extensive literature review, this research was based on the study of [6], which believed that air pollution can impact the overall economy indirectly by affecting employees' health in many forms which lead to a weak ability to work. Moreover, [7] stated that by affecting children or elderly adults, employee's productivity get decreases by reducing their working hours as a consequence of absenteeism in order to care their family in need.

Due to this cause, numerous people choose to live in urban areas with good air quality, despite the fact that living in urban areas can rarely guarantee both clean air and comfortable house, because properties in these areas are more expensive and due to rapid development and encroachment on green spaces, the environment isn't that good all around.

The question here is to ask whether air quality can influence the housing market [8]. Since on the other hand, depending in part, on their income, which is a function of their productivity, individuals may sort into areas with better air quality which links both air quality and employee productivity, as well as property prices. Furthermore, recent movements pushing to address sustainable development from an urban perspective have taken place throughout the world resulting in the inclusion of a stand-alone goal on cities and urban development in the 2030 Agenda (SDG 11) and the EU Green Deal.

To make real progress towards human ecosystems sustainability, the approach to better governance requires considering the environmental, economic, and social footprint in the design of their policies and initiatives. The air quality study will give us the ability to study the different environmental, social and economic consequences, such as the property value in this city, the employee's productivity, and their ability to work [9] in order to present the link between the air quality of this city and the different sectors mentioned above.

The objective of this work, is to study the existing relationship between air quality and employees' productivity, which indirectly affects the economy, thus the relationship of the latter and the value of properties taking the city of Cartagena (Spain) as a case study.

2 Objectives

The main objective of this research is to study the evolution of real estate prices and productivity over time and their relationship with urban air quality.

During the first stage of the study, presented in this paper, the research team analyzes the variables "real estate prices" and "urban traffic", and they have been considered as specific metrics of these variables. Showing whether urban mobility contributes to air pollution in the urban case studied, and how air quality directly or indirectly affects the overall economy, and specifically the property sector [10, 11].

In the second stage of the study, the variable "employee's productivity" will be developed, and made of several factors (industrial productivity, unemployment rate, level of health and occupational diseases, among others), establishing their relationship with urban air quality.

3 Methods and Materials

The air sample has been analyzed in different points of Cartagena, dividing it into several zones after selecting the sampling points using QGIS 3.18 software which will allow us to get a specific points, in order to measure it´s air quality by the equipment FLOW 2 PLUM LABS in different periods: Autumn-Winter; Spring-Summer (Volatile Organic Compounds (VOC), Ozone (O_3), Carbon Monoxide (CO), Carbon Dioxide (CO_2), Particulate matter (PM), Nitrogen Dioxide) (NO_2) beside of the data that will be recovered by Cartagena city council.

Afterwards, a statistical study will allow the research group to detail the amounts of air pollutants and/or greenhouse gases released within a defined geographical area, that will be realized by using the SPSS statistical software with principal components analysis (PCA) methodology as well as Mathematica software.

4 Discussion

Considering the database we have, formed from data of the city council, the autonomous community administration and real estate web portals, we can see in Fig. 1 that the price of properties has been increasing in the last few years (from 2018 to 2021), then we notice a gradual evolution. As the research work is in progress, currently, the collection of air quality data during this season that will allow us to proceed to the statistical study to compare it with this real estate evolution is in process.

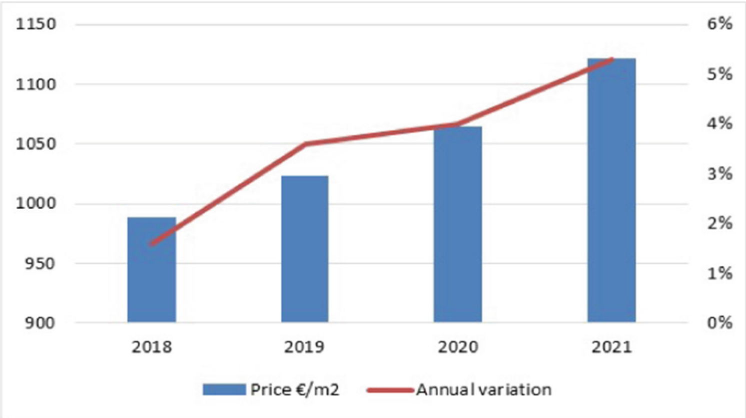


Fig. 1. Evolution of property prices in Cartagena.

The first results of this part of the project research will be obtained after studying the distribution of properties' price and houses along the different neighborhoods of the city. The existing correlation of the property price variable with the air quality variable will be analyzed, detailing in turn the different levels of particles and pollutants of the air and their distribution along different streets. This study will be carried out after the mobility study of the city, and its intrinsic relationship with the levels of environmental pollution that official institutions point out every day.

Mobility is crucial for the socioeconomic growth of urban areas. The high rates of motorization in cities dampen the arguments that seek to minimize their use. In this sense, an important part of the research project includes the study of mobility in the city of Cartagena during the last decade.

It is important to analyze the flow of vehicles in the city and its evolution, since the last decade the city council has pedestrianized around 80% of the streets in the historic center (as can be seen in Fig. 2), deriving all vehicle movement to perimeter streets, congesting them during peak hours along the day.

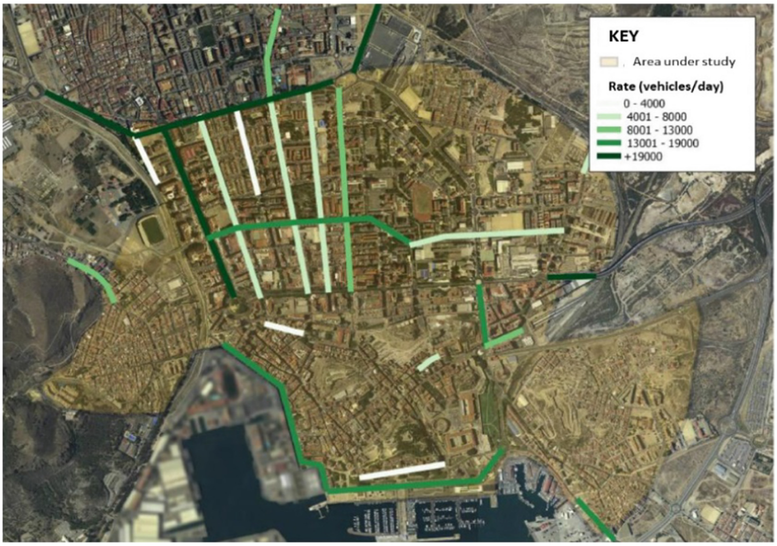


Fig. 2. Traffic map of the city, where the streets have been classified according to the ratio vehicles/day.

Simultaneously to the urban mobility study, urban air quality data were collected, taking initially measurements in two areas (the Historic center and the "Ensanche"). The first results of the measurement of urban air and its quality, in the historic center and its surrounding streets, are shown from Figs. 4, 5 and 6.

The Historic center is a highly pedestrianized area, with traffic mainly on its perimeter, and on certain streets inside the area to allow public transport and to supply stores, businesses and parcels. In this sense, the measurement of traffic in these streets has been carried out, and we show, as example of this behavior, the results obtained in a perimeter street (Fig. 3).

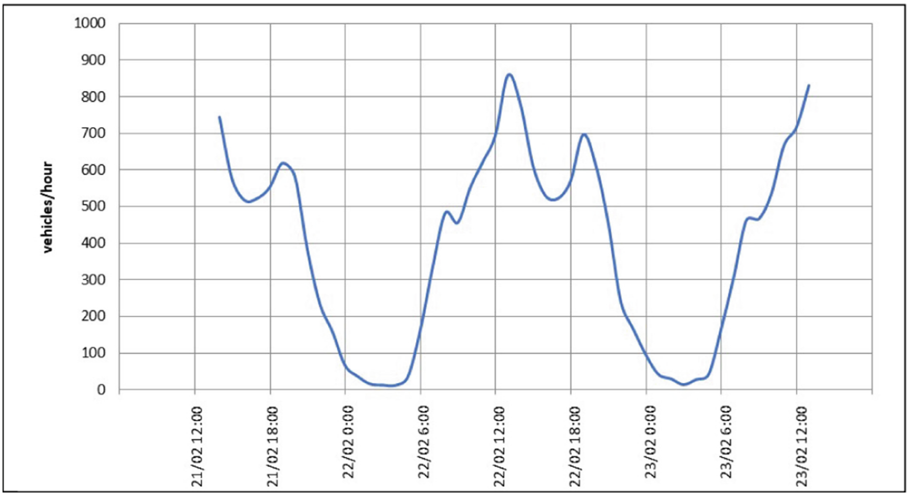


Fig. 3. Traffic flow measured during 48 h in February, in a city center street.

Figure 3 shows the traffic flow measured on Real Street (marked with a blue dot in Figs. 4 and 5) during 48 h in the last February. The traffic measurements carried out behave as a real time series, with a certain smoothing, but which faithfully reflects the pattern of traffic behavior on the street, and we can state that all perimeter streets have very similar trends:

– low levels of traffic at night hours
– continued traffic flow during the day, presenting peaks at first hour in the morning and at lunchtime,
– there are no significant changes in the pattern of behavior between light and cargo vehicles, beyond the fact that the proportion of heavy vehicles is greater in some streets than in others (perimeter or inner streets).

High traffic levels (measured at approximately 2:00 p.m., when workers left the dockyard factory) correspond to the maximum levels of CO_2, CO and O_3 at that point of measurement (Real Street). A priori, a direct relationship is established between the level of traffic and the level of air quality, but this must be analyzed in detail along different neighborhoods, such as the streets that act as entrances to the city.

The study of traffic flows during the time interval reflects a greater intensity of vehicles through the western and northern entrances of the city, standing out as the main entrances for the cargo vehicles to the city, and also moving around the perimeter of the pedestrianized city center. Some entries have decreased their flow, while others have increased them, according to the changes made by the local administration. These city entrances realized high levels of pollutants, and reflects the real traffic flows and their intensity along the period.

In Figs. 4, 5 and 6, we can see that the concentration of pollutants varies according to the location, although these concentrations never exceed the limit values set by law. But it is necessary to detect those critical points of higher values and analyze the urban mobility at a certain point at a time. In that way, the existing conflicts will be detected in each moment and place of the urban area studied.

Fig. 4. Measured levels of CO_2 in the city center.

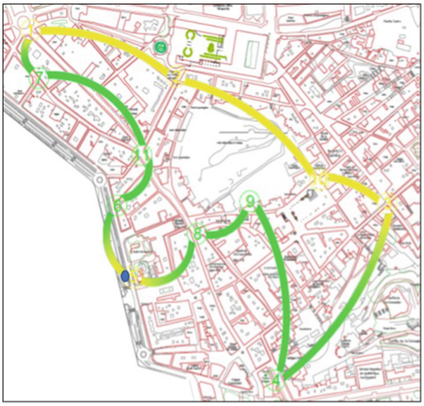


Fig. 5. Measured levels of O_3 in the city center.

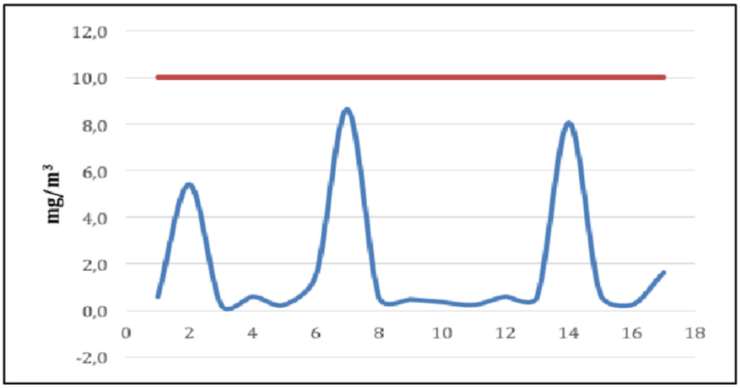


Fig. 6. Measured values of CO (maximum levels) in each observation point of the historic center

After making measurements of contaminating particles during an approximate period of two months, in each of the points referenced and at different times of the day, the average value obtained in the defined area is shown in Table 1.

The values measured must be compared with the limit values established by the current legislation RD/102/2001 [14] and the limit values proposed by the World Health Organization (WHO), and also the number of days that these values were exceeded during past years [12, 15], which serves as an indicator for our research work and the local administration about which are the main atmospheric pollutants in the urban area studied.

Table 1. Reference values and collected data in the urban area under study.

Contaminant particles *($\mu g/m^3$)*	Limit value by RD/102/2001	Limit value by WHO	Value measured in the area	Days that exceed limit value RD[a]	Days that exceed limit value WHO[a]
CO_2	*	*	28.6		
CO	10		5.04	0	0
NO	200	40	0	0	0
NO_2	125	20	8	1	5
O_3	120	100	47.8	22	129
PM2.5	25	10	24	0	0
PM10	50	20	56	7	10

* There are no limit values set in any reference document
[a]Results from report: "Plan de mejora de la calidad del aire para la Región de Murcia 2016–2018" [12]

In summary, the level of air quality is relatively good in the area under study (historic center), although the level of CO_2 and O_3 measured at specific points in the historic center of the city are not recommended, due to both high traffic flows and the scarcity of green areas. However, in this neighborhood the elevated price of properties (€/m^2), due to its limited availability and the historical ruins, results in inverse correlation with the considerable degree of environmental pollution in this neighborhood (city center).

In this first stage, the study of the variables "real estate prices" and "urban traffic" and their correlation with the air quality in each district of the city will help in the definition of economic, urban and social development policies in the global strategy of Sustainable City 5.0 [13] that the city council should implement for next decade.

5 Conclusions

In recent decades, air pollution has become a major environmental problem on the global scale, due to the rapid industrial growth and urbanization of many countries.

The point of this research is to evaluate the indirect impact of air quality on the economy, with reference to the impact and potential risk that urban mobility might present. Our contribution through this research is to provide enough information on the evolution and existence of these impacts, and to confirm their harmfulness as well as confirming whether the principal cause of air pollution is urban mobility, taking Cartagena as a case study.

And based on the fact that one of the global issue is the air quality and numerous cities worldwide have big interest in the environmental improvement and sustainability, our research will contribute in helping in the improvement of the quality of air by making citizens more aware of the various impacts associated with air pollution, which will lead us to change our policies and manage emissions to maintain sustainable air quality by proposing solutions undertaking the results obtained to help meet the air quality standards.

References

1. Toros, T.: Achieving environmental sustainability thru urban infill and redevelopment (2011). www.ilbi.org
2. Borrego, C., Martins, H., Tchepel, O., Salmim, L., Monteiro, A., Miranda, A.I.: How urban structure can affect city sustainability from an air quality perspective. Environ. Model. Softw. **21**(4), 461–467 (2006)
3. United Nations: Department of Economic and Social Affairs. 2018 Revision of World Urbanization Prospects (2018). https://www.un.org/development/desa/publications/2018-revision-of-world-urbanization-prospects.html
4. Lozzi, G., et al.: Research for TRAN committee – sustainable and smart urban transport. European Parliament, Policy Department for Structural and Cohesion Policies, Brussels (2020)
5. Manisalidis, I., Stavropoulou, E., Stavropoulos, A., Bezirtzoglou, E.: Environmental and health impacts of air pollution: a review. Front. Public Health (2020). www.Frontiersin.Org
6. McCarthy, N.: This is the global economic cost of air pollution, February 2020. www.weforum.org
7. Chang, T.Y., Zivin, J.G., Gross, T., Neidell, M.: The effect of pollution on worker productivity: evidence from call center workers in China. Am. Econ. J. Appl. Econ. **11**(1), 151–172 (2019)
8. Amini, A., Nafari, K., Singh, R.: Effect of air pollution on house prices: evidence from sanctions on Iran. Reg. Sci. Urban Econ. **93**, 103720 (2021)
9. Agrawal, M.: Effects of air pollution on agriculture: an issue of national concern. Natl. Acad. Sci. Lett. **28**(3), 93–106 (2005)
10. Azmi, A.S.M., Azhar, R.F., Nawawi, A.H.: The relationship between air quality and property price. Procedia Soc. Behav. Sci. **50**, 839–854 (2012)
11. Carriazo, F., Gomez-Mahecha, J.A.: The demand for air quality: evidence from the housing market in Bogotá. Colombia. Environ. Dev. Econ. **23**(2), 121–138 (2018)
12. DG-CARM: Plan de mejora de la calidad del aire para la Región de Murcia 2016–2018 (2016). www.cartagena.es
13. Cartagena: Agenda Urbana Cartagena. Una hoja de ruta para la Cartagena del futuro (2022). www.agendaurbana.cartagena.es
14. RD/102/2001, relativo a la mejora de la calidad del aire
15. Belmonte, P., Luengo, P.: Informe Calidad del Aire Región de Murcia Año 2017. Ecologistas en Acción de la Región Murciana (2017)

Logistic Challenges in Packaging Design from an "Omnichannel" and Sustainable Perspective

Jesús García-Arca(✉), A. Trinidad González-Portela Garrido, and J. Carlos Prado-Prado

Grupo de Ingeniería de Organización (GIO), University of Vigo, Escuela de Ingeniería Industrial, Campus Lagoas-Marcosende, 36310 Vigo, Spain
jgarca@uvigo.es

Abstract. The rapid development of e-commerce in recent years has shaken the foundations of distribution as we know it, which has forced many traditional retailers to operate in different channels ("omnichannel strategy"). This has led to the emergence of new logistics challenges in the configuration and management of a sustainable supply chain, which in turn affect one of the key elements: the packaging system. Thus, the aim of this paper is to identify, justify and classify the main logistics challenges facing companies and supply chains when it comes to dealing with efficient and sustainable packaging design in an omnichannel context. From a literature review and an analysis of cases, it has been possible to detail and categorize three major types of challenge: configurational, structural, and technological.

Keywords: Packaging · e-commerce · Omnichannel · Sustainability · Logistics

1 Introduction

The continuous, unstoppable growth of e-commerce has revolutionized and shaken structures and business models and processes throughout the supply chain worldwide, from manufacturers to retailers. Thus, the emergence of new players specialized in this new trading channel ("pure players" such as Amazon or Alibaba) has forced retailers (both large and small) operating in traditional channels with physical stores ("brick-and-mortar retailers") to enter this new electronic world.

This multiple and simultaneous way of selling is called "omnichannel" strategy (Taylor et al. 2019). However, the growth in online sales and increasingly demanding levels of service in aspects such as speed, product variety and flexibility have obliged omnichannel retailers to redesign their logistics strategies for distribution in an attempt to maintain their global levels of competitiveness vis-à-vis the large "pure-player" retailers (Hübner et al. 2016).

All these changes, futhermore, have been developed within a dynamic environment that affects, among other aspects, not only the availability of new technological solutions

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 233–238, 2023.
https://doi.org/10.1007/978-3-031-27915-7_42

including the automation of logistics processes, but also new approaches to information management (e.g., the Internet of Things (IoT), Big Data, or Machine Learning). At the same time, social awareness is equally important in terms of the deployment of the three pillars of sustainability (social, economic, and environmental), aligned with the U.N. sustainable development goals (SDG) as part of the Horizon 2030 Agenda. Likewise, these changes also affect one of the key elements in the development of an efficient and sustainable supply chain, that is, the packaging system (Pålsson et al. 2017; Pålsson 2018; Regattieri et al. 2014; 2019; García-Arca et al. 2021).

2 Methodology

Within this framework, the aim of this paper is to identify, justify, and classify, the main logistical challenges facing companies and supply chains when designing an efficient and sustainable packaging system in an omnichannel context. The scientific methodology to achieve this aim draws on two complementary perspectives: theoretical (literature review) and applied (combining case studies of pure-player and omnichannel retailers with the authors' own experience adopting the Action Research approach).

In terms of packaging design, distinct approaches have appeared in the literature in recent years. These include "*Packaging Logistics*" (Saghir 2002, Pålsson and Hellström 2016), followed by "*Sustainable Packaging Logistics*" (García-Arca et al. 2014), which support efficient and sustainable packaging design, promoting greater integration with product design and supply chain design. However, when talking of a packaging system in an omnichannel environment, are we really talking about a single packaging system or several?

Thus, in physical store-based supply chains, it is possible to distinguish primary packaging, i.e., that which is in contact with the product; secondary packaging, which groups several primary packs (typically in a box); and tertiary packaging, which groups several secondary packs, in order to facilitate handling, transport and storage operations (for example, a pallet) (García-Arca et al. 2021).

The idea behind this "traditional" system is based on a basically static supply chain conception, which envisages a fixed structure (primary, secondary, and tertiary packaging) between the manufacturer (or packer) and the retailer with physical shops (Pålsson et al. 2017). However, in an e-commerce setting, there is a need to enlarge this structure dynamically to the needs of each order so that it reaches the final customer. (Pålsson et al. 2017; Pålsson 2018; Regattieri et al. 2014; 2019; García-Arca et al. 2021). This should all be done, moreover, without losing sight of a broader commercialization framework (omnichannel), which can provide not inconsiderable synergies throughout the supply chain, particularly in the final stages (Taylor, 2019).

Normally, e-commerce makes it necessary to deploy additional packaging, called "express packaging" by some authors (Wang and Hu 2016; Pålsson 2018), which helps to group and protect the various products included in each order; an extra protection that includes the use of "cushioning". This protection often tends to increase the volume (and weight) of the new packages (Regattieri *et al.* 2014), which in turn has an impact on both transport efficiency (including last-mile transport and reverse logistics for returns), the generation of waste, and the productivity of the picking process.

3 Results and Discussion

According to the analysis carried out by the authors, the logistics challenges facing packaging design can be grouped into three major categories: configuration challenges, challenges in structuring the design process, and technological challenges.

Configuration challenges include the following:

- Clear and reliable structuring of the logistics information associated with each of the products of the range, including aspects such as the characteristics of the manufacturer's own packaging system (with the dimensions, levels and weights included), the commercial sales unit, the minimum order size, or the problems of product protection and handling. This information, despite being the basis for any type of algorithm to rationalize the packaging system, is not always available in Enterprise Resource Planning (ERP) systems; neither does it have the reliability required nor an update speed that is sufficiently agile.

  All this information complements the information collected at the level of the different packaging system design requirements (commercial, protection, productive, logistics, purchasing, environmental, ergonomic, legal, or communication) (García-Arca et al. 2021). In some cases, the manufacturer's or packer's packaging formats may change, depending on the channel through which they are sent; this approach of eliminating excess packaging is the focus of the "Frustration-Free Packaging" program, promoted by Amazon at its suppliers.
- Clear definition of the configuration of the supply chain to operate in each channel. This configuration conditions the productivity (with or without automation) of logistics processes, among which are to be found procurement, packing, last-mile transport, or reverse logistics (including the potential reuse of the packaging). Likewise, within this chain configuration is the definition of customer service level (particularly the delivery time) that will condition the possibility of greater or lesser grouping of orders and rationalization of the packaging to be used.

Structural challenges include:

- Adoption of a coordinated organizational structure at an internal level (different areas or departments of the company) and at an external one (other companies on the supply chain such as packaging manufacturers, packers, retailers, logistics operators, etc.). Such a structure will facilitate understanding and integration of the different design requirements mentioned above. Desireably, it will also coordinate with those responsible (internally and externally) for decision making at the product design level and also at the level of the supply chain itself, and it will do so in a "dynamic" way (Olander-Roese and Nilsson 2009), not just because the product range and the environment change rapidly, but also to respond to the challenges mentioned in this section.
- Deployment of suitable assessment metrics that guide the process to select packaging design alternatives. Given that packaging is subject to a range of design requirements, there is also a wide range of metrics (and measurement techniques) associated with it. These metrics could include sales, costs (García-Arca et al. 2021), benchmarking

variables (comparison with the competition; Gelici-Zeko et al. 2012) or environmental impact (by applying techniques such as Life Cycle Assessment (LCA); ISO 14040 2006). Indeed, faced with the difficulties of assessing each design alternative objectively from a multifunctional perspective, different evaluation models have been developed that combine quantitative scales with qualitative ones. The most widely used of the latter is the Packaging Scorecard method (Olsmats and Dominic 2003) which companies such as IKEA or Walmart have adapted.

Technological challenges include:

- Selection of packaging materials, applying solutions that are particularly environmentally friendly; this approach not only affects the packaging itself proposed by the manufacturer (or packer) but also any additional packaging that the new electronic channel may require. Such a context would also envisage promotion of packaging materials (including fillers and cushioning) such as paper and card which would gradually substitute plastics without affecting to product protection. There would also be promotion of packaging materials that contain an increasing percentage of recycled materials.
- Selection of the range or breadth of the packaging system for an omnichannel setting. The question in this context would be how many formats, of what type, and of what dimensions are there? Dimensional decisions that allow efficient volumetric occupation between the various levels of the packaging system are especially complex and not well solved by agile simulation or calculation (algorithms framed within a "three-dimensional bin packing problem" or *3D-BPP*, considred *NP-hard*; Wu et al. 2010; García-Arca et al. 2021). Additionally, in e-commerce, the different combinations of products depending on the order increase the complexity of such decision making (Freichel *et al.* 2020).

  The problem lies in the fact that in order to define the most interesting volumes (associated with the most suitable packaging range), it is necessary to seek a certain balance between the economies of scale in purchasing each of the formats and the need to avoid increasing complexity (and decreasing productivity) in the picking process or reducing transport efficiency and sustainaibility; all this in a context of dynamic orders and a growing product range. In order to have an increased variety of volumes without increasing the number of formats, there is frequently recourse to boxes that can be die-cut at variable heights. Likewise, many companies are opting to substitute some boxes for envelopes (Amazon or Zara, for example).
- Correct implementation of the range of packaging formats (and types). Correct implementation ensures selection of the most suitable format from the range for each order involved. Currently, some companies such as Amazon are applying Machine Learning techniques to support decisions about which packaging (from the available range) is the best for each order.
- Automation of logistics processes. Nowadays, most logistics process automation has focused on how to speed up the movement of products in the various stages of order picking (before final packing). However, there are already some (though still not many) experiences of automation of the packing process itself, and these have even included tailoring the packaging type depending on demand (particularly for "envelope" type

packaging). Logically, the information and decision-making algorithms mentioned previously are key in this type of automation.

- Correct traceability of packaging throughout the supply chain. When operating on many channels (including the electronic one), it is necessary to monitor and trace more items (with fewer products) and more a more heterogeneous range throughout the supply chain (Zhang *et al.* 2016). The disruptive "Internet of Things" (IoT) or "Physical Internet" (PI) approach (www.physicalinternetinitiative.org) applied to the concept of "smart" packaging (Ahmed *et al.* 2018) is part of this framework; the European "MODULUSHCA" project is an example.

  In this future vision, goods would be packaged in environmentally friendly, standardised "smart boxes". These "smart boxes" equipped with RFID chips would be handled, stored, and transported in an integrated way (with a high level of automation) in loading units through shared facilities and open networks; this would require standardisation through the use of modular system (600 * 400 mm; ISO 3394) and reusable packaging. A first approach to such packaging is to be found in the proposal for removable, modular, and reusable plastic boxes ("M-box") proposed by Landschützer et al. (2015).

4 Conclusions

The huge explosion of e-commerce in the last few years has forced many traditional retailers to operate in different channels, approach named "omnichannel strategy". This has led to the emergence of new logistics challenges in the design and management of a sustainable supply chain, which logically affect one of their key elements: the packaging system. As it was commented in tne paper, e-commerce often makes it necessary to deploy an additional packaging ("express packaging"), which helps to group and protect the various products included in each order. This situation implies the potential increasing of the volume (and weight) of the new packages, affecting transport efficiency, the generation of waste, and the productivity of the picking process, among other negative impacts.

Thanks to the literature review and the analysis of cases carried out in research, it has been possible to detail and categorize three major types of challenge: configurational, structural, and technological. These challenges open future avenues for development in both the research sphere and the practitioner sphere, as it provides a useful guide for improving sustainability and competitiveness in supply chains through the packaging design.

References

Ahmed, I., et al.: An overview of smart packaging technologies for monitoring safety and quality of meat and meat products. Packag. Technol. Sci. **31**(7), 449–471 (2018)

Freichel, S.L., Wollenburg, J., Wörtge, J.K.: The role of packaging in omni-channel fashion retail supply chains - how can packaging contribute to logistics efficiency? Logist. Res. **13**(1), 1–20 (2020)

García-Arca, J., Prado-Prado, J.C., González-Portela, A.T.: Packaging logistics: promoting sustainable efficiency in supply chains. Int. J. Phys. Distrib. Logist. Manag. **44**(4), 325–346 (2014)

Garcia-Arca, J., Comesaña-Benavides, J.A., Gonzalez-Portela Garrido, A.T., Prado-Prado, J.C.: Methodology for selecting packaging alternatives: an "action research" application in the industrial sector. Cent. Eur. J. Oper. Res. **29**, 1427–1446 (2021). https://doi.org/10.1007/s10100-020-00724-3

Gelici-Zeko, M.M., Lutters, D., Klooster, T.R., Weijzen, P.L.G.: Studying the influence of packaging design on consumer perceptions (of dairy products) using categorizing and perceptual mapping. Packag. Technol. Sci. **26**(4), 215–228 (2012)

Hübner, A., Holzapfel, A., Kuhn, H.: Distribution systems in omni-channel retailing. Bus. Res. **9**(2), 255–296 (2016). https://doi.org/10.1007/s40685-016-0034-7

ISO 14040:2006. Environmental management—Life cycle assessment—Principles and framework. Edited by ISO (2006).

ISO 3394:2012: Packaging—Complete, filled transport packages and unit loads—Dimensions of rigid rectangular packages. Edited by ISO (2012)

Landschützer, C., Ehrentraut, F., Jodin, D.: Containers for the Physical Internet: requirements and engineering design related to FMCG logistics. Logist. Res. **8**(8), 1–22 (2015). https://doi.org/10.1007/s12159-015-0126-3

Olander-Roese, M., Nilsson, F.: Competitive advantage through packaging design? Propositions for supply chain effectiveness and efficiency. In: Proceedings of ICED 2009, the 17th International Conference on Engineering Design, Palo Alto, CA, USA, 24–27 August 2009 (2009)

Olsmats, C., Dominic, C.: Packaging scorecard–a packaging performance evaluation method. Packag. Technol. Sci. **16**(1), 9–14 (2003)

Pålsson, H., Pettersson, F., Hiselius, L.W.: Energy consumption in e-commerce versus conventional trade channels - insights into packaging, the last mile, unsold products and product returns. J. Clean. Prod. **16**, 765–778 (2017)

Pålsson, H.: Packaging Logistics. Understanding and Managing the Economic and Environmental Impacts of Packaging in Supply Chains. Edited by Kogan Page, London (2018)

Pålsson, H., Hellström, D.: Packaging logistics in supply chain practice – current state, trade-offs and improvement potential. Int. J. of Logist. Res. Appl. **19**(5), 1–18 (2016)

Regattieri, A., Santarelli, G., Gamberi, M., Mora, C.: A new paradigm for packaging design in web-based commerce. Int. J. Eng. Bus. Manag. **6**, 6–14 (2014)

Regattieri, A., Santarelli, G., Piana, F.: Packaging logistics. In: Zijm, H., Klumpp, M., Regattieri, A., Heragu, S. (eds.) Operations, Logistics and Supply Chain Management. LNL, pp. 273–303. Springer, Cham (2019). https://doi.org/10.1007/978-3-319-92447-2_13

Saghir, M.: Packaging Logistics Evaluation in the Swedish Retail Supply Chain, Lund (2002)

Taylor, D., Brockhaus, S., Knemeyer, A.M., Murphy, P.: Omnichannel fulfillment strategies: defining the concept and building an agenda for future inquiry. Int. J. Logist. Manag. **30**(3), 863–891 (2019)

Wang, F., Hu, Y.: Research on green express packaging design under the electronic commerce. Open J. Bus. Manag. **4**, 621–628 (2016)

Wu, Y., Li, W., Goh, M., de Souza, R.: Three-dimensional bin packing problem with variable bin height. Eur. J. Oper. Res. **202**(2), 347–355 (2010)

Zhang, Y., Liu, S., Liu, Y., Li, R.: Smart box-enabled product–service system for cloud logistics. Int. J. Prod. Res. **54**(22), 6693–6706 (2016)

Sentiment Analysis Model Using Word2vec, Bi-LSTM and Attention Mechanism

M. Jaca-Madariaga[1](✉), E. Zarrabeitia-Bilbao[1], R. M. Rio-Belver[2], and M. F. Moens[3]

[1] Industrial Organization and Management Engineering Department, Faculty of Engineering Bilbao, University of the Basque Country (UPV/EHU), 48013 Bilbao, Spain
maite.jacamadariaga@ehu.eus

[2] Industrial Organization and Management Engineering Department, Faculty of Engineering Vitoria-Gasteiz, University of the Basque Country (UPV/EHU), 01006 Vitoria-Gasteiz, Spain

[3] Department of Computer Science, KU Leuven, 3001 Heverlee, Belgium

Abstract. Within the interdisciplinary field of data science, this paper proposes a sentiment classification model applied to text, specifically tweets, using neural networks. To do that, after gathering and pre-processing the data, firstly, word2vec model is used to convert tweets into word vectors. Secondly, Bi-LSTM neural network is used to capture the semantic meaning of the text. Thirdly, attention mechanism is added to extract the most relevant words. Fourthly, a sigmoid function is used to achieve the emotion classification. Thus, after crossing each layer of the neural network, the model finally returns the result of the binary classification to detect the emotion of the social media text data. The presented model gives an accuracy of 84.12%, surpassing other existing models for this purpose.

Keywords: Sentiment analysis · Text mining · Twitter · Word2vec · Bidirectional LSTM · Attention mechanism

1 Introduction

Nowadays social networks have become commonplace in daily life, especially as they are a valuable source of information. Millions of posts containing large amounts of data are generated on a daily basis. Some are probably of little interest, however, it would be useful to know how to treat and process most of them that are of interest. Thus, within data science, analysing social network data can help companies in decision making [4], improving value and gaining a competitive advantage over competitors [14]. In this way, possessing social information about a certain topic may help to predict stock values and future sales within industry [2, 5, 12], which entails being an advantageous resource in Engineering Management. Added to this, it is also used in a wide variety of fields such as banking, healthcare, public sector, and hospitality, among others. All of these cases involve the sentiment analysis concept, a computational combination of natural language processing and text mining which tries to detect and study high-quality information from text, extracting the real meaning behind it and returning the emotion of the text [7, 9].

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 239–244, 2023.
https://doi.org/10.1007/978-3-031-27915-7_43

When analysing social media data, Twitter is a communication channel par excellence. Twitter is a microblogging service that allows its users to read and write text messages with a maximum length of two hundred and eighty characters called tweets and currently a significant information gathering tool for social research and predictions [13]. Therefore, the text data used in this research work are tweets, as they reflect the opinion that society has on a given topic by providing a large amount of information. One of the most challenging issues faced when working with social networks is that data are unstructured and heterogeneous. Machines generally find it more complicated to understand unstructured data, e.g., audio, raw audio, images or text (as in our case), as the data are not well defined, so there is precisely a need to recognize what exactly is in these data. Consequently, as shown in this work, certain deep learning models become useful resources to address these issues.

2 Objectives and Methodology

The aim of this scientific study is to present a model which produces a sentiment analysis of tweets using deep learning algorithms. In this work, artificial neural networks are used to process the tweets and achieve the goal of analysing the sentiment. Concretely, the neural networks used are Word2Vec, bidirectional long-short term memory (Bi-LSTM) and attention mechanism.

Figure 1 describes the designed process, explaining the methodology followed step by step to finally achieve the sentiment classification result. The model has been created and trained with Jupyter Notebook, connected with Python programming language as a kernel. Jupyter is a web-based interactive computing notebook environment where human-readable docs can be edited and run while describing the data analysis [8]. The data used in this model are from a dataset called Sentiment140 created by Alec Go, Richa Bhayani, and Lei Huang, at Stanford University [10]. Sentiment140 [11] contains 1,600,000 tweets extracted using the Twitter API and that have already had their sentiment classified as a positive or negative. There are 800,000 tweets of each classification type respectively; this means that the dataset is not skewed. After obtaining the data, tweets are pre-processed. In this step, the corresponding texts of tweets are converted to lower case, and URLs, usernames, consecutive letters, emojis and contractions are replaced and non-alphabets are removed. The following step is to split the data. Considering the size of the dataset, it has been divided into two datasets: the training dataset with 90% of the total data and the test dataset with the remaining 10%. Then, text has been tokenized and padded. To represent the text need as a vector, the Word2vec model [6] is used. Thus, an embedding layer has been constructed, in which tokens are vectorized using the aforementioned model. The resulting distributed representation of words only takes the word's semantic information into account, ignoring the sentiment information. Consequently, a neural network is needed, so in this case the output of the embedding layer becomes the input to the Bi-LSTM layer, which has been selected because it has been found to be the most accurate classifier [1]. Bidirectional long-short term memory (Bi-LSTM) is a combination of two LSTMs units. The first unit reads the input sentence in a forward manner, and the second unit reads it backwards. Then it concatenates the hidden states of each LSTM to process the final word [3].

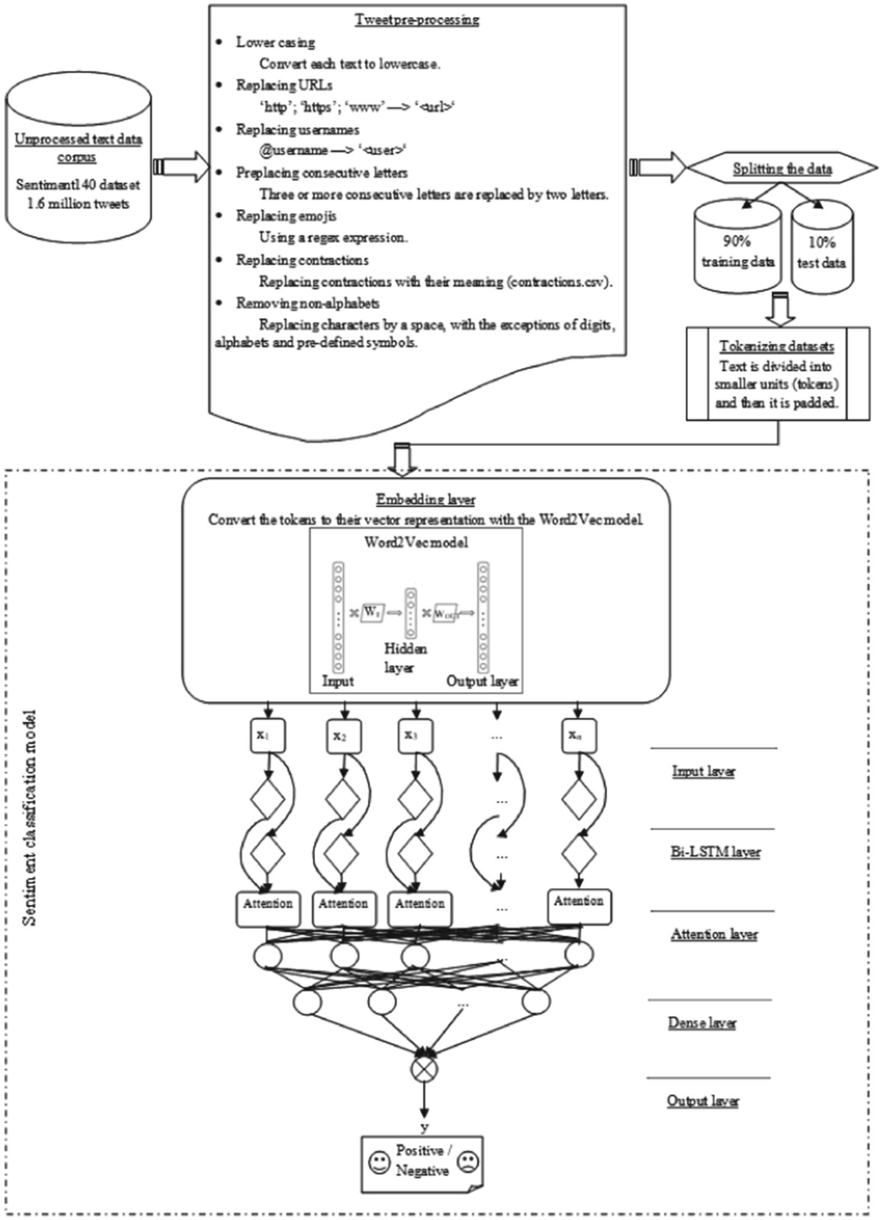


Fig. 1. Sentiment classification model for tweets using artificial neural network. Source: own elaboration

After the Bi-LSTM layer there is an attention layer. This layer is the one that improves the already previously existing model, since using self-attention mechanism, the key information of the text is extracted with the aim of focusing only on the key words of the text. Then, a GlobalMaxPooling1D layer downsamples the input representation by taking the maximum value over the time dimension. Finally, a fully connected dense layer with sigmoid function is used ascertain the positive or negative classification result. Figure 2 shows each layer of the model in detail.

```
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 embedding (Embedding)       (None, 60, 100)           6000000

 bidirectional (Bidirectiona  (None, 60, 200)          160800
 l)

 bidirectional_1 (Bidirectio  (None, 60, 200)          240800
 nal)

 seq_self_attention (SeqSelf  (None, 60, 200)          12865
 Attention)

 global_max_pooling1d (Globa  (None, 200)              0
 lMaxPooling1D)

 dense (Dense)               (None, 16)                3216

 dense_1 (Dense)             (None, 1)                 17

=================================================================
Total params: 6,417,698
Trainable params: 417,698
Non-trainable params: 6,000,000
_________________________________________________________________
```

Fig. 2. Details of sentiment model

3 Results and Discussion

The presented model is compiled with binary cross-entropy loss, Adam optimizer and accuracy evaluation metric, since the dataset is not skewed. After training through twelve epochs, the model gives an accuracy of 84.12%. Comparing the model with machine learning methods and other neural network structures [7, p. 3] the performance achieved here, in terms of accuracy, is highly improved. Even so, as shown in Fig. 3, the accuracy curve continues growing, which means that training for more epochs could yield better results.

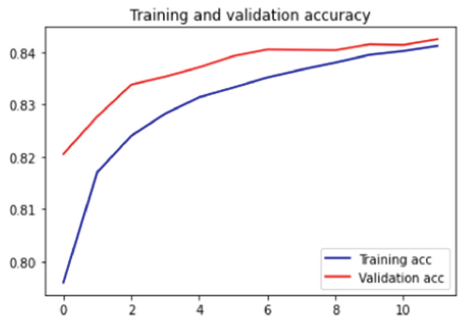


Fig. 3. Training and validation accuracy

Moreover, a confusion matrix has been created to understand how the model is performing on both classification types. The results show 42.50% of True Positive prediction and 41.90% of True Negative. It can be concluded that the model predicts more

False Positives (7.94%) than False Negatives (7.66%). So the model is somewhat biased towards predicting positive sentiment, although the difference between them is almost negligible.

4 Conclusion and Future Work

Neural networks are the latest trend in data science field, thereby this paper presents a neural network design to classify tweets by their sentiment. It tries to improve on results obtained by heuristic tools, because the problem with these is that although they can classify sentiment, it is possible that the same word, depending on the context, may have a positive sentiment or a negative sentiment. In this particular situation, there is no way to adjust this using heuristics tools, such as the VADER model, for example. However, by using neural networks, the model can be trained so that it learns from the context, resulting in an adequate classification for each occasion. Thus, the accuracy achieved with the presented model is 84.12%, which demonstrates high-quality performance in comparison with other existing methods.

As a future work, the proposed model is going to be applied to an unlabelled dataset of tweets to predict their emotion. Furthermore, the model structure can be used to determine any type of binary answer. So, in addition to tweets, classifying a product review or a comment left on a website would be also possible. Moreover, a true or false prediction could be made or, for example, detecting whether a news item is fake news or not. In addition to the aforementioned, the work can be extended to produce more types of classifications rather than just a binary result. Emotions could be divided through a ternary classification with positive, negative or neutral labels or even through a multi-class classification model designed according to the topic. And last but not least, a possible improvement for the present model has been detected: by training for more epochs than those made, probably achieving greater accuracy, seeing as how the accuracy curve is not yet flattened.

References

1. Chandra, S., Gourisaria, M.K., Harshvardhan, G.M., Rautaray, S., Pandey, M., Mohanty, S.N.: Semantic analysis of sentiments through web-mined Twitter corpus. In: ISIC 2021: International Semantic Intelligence Conference, 25–27 February 2021 (2021)
2. Chung, H., Shin, K.: Genetic algorithm-optimized long short-term memory network for stock market prediction. Sustainability **10**(10), 3765 (2018). https://doi.org/10.3390/su10103765
3. Elfaik, H., Nfaoui, E.H.: Deep attentional bidirectional LSTM for Arabic sentiment analysis in Twitter. In: 2021 1st International Conference on Emerging Smart Technologies and Applications, ESmarTA 2021, pp. 1–8 (2021). http://dx.doi.org/10.1109/esmarta52612.2021.9515751
4. Kraus, M., Feuerriegel, S.: Decision support from financial disclosures with deep neural networks and transfer learning. Decis. Support Syst. **104**, 38–48 (2017). https://doi.org/10.1016/j.dss.2017.10.001
5. Li, J., Bu, H., Wu, J.: Sentiment-aware stock market prediction: a deep learning method. In: 2017 International Conference on Service Systems and Service Management, pp. 1–6 (2017). https://doi.org/10.1109/ICSSSM.2017.7996306

6. Mikolov, T., Chen, K., Corrado, G., Dean, J.: Efficient estimation of word representations in vector space. In: 1st International Conference on Learning Representations, ICLR 2013 - Workshop Track Proceedings, pp. 1–12 (2013). https://doi.org/10.48550/arXiv.1301.3781
7. Nasukawa, T., Yi, J.: Sentiment analysis: capturing favorability using natural language processing. In: K-CAP 2003 (2003). https://doi.org/10.1145/945645.945658
8. Project Jupyter. https://jupyter.org/
9. Salloum, S.A., Al-Emran, M., Monem, A.A., Shaalan, K.: A survey of text mining in social media: Facebook and Twitter perspectives. Adv. Sci. Technol. Eng. Syst. J. **2**(1), 127–133 (2017). https://dx.doi.org/10.25046/aj020115
10. Sentiment140 - A Twitter Sentiment Analysis Tool. http://help.sentiment140.com/
11. Sentiment140 dataset with 1.6 million tweets, Kaggle. https://www.kaggle.com/kazanova/sentiment140
12. Sun, Z., Choi, T., Au, K., Yu, Y.: Sales forecasting using extreme learning machine with applications in fashion retailing. Decis. Support Syst. **46**(1), 411–419 (2018). https://doi.org/10.1016/j.dss.2008.07.009
13. Tyagi, V., Kumar, A., Das, S.: Sentiment analysis on Twitter data using deep learning approach. In: Proceedings - IEEE 2020 2nd International Conference on Advances in Computing, Communication Control and Networking, ICACCCN 2020, pp. 187–190 (2020). https://doi.org/10.1109/ICACCCN51052.2020.9362853
14. Wu, X., Zhu, X., Wu, G.-Q., Ding, W.: Data mining with big data. IEEE Trans. Knowl. Data Eng. **26**(1), 97–107 (2014). https://doi.org/10.1109/TKDE.2013.109

An Approach to Software Technology Selection for a Social Product Development Platform

Jordi Almendros Granero(✉), Juan José Alfaro Saiz, and Raul Rodriguez Rodriguez

Research Centre on Production Management and Engineering (CIGIP), Universitat Politècnica de València (UPV), Camino de Vera s/n, 46022 Valencia, Spain
jalmendros@cigip.upv.es, jalfaro@omp.upv.es, raurodro@upv.es

Abstract. This article will focus on selecting technologies for the INNOPROS platform. The employed technique for technology selection is an adaptation in order to improve productivity objectives. INNOPROS tries to tackle the Social Product Development (SPD) of Industry 4.0, where different players in a network interact to bring new products to the market. A series of challenges were initially presented for the project to fulfill, from which the functional requirements were obtained. With such requirements, a description of the decisions made during the project at the level of technology strategy is carried out. The conformance to specification has been improved thanks to the extra introspection performed and noticed by the stakeholders. Although quality is a very elusive concept and difficult to quantify, it is possible to observe an eager adaptation to the needs of its users.

Keywords: Technology selection · Social product development

1 Introduction

Nowadays, with the constant change of software technology, there is an increasingly wide range of possibilities for the realization of projects. In this article, we will focus on selecting technologies for the INNOPROS platform. The employed technique for technology selection is an adaptation in order to improve productivity objectives stated in [1]:

- To find the best frontend and backend technologies currently available in terms of productivity.
- To know the spectrum of functionalities available in frontend and backend technologies
- Determine which features are the most crucial when evaluating the capabilities of frontend and backend technologies in terms of productivity.

The use case for this includes a number of challenges inherited from the project proposal process. The outlined method is therefore limited to similar cases to the project.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 245–249, 2023.
https://doi.org/10.1007/978-3-031-27915-7_44

To begin with, we should familiarize ourselves with this platform. INNOPROS tries to tackle the Social Product Development (SPD) of Industry 4.0, where different players in a network interact to bring new products to market. It can generally be described as using social computing technologies, tools and media, influencing the product life cycle at any stage [2]. This may develop a core factor of success in innovation management, allowing a large number of participants to contribute to a particular co-creation initiative, hence enhancing the heterogeneity of knowledge stocks in the community [3]

A series of challenges were presented for the project to fulfill (Table 1). The objective of INNOPROS was to develop a framework to cover the main identified areas of supply chains to offer innovative and customized product-services. It promotes collaboration inside the product design and engineering stages.

Table 1. Challenges of INNOPROS project

Challenge identifier	Description
(C1) Product-service systems design	INNOPROS will contribute to the definition of a consistent approach and develop and apply some instruments for the design and development of reconfigurable and updatable product-services, taking into account modularity, value analysis and interoperability aspects
(C2) Innovative knowledge-based product-services	INNOPROS will remove barriers to the effective adoption of product-service in the supply chain context, providing a knowledge-based approach involving all the network partners in order to achieve a solution that responds to customer needs
(C3) Collaborative and user-centered design	INNOPROS proposes using a co-design software tool that will guide not only companies but also consumers within the design process and consolidate the specifications of the collaboratively designed new products-services
(C6) Open business models	INNOPROS proposes to convert conventional Enterprise Social Networks, which usually are used as an internal/external communication tool and, therefore, underused, into Enterprise Knowledge Management-based Open Innovation Social Networks. At the beginning of the co-creation value process, several stakeholders will constitute the OI network, facilitating end-user customers, suppliers, or external actors
(C10) Cloud computing platform	Hence INNOPROS will select and use a cloud-computing platform to support the primary activities related to the new products-services: Design, engineering, manufacturing, business models, market assessment and monitoring, control and management

The technology selection method can be of use for projects with similar circumstances. It can give an insight into why the system is composed in this way. The conditioning can be observed of the business requirements on the platform technologies. Also, it will conclude with thoughts on the quality of two of the fields that are currently considered most relevant within the software. These fields are the conformance to specifications and the meeting of customer needs [4].

2 Methodology

To obtain the requirements is necessary to be aware of the capabilities of an application. It is also essential to know how to discern when these capabilities operate. The resources available for the project and the dedication of its developers must be taken into account.

It is also convenient to consider the opinions and inputs of expert profiles that will use the application. In this sense, studies have been conducted on the effectiveness of elicitation techniques, concluding that structured interviews are one of the most effective techniques [5]. In the case of INNOPROS, interviews were done with design field experts that provided feedback for the product-service design process inside the platform.

Further, into the development, a brief Proof of Concept (PoC) was carried out for testing a possible market acceptance analysis tool. A PoC aims to verify if an idea can be created from a technical standpoint. It ensures that a statement is feasible and worth working on.

Once all this information is collected and with the challenges specified in (Table 1), an inference process is performed. The product will be the informational requirements. Once established, his functional requirements will be derived from technical analysis.

3 Platform's Technology Selection

The following describes the decisions made during the project at the level of requirements conception and technology selection. For this purpose, a diagram has been made separating the process in broad strokes (See Fig. 1).

The development team had the most experience using the String Boot framework.

In order to fulfill the first objective (To find the best frontend and backend technologies currently available in terms of productivity) had an advantage and hence was selected as our preferred option. For the frontend, was prioritized the second objective (To know the spectrum of functionalities available in frontend and backend technologies) and Thymeleaf was used instead of other more "outdated" already used alternatives.

To meet Challenge 10 (C10 - Table 1), a cloud computing platform is requested to perform the various activities to support the development of product-services. Many organizations of all sizes have already switched to this type of platform. There have already been proceedings with success stories of Cloud Computing Technology (CCT) applications in small companies [6].

Modularity provides flexibility in deployment for updates, development focus and protection against general failures. For this, containers give an ideal execution environment for different applications by sharing binaries, libraries and even the same operating system if required. Containers are also helpful for deployments and distribution

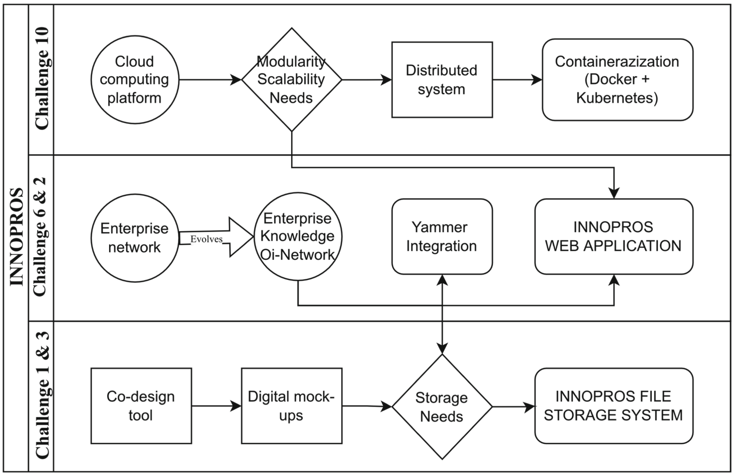


Fig. 1. INNOPROS platform's origins

in computing environments [7]. Therefore was decided to use Docker containers for INNOPROS Platform. Additionally, these containers can be used alongside Kubernetes to leverage their benefits.

Challenge 6 (C6 - Table 1) mentions the intention to evolve Enterprise Social Networks into Enterprise Knowledge Management-based Open Innovation Social Networks. A web application will be created to consolidate the interaction between the parties involved in developing products and services.

Finally, with Challenge 3 (C3 - Table 1) and Challenge 1 (C1 - Table 1), a co-design tool is requested to be included in the digital design module. To complete its functionality, data storage in file format was required. It was decided to implement a file storage service named INNOPROS FSS. This implementation was done using Nextcloud Files and fully customizing it to meet our needs.

4 Conclusions

It is good to consider that a technology strategy or an advanced one might not be enough. It must be transformed into technological capability and technological management capability. This will enable innovation success and promote organizational performance [8]. However, without an adequate strategy, it will be hard to fulfill the transformation.

It was not effortless to find the right fit for the platform. Literature shows that it is well worth the analysis process from a time dedication point of view. The experience gained may be of use in future projects. New developments in software technologies will be compared with those already in use. These past technologies will yield value clarifying the new advancement capabilities.

Everyone who invests in technology hopes to generate a return on investment or provide value. One essential step for this is to understand your processes. Revise software and technology implementation plans not only to accommodate existing processes but to think about how you might change them once your new tools are in place.

The methodology goals, the mentioned techniques and proposed challenges made an easier technology selection process. The conformance to specification has been improved thanks to the extra introspection performed and noticed by the stakeholders. Although quality is a very elusive concept and difficult to quantify, it is possible to observe an eager adaptation to the needs of its users.

Acknowledgements. This paper is part of the INNOPROS project (Grant PID2019-109894GB-I00) funded by MCIN/AEI/https://doi.org/10.13039/501100011033.

References

1. Koder, M.: Increasing full stack development productivity via technology selection (2021)
2. Thames, L., Schaefer, D.: Software-defined cloud manufacturing for industry 4.0. Procedia CIRP **52**, 12–17 (2016). https://doi.org/10.1016/J.PROCIR.2016.07.041
3. Piller, F., Vossen, A., Ihl, C.: From social media to social product development: the impact of social media on co-creation of innovation
4. Berander, P., Damm, L.-O., Eriksson, J., et al.: Software quality attributes and trade-offs. Blekinge Institute of Technology **97**, 19 (2005)
5. Davis, A., Dieste, O., Hickey, A., et al.: Effectiveness of requirements elicitation techniques: empirical results derived from a systematic review. In: Proceedings of the IEEE International Conference on Requirements Engineering, pp. 179–188. IEEE Computer Society (2006)
6. Attaran, M., Woods, J.: Cloud computing technology: improving small business performance using the Internet. J. Small Bus. Entrepreneurship **31**, 495–519 (2018). https://doi.org/10.1080/08276331.2018.1466850
7. Syed, M.H., Fernandez, E.B., et al.: The software container pattern. Florida Atlantic University (2015)
8. Hao, S., Yu, B.: The ımpact of technology selection on ınnovation success and organizational performance **3**, 366–371 (2011). https://doi.org/10.4236/ib.2011.34049

The Impact of Robotics Integration in Industrial Processes on the Circular Economy

Germán Arana-Landín[1](✉), Sergio Oliveira-Lizarribar[2], Iker Laskurain-Iturbe[1,2], and Alfredo Suárez González[1,2]

[1] Escuela de Ingeniería de Gipuzkoa, Universidad del País Vasco, 20018 Donostia-San Sebastián, Spain
{g.arana,iker.laskurain}@ehu.eus

[2] Fundación Tecnalia Research and Innovation, Paseo Mikeletegi, 7 - Parque Tecnológico, 20009 Donostia-San Sebastián, Spain
alfredo.suarez@tecnalia.com
http://sergio.tecnalia.com/

Abstract. Robotics is one of the technologies associated with the technological revolution that industry is undergoing, Industry 4.0, which must evolve in terms of sustainability. In the academic literature, many studies analyze the consequences of its integration in industrial processes related to economy, quality and/or safety, but those that analyze its impact on the circular economy are scarce. Therefore, a multiple case study of innovative integrations of robotics in industrial processes and their impact on circular economy indicators has been carried out. The results show that robotics has a very important potential impact on the circular economy. This influence is highly variable depending of the type of application and the way of adaptation of the technology to the specific case. However, in the design of processes that integrate robotics into industrial processes, environmental aspects are often not taken into account or environmental indicators are considered as secondary indicators. These results can be particularly relevant for Public policy makers and businesses managers in order to pave the way towards meeting the Sustainable Development Goals by 2030.

Keywords: Robotics · Circular economy · Sustainability · Environment

1 Introduction

The Circular Economy (CE) has emerged as a new economic model for sustainable development based on the maximization of the use of all available resources [1]. This new paradigm obliges companies to work to reduce as much as possible the consumption of material resources that enter their processes, as well as to reduce or eliminate the negative results generated in the system, such as emissions and waste. To achieve these objectives, it is necessary to work on the other "R"s that are pointed out in the different CE models existing in the literature. The most commonly "R"s used are Reuse, Recovery and Recycling [2].

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 250–254, 2023.
https://doi.org/10.1007/978-3-031-27915-7_45

To improve CE performance, companies must take advantage of the technological transformation that is occurring around them at an ever-increasing speed. Robotics, defined as the interaction between robots being able to work safely with humans, even learning from them [3], could play a fundamental role and generates multiple opportunities that should be analyzed in business and academia fields [4].

Taking into account this background, the objective of this paper is focused on analyzing how robotics can influence these 5Rs of CE. With this objective in mind, the following section presents the literature review, followed by the methodological section, the results and the discussion and conclusions.

2 Literature Review

In the academic literature, the influence of robotics on CE is scarce. Specifically, in relation to the resource consumption, some articles highlight the importance of integrating robotics with other technologies such as big data and cloud manufacturing factors in production systems, pointing out that this combination of technologies contributes to increasing efficiency in the use of materials and energy [4, 5]. Furthermore, the ability to influence on the reuse, recovery and recycling of robotic-based sorting systems in waste management is highlighted. They are increasingly used in sorting lines and can improve these 3 Rs, for example, by performing heavy physical sorting work or working in areas not suitable for human intervention (noise, dust, dirt, pollutants, etc.) [5]. With respect to waste and emissions management, Robotics is considered as a way to enable better end-of-life of products or to extend their life and generate less waste [6–9].

3 Methodology

After a review of the literature, the purposes, objectives, and research questions were defined. A multicase study was designed to obtain a greater penetration and understanding of the subject studied. The selected case studies were intended to be informative, to be innovative (participating in different editions of the BIND 4.0 program [4]) and to answer the research questions. An individual analysis per project and a cross-analysis were carried out. The protocol for data collection and analysis involved examining, categorizing, tabulating and reviewing the evidences, in an attempt to identify common patterns of behavior, and determine the connection between the data and the research objectives [6]. The information obtained from the report and the literature review were contrasted and triangulated using an item scale with 7 graduation levels from — to +++ to prepare the final report [6]. The construct validity of the research and its reliability were ensured by the development and application of a single research protocol. This was based on the construction of the theoretical framework, the use of multiple sources of evidence, the study of the chain of evidence and an analysis of the research data from different perspectives [6].

4 Results

In total 5 projects were analyzed to clarify unresolved issues and to reinforce or even reject previous conclusion of the literature using as main sources of evidence, direct communication with managers and technicians and internal documents (real cases, applications, reports, memories of the I4.0 projects…) [10]. The technology developers are innovative micro-companies, that have implemented their technological developments in very large companies. Table 1 presents these projects with fictitious names and the technologies that have been considered fundamental in the projects in addition to Robotics. In two cases robotics has been considered the only main technology but in the rest of the projects it has been integrated with Artificial Intelligence, Additive Manufacturing, Internet of Things and/or Virtual/Increased Reality. In addition, the sectors in which the applications of the projects have been developed are presented.

Considering the opinion of the managers and technicians and the documentation that support their explanations, in relation to the consumption of resources, reductions in material consumption have been detected in 4 of the 5 projects, although these have not been insignificant, see Table 2. With regard to energy, there is not the same degree of agreement. In the Ulia and Aitxuri projects, the integration of robots is linked to an improvement in energy efficiency, very high and high respectively, which is linked to a significant improvement in productivity and a reduction in process errors that prevent an increase in consumption due to remanufacturing. Finally, the influence of robotics on water consumption is considered to be slight or negligible in all projects.

Table 1. Main projects analyzed.

Project	Technologies	Application sector
Ulia	Artificial Intelligence	Automotive and aeronautics
Urgul	—	Food industry
Arlegor	Artificial Intelligence Additive Manufacturing, Internet of Things	Medical image diagnosis
Mendiola	Virtual/Increased Reality	Advanced assembly
Aitxuri	—	Machine tools

Regarding to the reuse, recovery and recycling, the project manager of Mendiola highlights the capacity to separate and classify the components allowing to increase the recovery and, when it is not possible, to prepare the waste in a way that facilitates their recycling. These aspects are also highlighted in the Arlegor project but are valued to a lesser extent, see Table 3. In relation to waste generation, the Ulia Project has achieved a significant reduction in waste, mainly due to a better use of raw materials and a reduction in defective products. Finally, in the Urgul Project, a reduction in emissions has been observed. The extraction of dust and toxic fumes by the robots facilitates subsequent filtering and reduces the consequences of emissions.

Table 2. Main influences detected in relation to resource consumption

Project	Materials	Energy	Water	Related aspect detected
Ulia	++	+++	+	Red. Manuf. Errors, Productivity improv.
Urgul	+	+	+	Improv. Process control
Arlegor	+	+	o	Reduct. Stock, Improv. Eficiency
Mendiola	o	o	o	Red. Manufacturing errors
Aitxuri	+	++	o	Red. Manuf. Errors, Productivity improv.

Note: o No influence, + low positive influence, ++ medium positive influence +++ high positive influence.

Table 3. Main influences detected in relation to waste management

Project	Reuse	Recovery	Recycle	Waste	Emissions	Related aspect detected
Ulia	+	+	+	+++	+	Red. of defective products
Urgul	+	+	+	+	+++	Extracts & filters toxic fumes
Arlegor	++	++	++	+	++	Own production, less transport
Mendiola	+	+++	+++	o	+++	Separ. & classif. Components
Aitxuri	o	o	o	+	o	Increasing tool life

Note: o No influence, + low positive influence, ++ high positive influence +++ Very high positive influence.

5 Discussion and Conclusion

In a few studies in academic literature, Robotics is considered as one of the technologies belonging to Industry 4.0 that has the greatest impact on the CE [4]. In this research, it has been possible to contrast some previous studies about how Robotics can have a positive influence on the 8 indicators of CE analyzed: materials consumption [4, 5], energy consumption [4, 5], water consumption, reuse, recovery, recycling [6, 9], waste generation [6, 8, 9] and emission generation [4, 6]. However, it does not influence all indicators in the same way or to the same extent. The influence varies a lot depending on the type of application and the way of adaptation of the technology to the specific case. Globally, the most influenced indicator has been the emissions generation and, conversely, the least influenced indicator has been water consumption. However, only in one case environmental aspects have been taken into account in the process of integrating robotics into industrial processes. In the rest of the cases, environmental issues are either not analyzed or not considered important. These results are not in line with some researches of the literature that explain the importance of certain CE indicators in the adoption of the technology [3, 6–9].

Considering the potential impact of Robotics on companies and their environmental performance, not only economic or quality management indicators, but also indicators related to CE, sustainability should become a priority objective for both companies and public administrations, which should foster programs that contribute to the integration of technologies, such as robotics, in companies in conjunction with sustainable development objectives.

References

1. Lopes de Sousa Jabbour, A.B., Jabbour, C.J.C., Godinho Filho, M., Roubaud, D.: Industry 4.0 and the circular economy: a proposed research agenda and original roadmap for sustainable operations. Ann. Oper. Res. **270**(1–2), 273–286 (2018). https://doi.org/10.1007/s10479-018-2772-8
2. Jouvet, P.A., de Perthuis, C.: Green growth: from intention to implementation. Int. Econ. **134**, 29–55 (2013)
3. Rosa, P., Sassanelli, C., Urbinati, A., Chiaroni, D., Terzi, S.: Assessing relations between Circular Economy and Industry 4.0: a systematic literature review. Int. J. Prod. Res. **58**(6), 1662–1687 (2020)
4. Laskurain-Iturbe, I., Arana-Landín, G., Landeta-Manzano, B., Uriarte-Gallastegi, N.: Exploring the influence of industry 4.0 technologies on the circular economy. J. Clean. Prod. **321**, 128944 (2021)
5. Herterich, M.M., Uebernickel, F., Brenner, W.: The impact of cyber-physical systems on industrial services in manufacturing. Procedia CIRP **30**, 323–328 (2015). https://doi.org/10.1016/j.procir.2015.02.110
6. Sarc, R., Curtis, A., Kandlbauer, L., Khodier, K., Lorber, K.E., Pomberger, R.: Digitalisation and intelligent robotics in value chain of circular economy oriented waste management–a review. Waste Manag. **95**, 476–492 (2019)
7. Caggiano, A.: Cloud-based manufacturing process monitoring for smart diagnosis services. Int. J. Comput. Integr. Manuf. **31**(7), 612–623 (2018). https://doi.org/10.1080/0951192X.2018.1425552
8. Álvarez-de-los-Mozos, E., Rentería-Bilbao, A., Díaz-Martín, F.: WEEE recycling and circular economy assisted by collaborative robots. Appl. Sci. **10**(14), 4800 (2020)
9. Daneshmand, M., Noroozi, F., Corneanu, C., Mafakheri, F., Fiorini, P.: Industry 4.0 and prospects of circular economy: a survey of robotic assembly and disassembly. Int. J. Adv. Manuf. Technol. **124**, 2973–3000 (2022). https://doi.org/10.1007/s00170-021-08389-1
10. Miles, M.B., Huberman, A.M., Saldaña, J.: Qualitative Data Analysis: A Methods Sourcebook, 3rd edn (2014)
11. Golafshani, N.: Understanding and validity in qualitative research. Qual. Rep. **8**(4), 597–607 (2003). https://doi.org/10.17763/haer.62.3.8323320856251826

Effects of the Inclusion of Life Cycle Thinking in the ISO 14001

Beñat Landeta-Manzano[1], Germán Arana-Landín[2(✉)], Ruben Jimenez-Redal[1], and Naiara Uriarte-Gallastegi[1]

[1] Universidad del País Vasco, Escuela de Ingeniería de Bilbao, Bilbao, Spain
{benat.landeta,ruben.jimenez,naiara.uriarte}@ehu.eus
[2] Universidad del País Vasco, Escuela de Ingeniería de Gipuzkoa, 20018 Donostia-San Sebastian, Spain
g.arana@ehu.eus

Abstract. ISO 140001 is the environmental management standard that has had the greatest diffusion worldwide. In its last update in 2015, it included product life cycle thinking, so that by 2018 all certified companies should include product life cycle thinking management in their management systems. Taking this fact into account, we compared the influence of ISO 14001 certification on the inclusion of eco-design practices in the management of a sample of 1951 large companies, which included 49.8% of certified companies. The results show that certified companies have a higher propensity to include eco-design practices in their management, before the process of updating the standard and during the three-year period that companies have had to update their systems to the new version. However, it has also been found that the proportion of companies that develop eco-design practices is very low among large companies that are usually the driving companies. Public administrations should take note of this fact in order to design programs to promote the integration of these practices, and thus, contribute to meeting the objectives of sustainable development.

Keywords: ISO 14001 · Eco-design practices · Sustainability

1 Introduction

The fundamental aim of the ecodesign should be the maximization of the value of the product in a sustainable way, while minimizing its negative impact [1]. To achieve the eco-design objectives, eco-design activities must be integrated into the strategic management and daily operations of companies in a dynamic process of continuous improvement of environmental performance, otherwise they will only be one-off improvements of limited scope [2]. To make a modest first approach many companies have opted for the use of manuals and guides that develop in a practical way basic procedures aimed at improving specific product parameters [3]. In addition, numerous methodologies aimed at undertaking the keys to successfully integrating ecodesign into a single tool have been designed in the las t decades [4]. These include environmental management standards based on processes of continuous improvement of ecological and economic indicators

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 255–260, 2023.
https://doi.org/10.1007/978-3-031-27915-7_46

of a product and based on the systematic integration of eco-design into the company's strategies and practices throughout the life cycle [5]. An example is the ISO 14006:2020 eco-design management standard that allows developing schemes for product design and development [6]. These environmental management standards (EMS) developed by ISO have been widely accepted in the business environment but the most widely used is ISO 14001 [7]. An EMS based on the ISO 14001 is aimed at planning a company's operational and administrative activities for managing its environmental aspects and processes [8]. The new version of ISO 14001 standard, in sections, 6.1 and 8.1 include actions to address risks and opportunities, product-oriented operational planning and control. In addition, it is explicitly cited to do so from a life cycle perspective [9]. In this sense, some authors point out that a bridge is built between management systems and the integration of eco-design practices based on an extended life cycle perspective (Life Cycle Thinking) [10]. This fact opens the door to a more integrated and structured eco-design activities within companies [10].

This aspect was not included in the previous standard. However, the degree of adoption of these eco-design-oriented practices by companies certified with the ISO 14001:2015 standard has not been sufficiently analyzed in the literature. Considering this gap in the literature, in this research we have focused on the level of eco-design practices in ISO 14001 certified and non-certified companies. For this purpose, an analysis of the existing literature is presented below. Subsequently, the research methodology used is presented. In Sect. 3, the results of the research are analyzed and, in Sect. 4, conclusions of interest to professionals in the sector and academic specialists are presented.

2 Methodology

The methodology used in this research is quantitative based on information obtained from the ASSET 4 database. It is a database developed by Thomson Router and provides investment research information on economic, environmental, social, and governance aspects of corporate performance. Specifically, for this research the information obtained was focused on three main groups of variables: ISO 14001 certification, characteristics of industrial companies and use of eco-design practices.

In relation to ISO 14001 certification it was checked whether the industries were certified at the end of each of the years corresponding to the period 2014 to 2018. Secondly, access was obtained to the general characteristics of the companies. Specifically, their size was analysed according to the number of workers, their sectoral classification and their location. Finally, the information on the application of eco-design practices in each of the years of the period 2014 to 2018 was checked. In order to obtain information on the application of eco-design practices by the companies, they had to respond and/or present evidences in relation to the question:

Does the company report on specific products which are designed for reuse, recycling or the reduction of environmental impacts?

A sample of 1951 medium and large companies in sectors where the environmental performance of the resulting product is relevant and there is a sufficient number of certified and non-certified companies to be able to carry out the study. In order to homogenize the characteristics of the companies, small companies with less than 50 employees were discarded. The study focused on companies that manufacture products with a more relevant environmental impact (Table 1). To carry out this sector classification, Thomson Reuters Business Classification (TRBC) has been used for the industry classification because it is appropriate in relation to the objectives of the research. Specifically, it organizes firms based on similar production processes or products [11]. Companies belonging to sectors where the proportion of certified companies is very low and/or do not develop environmental practices related to the environmental performance of the product such as Energy, Financials, Telecommunication services and Utilities have been excluded from the study. In Table 1, it can be seen that at a sector level there are differences in the proportion of companies certified according to the ISO 14001 standard in the sectors analysed. Specifically, among the industrial companies there is a higher proportion of companies certified in the five periods and in the Consumer cyclicals subsector a lower proportion. Finally, companies were classified according to their location. Significant differences were detected in the proportion of certified companies according to their geographical location. Specifically, Table 1 shows that the proportion of companies certified in accordance with ISO 14001 is higher in the European Union and Japan and lower in Oceania and the American continent.

Table 1. Evolution of ISO 14001 certification according to sectorial classification and location

	N	2014	2015	2016	2017	2018
Basic Materials	397	0.514	0.514	0.534	0.554	0.549
Industrials	438	0.605	0.610	0.642	0.637	0.655
Consumer cyclicals	481	0.274	0.272	0.285	0.297	0.318
Consumer non cyclicals	206	0.461	0.437	0.466	0.481	0.485
Healthcare	180	0.333	0.361	0.372	0.394	0.400
Technology	249	0.534	0.550	0.566	0.570	0.570
European Union	170	0.747	0.759	0.777	0.771	0.782
Rest of Europ	247	0.599	0.575	0.583	0.595	0.599
USA	432	0.315	0.308	0.324	0.326	0.331
Rest of America	127	0.307	0.291	0.315	0.331	0.331
Japan	263	0.741	0.741	0.753	0.741	0.761
Rest of Asia–Pacific	447	0.389	0.407	0.434	0.465	0.481
Africa	65	0.523	0.539	0.585	0.585	0.554
Oceania	200	0.180	0.205	0.220	0.235	0.235
Total	1,951	0.456**	0.458**	0.479**	0.489**	0.498**

$**p < 0.01$ The Anova test was carried out via trans-formation of the binomial function for calculation based on proportions and the number of firms who are certified in each region, and the expectancy inter-val of certified firms in the region.

The characteristics of the sample were key in designing the research process. The analysis was developed using SPSS version 27 statistical software. Specifically, the proportion of companies developing eco-design practices aimed at improving environmental product performance was first compared between the groups of certified and non-certified companies. Secondly, we compared the proportions of companies that, not having implemented the practices in 2014, have started to implement them in the period 2014–2018 in the samples of certified and non-certified companies. Each of these analyses was divided into two phases in which the data were stratified according to sector and geographical location. In addition, a statistical analysis was integrated into these phases to check whether there were significant differences in the dissemination of eco-design practices according to the sector to which the companies belonged and according to their geographical location.

3 Results

The proportion of certified companies applying these practices is higher than the non certified ones. At a sectoral level, an exception is detected and it is for the case of Consumer non cyclicals in the period of 2018. At a geographical level, exceptions are detected in Rest of America, Africa and Oceania for the case of Eco-design products.

Likewise, there is a greater proportion of certified companies that begin to implement eco-design practices in the period 2014–2018. However, in the sector analysis only in the Basic materials sector significant differences can be appreciated. In the geographical analysis, only in the USA is it detected that the proportion of certified companies that start to apply these practices is higher. At the sectoral level, it is observed that there are sectoral differences in the distribution by sector. Specifically, the low proportion existing in the Industrials and Consumer non cyclicals sector stand out. Among the Consumer Cyclicals companies, the proportion of companies that develop eco-design practices is greater. On a geographical level, the high proportions of companies that apply eco-design products practices in European Union and Japan is noteworthy. Specifically, among the companies certified 0.534% and 0.530% respectively in 2018. In contrast, in Oceania, Africa and Rest of America, the proportions are significantly lower for both tools (Table 2).

Table 2. Diffusion of eco-design practices according to sectorial classification and location

	2014		2018		2014–2018	
	NC++	Cert.++	NC++	Cert.++	NC++	Cert.++
Basic Materials	0.047**	0.270**	0.078**	0.336**	0.047*	0.102*
Industrials	0.075**	0.276**	0.079**	0.259**	0.023	0.026
Consumer cyclicals	0.086**	0.424**	0.108**	0.490**	0.049	0.091
Consum. non cyclicals	0.054**	0.200**	0.160	0.260	0.072	0.116
Healthcare	0.033**	0.250**	0.046**	0.319**	0.025	0.100
Technology	0.009**	0.414**	0.101**	0.457**	0.060	0.128
Location	NC++	Cert.++	NC++	Cert.++	NC++	Cert.++
European Union	0.140**	0.504**	0.108**	0.534**	0.046	0.063
Rest of Europ	0.061**	0.216**	0.162	0.243	0.081	0.068
USA	0.098**	0.331**	0.142**	0.378**	0.051*	0.103*
Rest of America	0.023	0.103	0.059*	0.191*	0.034	0.103
Japan	0.103**	0.467**	0.111**	0.530**	0.044	0.093
Rest of Asia–Pacific	0.033**	0.178**	0.069**	0.219**	0.048	0.081
Africa	0.032	0.118	0.035	0.139	0.032	0.088
Oceania	0.018	0.056	0.033*	0.128*	0.018*	0.083*
Total	0.059**	0.307**	0.096**	0.345**	0.045**	0.083**

**$p < 0.01$ in one-tailed tests; *$p < 0.05$ in one-tailed tests; cell entries are standardized coefficients. The Chi-squared unilateral independence test was carried out via transformation of the binomial function for cal-culation based on the proportion of certified compa-nies applying these practices and the expected pro-portion of non-certified companies applying them. ++$p < 0.01$ in two-tailed tests; The Chi-squared test based on the proportion of certified and non-certified companies in each sector or location that are ex-pected to apply these practices.

4 Conclusions

One of the fundamental changes included in the revision of the ISO 14001 standard in 2015 was life cycle thinking. This thinking requires the inclusion of environmental criteria from the product design phase and the development of practices linked to product ecodesign. However, the study found that before the publication of the new version in 2015, certified medium-large companies already included more eco-design practices in their management than non-certified companies in the sectors analyzed; Basic Materials, Industrials, Consumer cyclicals, Consumer. Non-cyclicals, Healthcare and Technology. In the period from 2014 to 2018, the proportion of companies that have integrated eco-design practices into their management has also increased to a greater extent, so that, on average, this target of updating the standard has been met.

However, it has been found that the proportion of companies that develop this type of practice is very low among large companies, which are the ones that traditionally act as the driving force behind this type of change. For these reasons, in order to achieve the sustainable development objectives established in the 2030 agenda, a change in the way of doing things at the business and social level is necessary and should be promoted by different parties. Using different tools, public and private institutions should encourage the development of these practices among large companies so that they can develop a traction effect, among the rest of the companies. The promotion of public-private research so that companies can have more ecodesign tools at their disposal, the inclusion of different kind of green taxes or tax deductions or the definition of more demanding laws on environmental issues could be some examples.

References

1. Dahmani, N., Benhida, K., Belhadi, A., Kamble, S., Elfezazi, S., Jauhar, S.K.: Smart circular product design strategies towards eco-effective production systems: a lean eco-design industry 4.0 framework. J. Clean. Prod. **320**, 128847 (2021)
2. García-Sánchez, I.M., Gallego-Álvarez, I., Zafra-Gómez, J.L.: Do the ecoinnovation and ecodesign strategies generate value added in munificent environments? Bus. Strategy Environ. **29**(3), 1021–1033 (2020)
3. Rodrigues, J., et al.: Life cycle assessment of agromining chain highlights role of erosion control and bioenergy. J. Clean. Prod. **139**, 770–778 (2016)
4. Boucher, J., Evequoz, P., Friot, D., Mayer, S., Van Lierde, N.: Adopting a life cycle perspective through ISO14001: a game changer. OVAM (2017)
5. Arana-Landin, G., Heras-Saizarbitoria, I., Cilleruelo-Carrasco, E.: A case study of the adoption of a reference standard for ISO 14006 in the lift industry. Clean Technol. Environ. Policy **14**(4), 641–649 (2012). https://doi.org/10.1007/s10098-011-0427-4
6. Landeta-Manzano, B., Arana-Landín, G., RuizdeArbulo, P., DíazdeBasurto, P.: Longitudinal analysis of the eco-design management standardization process in furniture companies. J. Ind. Ecol. **21**(5), 1356–1369 (2017)
7. ISO: The ISO survey of certifications 2018. International Organization for Standardization, Geneva (2019)
8. Brambila-Macias, S.A., Sakao, T.: Effective ecodesign implementation with the support of a lifecycle engineer. J. Clean. Prod. **279**, 123520 (2021)
9. International Standard Organization (ISO): Environmental Management System – Requirements with Guidance for Use. ISO 14001:2015, Geneva (2015)
10. Charter, M., Polonsky, M.J. (eds.): Greener Marketing: A Global Perspective on Greening Marketing Practice. Routledge (2017)
11. Roman, E., Ulicny, B., Du, Y., Poduval, S., Ko, A.: Thomson Reuters' solution for triple ranking in the FEIII 2017 challenge. In: Proceedings of the 3rd International Workshop on Data Science for Macro-Modeling with Financial and Economic Datasets, May 2017

A Pruning Tool for the Multi-objective Optimization of Autonomous Electrification Systems

Antonin Ponsich[1](✉), Bruno Domenech[1], Laia Ferrer-Martí[2], Marc Juanpera[1], and Rafael Pastor[1]

[1] Department of Management, Universitat Politècnica de Catalunya – Barcelona Tech, 08028 Barcelona, Spain
antonin.sebastien.ponsich@upc.edu

[2] Department of Mechanical Engineering, Universitat Politècnica de Catalunya – Barcelona Tech, 08028 Barcelona, Spain

Abstract. Despite global progresses worldwide, many people living in rural areas still have no electricity. Autonomous generation systems based on renewable energy and microgrid distribution represent a viable alternative, but their design is complex. In a recent work, the design of electrification systems is tackled through a multi-objective optimization (MO) approach that simultaneously minimizes the system cost and maximizes the energy and power supplied to consumers. However, hundreds of non-dominated solutions may result from this MO process, hindering the subsequent task of decision-makers confused by too many alternative configurations. In this framework, this work proposes a computational tool based on ε-dominance and cluster analysis to prune the set of non-dominated solutions to a manageable number. The numerical experiments highlight that, regardless the size of the community to be electrified, the proposed tool successfully determines a reduced number of diverse trade-off alternatives, among which decision-makers are able to comprehensively select their preferred option.

Keywords: Rural electrification · Multi-objective optimization · Archive pruning

1 Introduction and Motivations of the Work

Among the 900 million people currently lacking access to electricity [1], most of them live in rural and isolated areas, far from a possible connection to national grids. In this context, stand-alone electrification systems based on renewable energies (solar and wind, mainly) represent a promising alternative with successful implementations all over the world. The design of such systems involves determining the location and size of power generation equipment, as well as the wiring connections for microgrid-based distribution, so that users' demands (in terms of energy and power) are met. In this perspective, most works use a single-objective optimization approach, which determines the minimal cost

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 261–265, 2023.
https://doi.org/10.1007/978-3-031-27915-7_47

configuration of the electrification system, considering energy and power demands as hard constraints.

This strategy has two drawbacks. First, the preliminary task of user demand estimation is complicated because, in particular in rural contexts, it may be the first time that populations have access to electricity services. Therefore, evaluating their needs, expressed as abstract concepts (power and energy), might result confusing. Also, the access to electricity may generate new habits regarding electricity usage, making the proper evaluation of demand more complex. On the other hand, due to the combinatorial nature of the optimization problem, the demand constraints are unlikely to be saturated at the optimal solution, meaning that the system is often overfitted.

The consequence of these two issues is that the (unique) electrification system obtained with single-objective approaches is designed on the basis of inaccurate demand estimations and is often not fitted to user real needs. In particular, it might be possible to design much cheaper systems providing almost equal energy/power supplies, or reversely, slightly more expensive systems that may cover much higher demands.

In a former work [2], an alternative design process based on multi-objective optimization (MO) was proposed, by simultaneously minimizing the total cost and maximizing the energy and the power supplied to every user. The aim is to provide decision-makers with several system configurations representing different trade-offs among these three optimized objectives. Indeed, a solution technique based on ε-constraints proved to be able to produce a set of non-dominated solutions lying within energy/power ranges defined around approximate nominal values (whose accuracy is no longer required). However, computational tests performed over instances of increasing size (i.e., communities to be electrified with increasing numbers of demand points) showed that hundreds of such non-dominated solutions might be found. This trend hinders the subsequent task of decision-makers, who might feel confused in front of too many indistinguishable system configurations.

In this framework, the present work introduces a computational tool aiming to prune the non-dominated solution set (denoted in what follows as *NDS*, with $|NDS| = nd$) to provide decision-makers with a reduced set (*DMS*, having a manageable size *dm*). The methods included in this tool are inspired from several processes drawn from Multi-Objective Evolutionary Computation, in which the maintenance of a so-called "archive" containing the non-dominated solutions identified is a classical task (see for instance [3]). In particular, the pruning strategy designed here first applies a pre-processing filter based on ε-dominance and, as a second step, a clustering procedure is triggered to maintain in *DMS* the *dm* most efficient solutions.

2 Description of the Pruning Strategy

As explained in the previous section, the pruning tool developed here receives as an input a non-dominated set *NDS* containing *nd* trade-off solutions obtained from a MO search engine (in this case, ε-constraints). The procedure outputs a decision-making set *DMS*, containing *dm* solutions, so that the *global quality* of the original set *NDS* is only marginally deteriorated when pruned to get *DMS* (the way this *global quality* can be evaluated is explained in the next section). In this study, *dm* is arbitrarily set to 10 because it is appropriate in the rural electrification framework, but this user-defined parameter can be modified.

The design of the pruning tool has been carried out considering several options regarding internal methods, finally retaining the best one (described here) through numerical testing, so that this strategy can be seen as *ad-hoc* to the rural electrification problem studied here. The internal components are inspired from procedures generally found within several Multi-Objective Evolutionary Algorithms (MOEAs) operators, which iteratively prune a repository of non-dominated solutions (called archive) when its size exceeds a predefined bound. These operators are typically based on clustering techniques, on objective space partitioning, or on the use of indicators to iteratively remove the solutions that least participate to the archive diversity. The interested reader is referred to [3] for more information. However, these procedures are adapted to the problem treated here and specific implementations are developed in this work.

The pruning strategy involves two stages. First, a filter based on ε-dominance allows removing solutions that can be considered as inefficient. Indeed, this concept is particularly useful in our framework since, when comparing two (non-dominated) solutions, it discards that one that is slightly better for some objective(s) but much worse for the other one(s). In mathematical terms, if s and t are two solutions and $f_1, f_2, \ldots, f_m$ are m objectives to be minimized, then s is said to ε-dominate t iff $\forall j \in \{1, \ldots, m\}, f_j(s) - \varepsilon_j \leq f_j(t)$, where the εj ($j = 1, \ldots, m$) parameters are small values representing acceptable deteriorations for each objective j, to be set depending on the tackled problem [4]. In this work, a particular implementation is developed so that, when comparing two solutions, if each one ε-dominates the other, then both are preserved, letting the second stage of the pruning tool decide that one to be removed.

Subsequently, in case the first stage does not reduce the number of solutions in *DMS* to *dm* (or less), a second procedure is triggered. Based on cluster analysis, the remaining solutions in *DMS* are grouped together so that solutions belonging to the same group are similar and that two solutions drawn from different groups are not. In the clustering algorithm used here (called *Average Linkage Method*, and included in classical MOEAs, see [5]), the similarity measure is the Euclidean distance in the objective space. First, a cluster is created for each solution and, iteratively, the two "more similar" clusters are merged until the remaining number of clusters is *dm*. The centroid of each cluster (i.e., the solution closest to the cluster gravity center) is selected as an output.

3 Computational Experiments

In order to evaluate the efficacy of the pruning tool developed in this work, a set of test problems is solved. This set contains in total 16 instances, built from two real communities in Peruvian highlands, namely Alto Peru (AP) and El Alumbre (EA). AP and EA have respectively 26 and 35 demand points; the other instances are randomly created using a generator developed in [6], which creates random geographic locations for a user-defined number of demand points. Here, in addition to the two base communities AP and EA, 6 new instances are created using 50, 75 and 100 demand points (which is a very high number of households for a rural community), in order to study the scalability of the proposed tool. Also, the potential wind energy resources are obtained from an interpolation from real reports available over a meshing of the considered territory. Finally, for each instance, two scenarios associated to the levels assigned to the nominal demands are considered (High and Low) and, in each scenario, the range of demand variations considered around nominal values is set to 20% (i.e., the maximal and minimal accepted demands are respectively equal to the nominal values ±10%).

For each of the 16 instances, a MO process (based on ε-constraints) was performed in order to obtain a set *NDS* (see [2]), which is the input of the pruning tool. The latter is then applied to each *NDS* in order to produce a decision-making set *DMS* of size $dm \leq 10$. Results quality is evaluated through the hypervolume indicator, which represents the hyper-space enclosed by a set of solution points and a user-defined reference point (the greater the hypervolume, the greater the quality of *DMS*). This indicator is particularly relevant because it is the only one known to be Pareto-compliant, meaning that the maximum hypervolume is achieved only for the optimal Pareto front of a MO problem. Here, the hypervolumes of both *NDS* and *DMS* are computed for each instance and denoted as $HV(NDS)$ and $HV(DMS)$. Then, the normalized hypervolume of *DMS* can be deduced: $HV^{norm}(DMS) = 100 \times HV(DMS)/HV(NDS)$. Logically, $HV^{norm}(DMS) \leq 100$ and a $HV^{norm}(DMS)$ value close to 100 indicates that, by pruning *NDS*, the obtained *DMS* has an almost equal hypervolume, i.e., reducing the set of non-dominated solutions has almost no impact on the *global quality* of the Pareto front approximation. The instance features and the obtained normalized hypervolumes are available in Table 1.

Table 1. Results obtained with the proposed pruning tool.

Instance	Low demand level		High demand level	
	nd	HV^{norm}	*nd*	HV^{norm}
AP – 26 points	103	81.2	140	81.5
AP – 50 points	104	85.3	71	91.4
AP – 75 points	100	73.9	181	72.9
AP – 100 points	75	88.9	191	81.3
EA – 35 points	85	86.5	324	74.2
EA – 50 points	115	81.4	276	75.7
EA – 75 points	131	87.5	366	78.7
EA – 100 points	233	84.2	528	72.9
Average	118.25	83.61	259.63	78.58

The first observation in Table 1 comes from the comparison of the results obtained for the Low and High demand scenarios. Since demand ranges are built as a ratio of the nominal demands, greater nominal demands involve wider demand ranges. This is why, in general, more non-dominated solutions (*nd*) are identified for the High demand level. Since the final size of *DMS* is always 10, more solutions are removed from *NDS* in the High demand case, which explains worse results (lower hypervolumes).

On the other hand, the normalized hypervolumes are on average equal to 83.61% and 74.58% for the Low and High levels respectively. In other words, the quality deterioration of the original set *NDS* due to the pruning strategy is on average not greater than 17% and 25%. This result is particularly significant when accounting for the size reduction of *NDS*: *nd* is, on average, approximately equal to 120 and 260 solutions for the Low/High levels, respectively. Therefore, while *NDS* is reduced by a mean amount of about 92% and 96% (to only 10 remaining in *DMS*) in the Low/High demand cases, the pruning strategy preserves about 84% and 75% of the global quality of the original sets, respectively. In the worst case (EA – 100 points, High demand, $HVnorm = 72.9\%$), *DMS* represents less than 2% of the initial *NDS*. Finally, it should be mentioned that, as observed in Table 1, the size of the electrified community has no impact on the performance level of the pruning tool.

4 Conclusions

In this work, a computational tool has been introduced for pruning a set of non-dominated solutions, in the framework of the multi-objective design of rural electrification systems. This tool involves two main operators based on ε-dominance and cluster analysis. The results highlight the efficacy of the procedure, which preserves on average more than 80% of the initial set quality while maintaining only 5% of its original components. In this way, a manageable number of electrification designs can be provided to decision-makers, without a significant loss of efficient solutions. Finally, this pruning strategy is ready to be included within a global tool for the design of electrification systems based on multi-objective optimization: the first module performs a multi-objective optimization process based on ε-constraints [2] and the second one is the pruning strategy presented here.

References

1. International Energy Agency: World Energy Outlook: Electricity Access Database (2021). https://www.iea.org/reports/world-energy-outlook-2021. Accessed 27 Feb 2022
2. Ponsich, A., Domenech, B., Ferrer-Martí, L., Juanpera, M., Pastor, R.: An ε-constraint method for the multi-objective optimization of stand-alone electrification systems for isolated communities. In: Proceedings of the 14th International Conference on Industrial Engineering and Industrial Management, Leganés, Spain (2020). Paper ID: 012
3. Schütze, O., Hernández, C., Talbi, E.-G., Sun, J.Q., Naranjani, Y., Xiong, F.-R.: Archivers for the representation of the set of approximate solutions for MOPs. J. Heuristics **25**(1), 71–105 (2018). https://doi.org/10.1007/s10732-018-9383-z
4. Laumanns, M., Thiele, L., Deb, K., Zitzler, E.: Combining convergence and diversity in evolutionary multiobjective optimization. Evol. Comput. **10**(3), 263–282 (2002)
5. Zitzler, E., Thiele, L.: Multiobjective evolutionary algorithms: a comparative case study and the Strength Pareto approach. IEEE Trans. Evol. Comput. **3**(4), 257–271 (1999)
6. Ferrer-Martí, L., Domenech, B., García-Villoria, A., Pastor, R.: A MILP model to design hybrid wind-photovoltaic isolated rural electrification projects in developing countries. Eur. J. Oper. Res. **226**, 293–300 (2013)

Life Cycle Assessment of an Autonomous Underwater Vehicle. ENDURUNS Project Case

Pedro José Bernalte Sanchez[1], Fausto Pedro Garcia Marquez[1(✉)], Mayorkinos Papaelias[2], Simone Marini[3], and Nikolla Gjeci[3]

[1] Ingenium Research Group, University of Castilla La Mancha, Ciudad Real, Spain
{Pedro.Bernalte,FaustoPedro.Garcia}@uclm.es

[2] A School of Metallurgy and Materials, The University of Birmingham, Edgbaston, Birmingham, UK
m.papaelias@bham.ac.uk

[3] Institute of Marine Sciences, National Research Council of Italy (CNR), La Spezia, Italy
simone.marini@sp.ismar.cnr.it, nikolla.gjeci@onairweb.com

Abstract. The use of the autonomous vehicles for marine and submarine works has evolved considerably in the last decade. The appearance of new imaging, navigation and communications technologies allow large operability possibilities. The Autonomous Underwater Vehicles are used currently for several offshore missions and applications. There exists some innovative purposes in the line of the sustainable development and green energy mobility. ENDURUNS project is an European research initiative in the framework of "Horizon 2030" with the aim of seabed survey. The novelty of this project is the use and implementation of renewable energy (Hydrogen Fuel Cell) for the underwater vehicle developed, achieving the zero emissions objective. This paper analysed the product environmental management using the Life Cycle Assessment methodology, ISO 14040. This analysis reports different values of Damage and Environmental Impact. The Eco-Indicator 99 method is employed with the SimaPro software. The results obtained from the analysis are used to evaluate the Life Cycle environmental impact.

Keywords: ENDURUNS project · Autonomous underwater vehicle · Renewable energies · Sustainable development · Life cycle · Environment impact

1 Introduction

In the last few years, these vehicles have been improved by the automatization and robotization upgrades achieving the challenge to be unmanned vehicles, called Autonomous Underwater Vehicles. These innovations preserve away the submersion risks for the driver, or operator, during the missions. There are interesting reviews in this field with historical and technical notes in references [1, 2]. ENDURUNS project develops this objective with the financial support from the European Commission into the "Horizon 2020" programme [3]. Thus, the project is framed in a global movement around the oceans survey and maritime mobility interest.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 266–271, 2023.
https://doi.org/10.1007/978-3-031-27915-7_48

To measure the impact of this project in terms of sustainability and environment impact, it is required the Life Cycle (LC) description and Life Cycle Assessment (LCA) evaluation. Thereby, it takes in account the normativism and policies that this study requires. The ISO 14000 series describes the most relevant aspect of the LC issues.

The rest of the paper is presented as follows: In Sect. 1, it is described the state of art and methodology background for this study. In Sect. 2, it is detailed the Life Cycle Assessment (LCA) developed for the ENDURUNS AUV. In Sect. 3, it is presented the most representative results evaluating them. Finally, in Sect. 4, it is resumed the main conclusions of this work.

2 Methodology Fundaments

The LC study can be developed at different levels of complexity depending on the stages included itself. The complete LC are defined from the initial of the product until the dismantling and recycled, completing the ecological loop called as cradle to cradle, as it is described in [4]. Figure 1 shows the graphical LC representation of the ENDURUNS case of study for the AUV, composed by six stages. However, there exist different levels to simplify the study, e.g., the cradle to gate approach, which is focused only in the manufacturing process as it is resumed in [5].

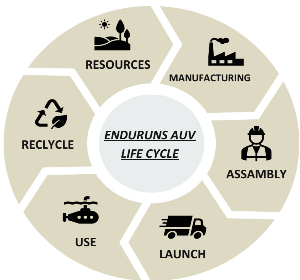


Fig. 1. ENDURUNS AUV life cycle stages

The contribution of a product to the contamination is determined by the emissions and environmental damage produced during its LC [6, 7]. In Europe, it is used the European Conformity (CE) and Environmental Product Declaration (EPD) certificates. EPD is a certificate that provides relevant, verified, quantitative, and comparable information about the environmental impact of a product [8, 9]. The LCA framework is structured in four interconnected phases [10]: Goal and Scope Definition (Phase 1); Inventory analysis (Phase 2); Impact Assessment (Phase 3), and; Interpretation (Phase 4) [11].

3 Life Cycle Assessment for ENDURUNS AUV

The framework of the LCA describes four well-defined phases to accomplish a successful study. However, this is a theoretical assumption. Certain stages of the UAV LC like assembly, launch or product use represents individual altogether contributions, while the AUV are decomposed in its different components. Thus, the simulation case defines the cradle to grave study.

3.1 Objective, Scope and Definition

This phase defines the aim, scope, and context of the study. The LCA developed for the ENDURUNS AUV implies a deep analysis of the LC processes and subprocesses until the product retirement [12, 13]. The scope of this study corresponds to the Cradle to Grave LC stages, in this case: the manufacturing processes of each AUV component, the assembly process, the launch and the set-up operation, the use implications during the AUV life and, finally, the end of life, or dismantling process [14, 15]. To develop this study, it has been considering the information obtained from the project updates. The most intensive and complex subprocess evaluated is the components of the UAV [16]. The prototype it shown in Fig. 2.

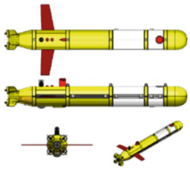


Fig. 2. ENDURUNS AUV prototype

It is possible to observe the modular character of the UAV: propulsion, mapping, energy, and buoyancy parts. This configuration contributes to the UAV versatility, allowing future modifications in function new mission requirements [17, 18]. This fact supposes a positive point in the sustainability field. Finally, the results obtained from the model are useful for the environmental analysis of the project, helping to evaluate the emissions and wastes generated, contributing with the sustainable optimization that it is purposed in ref. [19].

3.2 Inventory Analysis

This phase tries to resume and quantify the inputs and outputs involved in the LC processes and stages. These flows correspond with the raw materials, energy use and waste generation along the product LC, as it is described in ref. [20]. This part of the study needs a great volume of data. The use of the SimaPro software brings the workspace to develop this process and storage all the information. The system boundary of the product is represented by the square dotted line, leaving aside the materials extractions. Each process of the product LC defined previously must be added to the software model. It is possible to divide the inventory into the different processes, including the individual flows on them.

Table 1. Eco-Indicator 99 results for ENDURUNS USV

Damage Cat.		Human health (DALY)						Ecosystem quality (PDF*m^{2}year)			Resources (MJ)	
Impacts		Carcinogens	Resp. organics	Resp. inorganics	Climate change	Radiation	Ozone layer	Ecotoxicity	Acidification	Land use	Minerals	Fossil fuels
Product life cycle processes	Manufacturing	4,23E−3	2,13E−6	3,05E−3	4,13E−4	4,88E−6	1,99E−7	1,02E4	52,9	1,35E3	564	1,72E3
	V. assembly	1,82E−4	5,37E−8	1,13E−4	3,64E−5	6,88E−7	1,15E−8	495	3,05	59,2	13,3	146
	Set Up	4,57E−6	1,95E−8	7,84E−5	2,55E−5	7,16E−7	3,05E−8	11,6	1,97	1,21	0,29	82,1
	Launch	2,08E−5	7,64E−7	1,45E−3	1,05E−4	9E−7	8,89E−8	304	60,3	8,42	3,87	821
	Use	3,45E−4	4,48E−6	1,17E−3	6,16E−4	5,15E−6	9,25E−7	693	31,1	160	33,9	1,42E4
	Maintenance	1,75E−5	5,73E−7	1,08E−3	7,65E−5	5,99E−7	6,31E−8	231	45,1	6,96	2,99	609
	Dismantling	−4,4E−4	2,56E−7	6,51E−4	3,51E−5	2,43E−7	2,9E−8	806	20	1,93	−97	287
	Recycling	2,61E−4	−5,8E−8	−5,2E−5	1,56E−5	1,68E−7	1,6E−8	2,62E3	−0,6	3,28	5,24	39,3
	Partial sum	4,62E−3	8,21E−6	7,53E−3	1,32E−3	1,33E−5	1,36E−6	1,54E4	214	1,59E3	526	1,79E4
	Total	0,0135						3340			1840	

3.3 Impact Assessment

Following the guidelines of the UNE-EN-ISO 14040:2006, there exist several methodologies developed to measure the environmental impact, among the most popular: Recipe, IMPAC 2002+, Eco-Indicator 99, EDP or ILCD [21, 22]. In this paper, it has been applied the Eco-Indicator 99 method to evaluate the ENDURUNS AUV case. Table 1 shows the numerical results obtained.

This methodology was developed by Mark Goedkoop, with the PRè-Consultans team collaboration, to avoid the weighting step issues arising from the ISO 14040 [23]. SimaPro software brings also a clear graphical representation of the LCA results.

3.4 Interpretation

This phase of the LCA intended to provide a resume of the results and outcomes from the method. The interpretation of these values allows the analysis of the product contamination grade. In this case, it is obtained a preliminary and estimated evaluation of the ENDURUNS project AUV.

4 Conclusions

Research initiatives as ENDURUNS project, in the framework of "Horizon 2020" by the European commission, requires a detailed Life Cycle Assessment due to its eco-design character. The autonomous underwater vehicle developed in the ENDURUNS project features with a hydrogen fuel cell as energy source. Thus, the conclusions derived from the study can be employed as environmental impact auditory. The main conclusions are resumed in the following points:

- The Damage Categories numerical results allows to detect the higest values of each enviromental impact and life cycle process.
- The contribution of each process of the life cycle is measurable.

Acknowledgements. The work reported here with has been supported by the European Project H2020 under the Research Grants H2020-MG-2018-2019-2020, ENDURUNS.

References

1. Sánchez, P.J.B., Papaelias, M., Márquez, F.P.G.: Autonomous underwater vehicles: instrumentation and measurements. IEEE Instrum. Meas. Mag. **23**, 105–114 (2020)
2. Sahoo, A., Dwivedy, S.K., Robi, P.: Advancements in the field of autonomous underwater vehicle. Ocean Eng. **181**, 145–160 (2019)
3. Marini, S., et al.: ENDURUNS: an integrated and flexible approach for seabed survey through autonomous mobile vehicles. J. Mar. Sci. Eng. **8**, 633 (2020)
4. Bjørn, A., Hauschild, M.Z.: Cradle to cradle and LCA. In: Hauschild, M.Z., Rosenbaum, R.K., Olsen, S.I. (eds.) Life cycle assessment, pp. 605–631. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-56475-3_25

5. Qureshi, A.J., Gericke, K., Blessing, L.: Stages in product lifecycle: trans-disciplinary design context. Procedia CIRP **21**, 224–229 (2014)
6. Acaroğlu, H., Márquez, F.P.G.: High voltage direct current systems through submarine cables for offshore wind farms: a life-cycle cost analysis with voltage source converters for bulk power transmission. Energy **249**, 123713 (2022)
7. Márquez, F.P.G., Lewis, R.W., Tobias, A.M., Roberts, C.: Life cycle costs for railway condition monitoring. Transp. Res. Part E Logist. Transp. Rev. **44**, 1175–1187 (2008)
8. Özkan, A., et al.: Life cycle assessment and life cycle cost analysis of magnesia spinel brick production. Sustainability **8**, 662 (2016)
9. Ahmad, I., Noor, R.M., Ahmed, Z., Akram, N., García Márquez, F.P.: A cooperative heterogeneous vehicular clustering framework for efficiency improvement. Front. Inf. Technol. Electron. Eng. **22**, 1247–1259 (2021). https://doi.org/10.1631/FITEE.2000260
10. Sánchez, P.J.B., Junior, V.L.J., Papaelias, M., Márquez, F.P.G.: Life cycle assessment of an autonomous underwater vehicle. In: Xu, J., García Márquez, F.P., Ali Hassan, M.H., Duca, G., Hajiyev, A., Altiparmak, F. (eds.) ICMSEM 2021. LNDECT, vol. 79, pp. 577–587. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-79206-0_43
11. Hauschild, M.Z.: Introduction to LCA methodology. In: Hauschild, M.Z., Rosenbaum, R.K., Olsen, S.I. (eds.) Life cycle assessment, pp. 59–66. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-56475-3_6
12. Sánchez, P.J.B., Asensio, M.T., Papaelias, M., Márquez, F.P.G.: Life cycle assessment in autonomous marine vehicles. In: Xu, J., García Márquez, F.P., Ali Hassan, M.H., Duca, G., Hajiyev, A., Altiparmak, F. (eds.) ICMSEM 2021. LNDECT, vol. 79, pp. 222–233. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-79206-0_17
13. García Márquez, F.P., Peinado Gonzalo, A.: A comprehensive review of artificial intelligence and wind energy. Arch. Comput. Methods Eng. **29**, 2935–2958 (2022). https://doi.org/10.1007/s11831-021-09678-4
14. Giezeman, I., Verhees, F.: Eco-labelling: practical use of the cradle-to-grave approach. In: Zarrilli, S., Jha, V., Vossenaar, R. (eds.) Eco-Labelling and İnternational Trade, pp. 195–205. Palgrave Macmillan, London (1997). https://doi.org/10.1007/978-1-349-25492-7_13
15. Pliego Marugán, A., García Márquez, F.P., Lorente, J.: Decision making process via binary decision diagram. Int. J. Manag. Sci. Eng. Manag. **10**, 3–8 (2015)
16. Ramírez, I.S., Bernalte Sánchez, P.J., Papaelias, M., Márquez, F.P.G.: Autonomous underwater vehicles and field of view in underwater operations. J. Mar. Sci. Eng. **9**, 277 (2021)
17. Junior, V.L.J., Ramirez, I.S., Marquez, F.P.G., Papaelias, M.: Numerical evaluation of type I pressure vessels for ultra-deep ocean trench exploration. Results Eng. **11**, 100267 (2021)
18. Sanchez, P.J.B., et al.: Use of UIoT for offshore surveys through autonomous vehicles. Pol. Marit. Res. **28**, 175–189 (2021)
19. Bhinge, R., Moser, R., Moser, E., Lanza, G., Dornfeld, D.: Sustainability optimization for global supply chain decision-making. Procedia CIRP **26**, 323–328 (2015)
20. Mattila, T.J.: Use of input–output analysis in LCA. In: Hauschild, M.Z., Rosenbaum, R.K., Olsen, S.I. (eds.) Life Cycle Assessment, pp. 349–372. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-56475-3_14
21. Owsianiak, M., Laurent, A., Bjørn, A., Hauschild, M.Z.: IMPACT 2002+, ReCiPe 2008 and ILCD's recommended practice for characterization modelling in life cycle impact assessment: a case study-based comparison. Int. J. Life Cycle Assess. **19**, 1007–1021 (2014). https://doi.org/10.1007/s11367-014-0708-3
22. Márquez, F.P.G., Karyotakis, A., Papaelias, M.: Renewable Energies: Business Outlook 2050. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-45364-4
23. Goedkoop, M., Spriensma, R.: The eco-indicator 99: a damage oriented method for life cycle assessment, methodology report. PreConsultans BV, The Netherlands, 12 (2000)

The Validity of the Environmental Kuznets Curve in Terms of the Ecological Foot Print and Energy Consumption Diversity: The Case of Turkey

Hatice Melissa Kartal[1], Hakan Acaroğlu[1], and Fausto Pedro Garcia Marquez[2](✉)

[1] Department of Economics, Faculty of Economics and Administrative Sciences, Eskisehir Osmangazi University, 26480 Eskişehir, Turkey
hacaroglu@ogu.edu.tr

[2] Ingenium Research Group, University of Castilla-La Mancha, Ciudad Real, Spain
FaustoPedro.Garcia@uclm.es

Abstract. This study investigates the environmental Kuznets curve (EKC) hypothesis for Turkey between 1971 to 2015. The aim of the study is to illustrate the relationship between CO_2 emission and ecological footprint and economic growth, trade openness, primary energy consumption, coal consumption, and hydroelectric consumption. ARDL bounds test is used to examine the relationship between variables. The results support that the EKC hypothesis is valid for Turkey. The results of the models reveal that in the case of CO_2 emission is the dependent variable, coal consumption and trade openness increase the CO_2 emission in the long run, whereas, hydroelectricity consumption decreases it. In the case of the ecological footprint is the dependent variable, while the ecological footprint decreases trade openness, primary energy consumption and coal consumption increase it. Based on the findings, it can be said that trade openness, primary energy consumption, coal consumption and hydroelectric consumption have significant effects on environmental degradation in Turkey.

Keywords: Environmental Kuznets curve · Ecological footprint · CO_2 emissions · Trade openness · Energy consumption

1 Introduction

The relationship between economic growth and environmental degradation has been examined by many studies since the 1990s [1–4]. The Environmental Kuznets Curve (EKC) hypothesis is used to investigate the relationship between economic growth and environmental degradation. According to the EKC hypothesis, there is an increase in environmental pollution in the early stages of economic growth. However, in the later stages of economic growth, environmental degradation decreases with the increase in environmental awareness and environmental expenditures [5, 6].

In addition to economic growth, trade openness and energy consumption also affect environmental degradation. The relationship between Gross Domestic Product (GDP=,

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 272–279, 2023.
https://doi.org/10.1007/978-3-031-27915-7_49

energy consumption, trade openness and environmental degradation has been studied by many researchers, and most of these studies have used the Autoregressive Distributed Lag (ARDL) bounds testing approach [7–10]. However, in most of the above-mentioned studies, CO_2 emission was used as an indicator of environmental degradation. CO_2 emission, which represents solely an air pollution, may not be an adequate indicator of environmental degradation [11, 12]. Also, inferences based on CO_2 emissions may not valid for resource stocks [13]. Therefore, it is important to examine the factors affecting the ecological footprint, which is a whole indicator of environmental degradation [14, 15, 16]. The main objective of this study is to include ecological footprint as an indicator of environmental degradation in the analysis of the relationship between GDP, trade openness, energy consumption diversity (primary energy consumption, coal consumption and hydroelectric consumption) and environmental degradation [6, 17, 18]. The second objective of this study is to obtain a more reliable result by examining the validity of the EKC hypothesis for both CO_2 emission and ecological footprint in Turkey. In line with these purposes, the relationship between ecological footprint and CO_2 emissions and GDP, trade openness, types of energy consumption (primary energy consumption, coal consumption and hydroelectricity consumption) are examined with the ARDL bounds test approach between the years 1971–2015, for Turkey.

2 Data and Model

2.1 Data

See Table 1.

Table 1. The variables, explanations and sources

Variable	Explanation	Source
CO_2	CO_2 emissions (per capita metric tonnes)	World Bank
EF	Ecological Footprint (per capita)	Global Footprint Network
Y	GDP per capita (constant 2015 US $)	World Bank
Y^2	GDP per capita square (constant 2015 US $)	World Bank
EX	Goods and Services Export divided by GDP	World Bank
PEC	Primary Energy Consumption (per capita)	British Petroleum Statistical Review of World Energy 2021
CC	Coal Consumption	British Petroleum Statistical Review of World Energy 2021
HEC	Hydroelectric Consumption	British Petroleum Statistical Review of World Energy 2021

2.2 Model

In this study, the following equations are created to test the validity of the EKC hypothesis.

$$lnCO_{2t} = \beta_0 + \beta_1 lnY_t + \beta_2 (lnY_t)^2 + \beta_3 lnEX_t + \beta_4 lnPEC_t + \varepsilon_t \tag{1}$$

$$lnCO_{2t} = \beta_0 + \beta_1 lnY_t + \beta_2 (lnY_t)^2 + \beta_3 lnEX_t + \beta_4 lnCC_t + \varepsilon_t \tag{2}$$

$$lnCO_{2t} = \beta_0 + \beta_1 lnY_t + \beta_2 (lnY_t)^2 + \beta_3 lnEX_t + \beta_4 lnHEC_t + \varepsilon_t \tag{3}$$

$$lnEF_{2t} = \alpha_0 + \alpha_1 lnY_t + \alpha_2 (lnY_t)^2 + \alpha_3 lnEX_t + \alpha_4 lnPEC_t + \varepsilon_t \tag{4}$$

$$lnEF_{2t} = \alpha_0 + \alpha_1 lnY_t + \alpha_2 (lnY_t)^2 + \alpha_3 lnEX_t + \alpha_4 lnCC_t + \varepsilon_t \tag{5}$$

$$lnEF_{2t} = \alpha_0 + \alpha_1 lnY_t + \alpha_2 (lnY_t)^2 + \alpha_3 lnEX_t + \alpha_4 lnHEC_t + \varepsilon_t \tag{6}$$

3 Results and Discussion

Firstly, Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests are performed to determine the stationarity level of the variables. The lag lengths for the ADF test are prepared according to the Schwarz information criterion. The lag lengths for the PP unit root test are prepared according to the Newey-West information criterion. The results of the ADF and PP unit root tests are given in Table 2. According to the ADF unit root test results, while all series contain unit root at the level, they do not contain unit root after their first difference is taken. According to the PP unit root test result, all

Table 2. ADF and PP Unit Root test results

Variables	ADF		PP	
	Level	First difference	Level	First difference
CO_2	−1.4403	−6.7687***	−1.5825	−7.5309***
EF	−0.8035	−10.2840***	−0.9680	−13.9432***
Y	0.5807	−6.3189***	0.6325	−6.3198***
Y^2	0.7657	−6.2600***	0.8330	−6.2617***
EX	−1.3773	−5.8942***	−1.4030	−5.8942***
PEC	−1.7899	−6.7635***	−1.9757	−6.7650***
CC	−1.2094	−7.0461***	−1.2094	−7.0461***
HEC	−2.3856	−7.3816***	−3.0572**	−7.6926***

Note: *,**,*** denote significance at the 10%, 5% and 1% levels, respectively.

series except HEC contain unit root at the level. However, when the first difference is taken, it is seen that they do not contain a unit root.

In Table 3, ARDL bounds test results are given in order to determine the cointegration relationship between the variables. According to the findings, the F statistical value is found above the upper limit critical value in all models. This situation reveals the existence of a cointegration relationship between the variables.

Table 3. Bounds test results

Models	Lag length	F-statistics	I(0)	I(1)
Model 1	(1, 0, 3, 1, 3)	6.04117	2.893	4
Model 2	(2, 0, 3, 0, 2)	6.4292	2.893	4
Model 3	(1, 0, 0, 0, 2, 0)	18.4452	2.39	3.38
Model 4	(1, 0, 0, 0, 0)	18.6621	2.85	3.905
Model 5	(1, 1, 0, 0, 1)	20.6835	2.85	3.905
Model 6	(2, 1, 0, 3, 0)	9.5424	2.893	4
Model 7	(3, 1, 0, 0, 0, 2)	6.5311	2.734	9.92
Model 8	(1, 1, 0, 0, 0)	16.1058	2.85	3.905

Note: I(0) and I(1) values in the table are written according to 5% significance level.

Table 4 includes the diagnostic test results of the models. According to the findings in Table 4, it is concluded that there is no problem of time-varying variance with the BPG test, there is no problem of autocorrelation with the LM test, the error terms have a normal distribution with the JB test, and there is no specification problem with the Ramsey RESET test.

Table 4. Diagnostic test results

Models	BPG	LM	JB	RAMSEY	R^2
Model 1	0.1479	0.7873	0.8368	0.9676	0.9940
Model 2	0.4885	0.3574	0.2183	0.6612	0.9959
Model 3	0.7190	0.8328	0.8411	0.5273	0.9925
Model 4	0.7402	0.6192	0.0667	0.2488	0.9801
Model 5	0.3047	0.4838	0.1347	0.3214	0.9836
Model 6	0.3840	0.8142	0.4949	0.4394	0.9755

According to the long-run coefficients estimated in Table 5, while GDP, trade openness and per capita coal consumption increase CO_2 emissions, the square of GDP and per capita hydroelectric consumption decrease it. The fact that GDP is positive and the square of GDP is negative indicates that the EKC hypothesis is valid in Turkey in the long run. These results are similar to [3, 19, 20]. In addition, a 1% increase in trade openness causes an increase in CO_2 emissions of 0.0497% and 0.0525%, respectively, in the long run. A 1% increase in coal consumption per capita causes an increase of 0.1896% in CO_2 emissions in the long run, while a 1% increase in hydroelectric consumption per capita causes a 0.0498% decrease in CO_2 emissions. It has been found that primary energy consumption has no effect on CO_2 emissions in the long run.

Table 5. ARDL long term estimation results for CO_2 emissions

Variables	Model 1		Model 2		Model 3	
	Coefficient	t statistics	Coefficient	t statistics	Coefficient	t statistics
Y	7.9066***	2.9425	8.3152***	7.8309	12.1554***	6.9834
Y^2	−0.4019***	−2.8562	−0.4285***	−7.2898	−0.6387***	−6.5316
EX	0.0497**	2.0952	0.0014	0.1126	0.0525***	2.7877
PEC	0.0650	0.4503				
CC			0.1896***	3.9278		
HEC					−0.0498**	−2.0265

Note: *,**,*** denote significance at the 10%, 5% and 1% levels, respectively.

Table 6 shows the short-term estimation results. According to the results, the coefficient of error correction term in all models is negative and significant as expected.

Table 6. ARDL short term estimation results for CO_2 emissions

Variables	Model 1		Model 2		Model 3	
	Coefficient	t statistics	Coefficient	t statistics	Coefficient	t statistics
CO_2 (−1)			0.3500***	2.8915		
Y^2	−0.4736***	−6.3524	−0.4850***	−6.3408		
Y^2 (−1)	−0.0306***	−3.4728	−0.0201***	−3.1486		
Y^2 (−2)	−0.0236***	−2.8490	−0.0100**	−2.2266		
EX	0.0113	0.4633				
PEC	0.5394***	4.7975				
PEC (−1)	0.4450***	3.7760				
PEC (−2)	0.2173*	1.8984				
CC			0.3379***	6.9402		
CC (−1)			−0.1023	−1.5755		
ECT (−1)	−1.0762***	−6.5192	−1.0824***	−6.7085	−0.8045***	−11.2563

Note: *,**,*** denote significance at the 10%, 5% and 1% levels, respectively.

According to the long-run coefficients estimated in Table 7, while GDP, primary energy consumption and per capita coal consumption increase the ecological footprint, the square of GDP and trade openness decrease. It has been found that per capita hydroelectric consumption has no effect on the ecological footprint in the long run. The fact that GDP is positive and the square of GDP is negative indicates that the EKC hypothesis is valid in Turkey in the long run. These results are similar those of reported by [4, 21]. In addition, a 1% increase in trade openness causes a decrease of 0.0916%, 0.1407% and 0.0629% in the long-term ecological footprint, respectively. The 1% increase in primary energy consumption and per capita coal consumption causes the ecological footprint to increase by 0.1983% and 0.1784%, respectively.

Table 7. ARDL long term estimation results for ecological footprint

Variables	Model 4		Model 5		Model 6	
	Coefficient	t statistics	Coefficient	t statistics	Coefficient	t statistics
Y	4.2876*	1.9191	8.0704***	7.4392	6.0545***	4.0562
Y^2	−0.2286*	−1.9345	−0.4303***	−7.0711	−0.3138***	−3.7385
EX	−0.0916***	−3.9779	−0.1407***	−6.3897	−0.0629***	−3.8407
PEC	0.1983*	1.7334				
CC			0.1784***	4.2624		
HEC					0.0276	1.4052

Note: *,**,*** denote significance at the 10%, 5% and 1% levels, respectively.

Table 8 shows the short-term estimation results. According to the results, the coefficient of error correction term in all models is negative and significant as expected.

Table 8. ARDL short term estimation results for ecological footprint

Variables	Model 4		Model 5		Model 6	
	Coefficient	t statistics	Coefficient	t statistics	Coefficient	t statistics
EF (−1)			0.1430	1.6002		
Y	4.2735***	14.3907	10.7425***	8.9807	6.3134***	12.3416
EX			−0.0777***	−3.6293		
EX (−1)			0.1034***	3.5405		
EX (−2)			0.0731***	3.6359		
PEC	0.4905***	5.1399				
ECT (−1)	−0.9008***	−11.8885	−1.2900***	−8.1541	−0.9616***	−10.4734

Note: *,**,*** denote significance at the 10%, 5% and 1% levels, respectively.

4 Conclusions

This study tests the existence of the EKC hypothesis for Turkey for both CO_2 emissions and ecological footprint. In the study, the effects of GDP, trade openness, primary energy consumption, coal consumption and hydroelectric consumption on environmental degradation are examined with the ARDL bounds test. The findings support that the EKC hypothesis is valid for both CO_2 emission and ecological footprint in Turkey.

According to the findings, trade openness increases CO_2 emissions while reducing the ecological footprint. While a 1% increase in primary energy consumption causes an increase of 0.1983% in ecological footprint, it has no effect on CO_2 emissions. Findings for coal consumption are similar for both CO_2 emissions and ecological footprint. A 1% increase in coal consumption causes CO_2 emissions and ecological footprint to increase by 0.1896% and 0.1784%, respectively. This finding shows that CO_2 emissions and ecological footprint can be reduced by reducing coal consumption. Hydroelectric energy has the highest share among renewable energy sources in Turkey. A 1% increase in hydroelectric consumption causes a 0.0498% decrease in CO_2 emissions. This finding shows that promoting hydroelectric consumption is an effective policy in order to reduce CO_2 emissions in Turkey. However, the findings for CO_2 emissions in hydroelectric consumption differ from the findings for the ecological footprint. Hydroelectric consumption has no impact on the ecological footprint. This finding shows that hydroelectric consumption is not an effective policy to reduce the ecological footprint. Although hydraulic energy is a renewable and clean energy source, unless necessary precautions are taken, it can lead to negative consequences on the ecosystem and cause a decrease in ecological diversity. The findings show that hydroelectric resources are not used effectively to reduce the ecological footprint in Turkey.

References

1. Danish, Ozcan, B., Ulucak, R.: An empirical investigation of nuclear energy consumption and carbon dioxide (CO_2) emission in India: bridging IPAT and EKC hypotheses. Nucl. Eng. Technol. **53**, 2056–2065 (2021)
2. Dinda, S.: Environmental Kuznets curve hypothesis: a survey. Ecol. Econ. **49**, 431–455 (2004)
3. Pata, U.K.: Renewable energy consumption, urbanization, financial development, income and CO_2 emissions in Turkey: testing EKC hypothesis with structural breaks. J. Clean. Prod. **187**, 770–779 (2018)
4. Sharif, A., Baris-Tuzemen, O., Uzuner, G., Ozturk, I., Sinha, A.: Revisiting the role of renewable and non-renewable energy consumption on Turkey's ecological footprint: evidence from Quantile ARDL approach. Sustain. Cities Soc. **57**, 102138 (2020)
5. Panayotou, T.: Empirical tests and policy analysis of environmental degradation at different stages of economic development. International Labour Organization (1993)
6. Márquez, F.P.G., Karyotakis, A., Papaelias, M.: Renewable Energies: Business Outlook 2050. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-45364-4
7. Fuinhas, J.A., Marques, A.C.: Energy consumption and economic growth nexus in Portugal, Italy, Greece, Spain and Turkey: an ARDL bounds test approach (1965–2009). Energy Econ. **34**, 511–517 (2012)
8. Jebli, M.B., Youssef, S.B.: The environmental Kuznets curve, economic growth, renewable and non-renewable energy, and trade in Tunisia. Renew. Sustain. Energy Rev. **47**, 173–185 (2015)

9. Sinha, A., Shahbaz, M.: Estimation of environmental Kuznets curve for CO_2 emission: role of renewable energy generation in India. Renew. Energy **119**, 703–711 (2018)
10. Kongbuamai, N., Zafar, M.W., Zaidi, S.A.H., Liu, Y.: Determinants of the ecological footprint in Thailand: the influences of tourism, trade openness, and population density. Environ. Sci. Pollut. Res. **27**(32), 40171–40186 (2020). https://doi.org/10.1007/s11356-020-09977-6
11. Solarin, S.A., Bello, M.O.: Persistence of policy shocks to an environmental degradation index: the case of ecological footprint in 128 developed and developing countries. Ecol. Ind. **89**, 35–44 (2018)
12. Salam, R.A., et al.: An overview on energy and development of energy integration in major South Asian countries: the building sector. Energies **13**, 5776 (2020)
13. Ulucak, R., Lin, D.: Persistence of policy shocks to ecological footprint of the USA. Ecol. Ind. **80**, 337–343 (2017)
14. Acaroğlu, H., García Márquez, F.P.: Comprehensive review on electricity market price and load forecasting based on wind energy. Energies **14**, 7473 (2021)
15. Sadeghian, O., et al.: A comprehensive review on energy saving options and saving potential in low voltage electricity distribution networks: building and public lighting. Sustain. Cities Soc. **72**, 103064 (2021)
16. García Márquez, F.P., Peinado Gonzalo, A.: A comprehensive review of artificial intelligence and wind energy. Arch. Comput. Methods Eng. **29**, 2935–2958 (2022). https://doi.org/10.1007/s11831-021-09678-4
17. Acaroğlu, H., Márquez, F.P.G.: A life-cycle cost analysis of High Voltage Direct Current utilization for solar energy systems: the case study in Turkey. J. Clean. Prod. **360**, 132128 (2022)
18. Acaroğlu, H., Márquez, F.P.G.: High voltage direct current systems through submarine cables for offshore wind farms: a life-cycle cost analysis with voltage source converters for bulk power transmission. Energy **249**, 123713 (2022)
19. Bölük, G., Mert, M.: The renewable energy, growth and environmental Kuznets curve in Turkey: an ARDL approach. Renew. Sustain. Energy Rev. **52**, 587–595 (2015)
20. Uzar, U., Eyuboglu, K.: The nexus between income inequality and CO_2 emissions in Turkey. J. Clean. Prod. **227**, 149–157 (2019)
21. Shokoohi, Z., Dehbidi, N.K., Tarazkar, M.H.: Energy intensity, economic growth and environmental quality in populous Middle East countries. Energy **239**, 122164 (2022)

Prediction Analysis of Crop and Their Futuristic Yields Using Random Forest Regression

Uma Maheswari Ramisetty[1], Venkata Nagesh Kumar Gundavarapu[2], R. Rajender[3], Isaac Segovia Ramírez[4], and Fausto Pedro García Márquez[4(✉)]

[1] Vignan's Institute of Information Technology, Visakhapatnam, India
[2] JNTUA College of Engineering Pulivendula, Pulivendula, India
[3] Department of Computer Science and Engineering, Lendi Institute of Engineering and Technology, Jonnada, Vizianagaram, Andhra Pradesh, India
[4] Ingenium Research Group, University of Castilla-La Mancha, Ciudad Real, Spain
faustopedro.garcia@uclm.es

Abstract. Agriculture has a substantial impact on the global economy. One of the main threats to agriculture in the long term is climate change and other environmental factors. The primary determinant of the crop yield is weather conditions (e.g., rain, temperature, etc.). Historical data, e.g., weather, soil, and historic crop yield, are all taken into account for yield predictions. Previously developed models had lower accuracy, even though they had used many datasets that cluttered the models. This paper introduces machine learning methods to predict the food crop yield capacity of 10 food crops, that are widely consumed around the world. Several machine learning algorithms, including Random Forest Regressor, Linear Regression and decision tree Classifier are implemented on various data sets to perform a crop yield prediction. The random forest regression model is used to achieve higher accuracy using different datasets like temperature, rainfall, yield etc. It has been found that the accuracy for Multiple Linear Regression is 11.9%, the accuracy for Random Forest Regression is 99.8% and the accuracy for decision tree classifier is 97.8%.

Keywords: Random forest · Multiple linear regression · Decision tree · Precision · Accuracy · Crop yield · Temperature · Pesticides · Rainfall · Area

1 Introduction

As the population grew, and therefore, the need for food is also increasing. It is critical to identify the factors that influence crop yield to increase the agricultural domain's efficiency. Weather conditions mainly influence crop yields (rain, temperature, etc.). Crop yield data is critical for accurate risk management decisions and to provide useful predictions. Humanity has a great variety of cuisines around the world, but it sticks to the same essential ingredients for its sustenance and are almost pretty similar. Some of the most basic ingredients that are usually considered staple food are corn, wheat, rice and few other simple and similar ones. It is essential to control the crop is yielded in order

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 280–285, 2023.
https://doi.org/10.1007/978-3-031-27915-7_50

to maintain a healthy ratio between the crops produced and the growing population. The best method to understand the growth of the production is to maintain a record over the past production and predict the future outcomes. Crop yields can be predicted using data from recent years regarding the application of pesticides, the amount of rainfall and the temperature variations over a particular area. Preventing crop loss before harvest enables policy makers and farmers to implement proper conservation and marketing measures in advance. In the past, farmers predicted their yield using the learnings from the previous year's yield. Many researchers [1–9] have worked on crop yield prediction using various Machine Learning (ML) algorithms, but none of them have worked with Random Forest Regression (RFR) along with datasets having temperature, pesticides, yield, rainfall [10, 11]. In this paper, RFR has been used to improve accuracy for predicting the crop yield. The proposed model uses the RFR with various datasets as mentioned above. As there are many researchers who worked on this crop yield prediction model, they have incorporated a minimum number of dataset. Due to the minimal number of data sets being considered, accurate and the required results may not be obtained.

This paper proposes a model to predict the crop yield before cultivating onto the agricultural field. This approach attempts to solve the issue by building a prototype of an interactive predictive system. The main objective is to apply ML techniques to predict crop yield with an easy-to-use interface, increasing the accuracy of crop yield prediction and analyzing different climatic parameters. The impact of rainfall on a particular land area and the applied pesticides may spoil the crop even though the precautions were taken regarding the temperature. These problems are associated by considering minimum number of datasets. To overcome these problems, a model must be available to provide accurate results considering a suitable number of datasets. In this paper, the results using various models are compared and the best model is implemented.

2 Proposed Random Forest Regression

Multiple linear regression, decision tree, random forest and XG boost algorithms are used in this model to build crop yield prediction model [12]. Several ML algorithms have been used to ensure the maximum efficiency and predictability of the model [13, 14]. The efficiency rate of each model has been determined, showing the algorithm with the best results. The dataset is initially collected from various sources and then it is pre-processed, ensuring that the data is compatible with the training of several ML models instead of being limited to only one model [12]. Once it has been procured, the wanted features are selected [15]. The selected data is provided as trained data to the model. After the model was trained, a new data set is given, and the results are obtained and evaluated. Predictive modelling uses the relationship between an independent (predictor) and dependent (result) variables to discover patterns (target). A RFR model, a decision tree regression model and a multiple linear regression model are used to obtain these predictions. For the RFR, the approach is to generate a multitude of decision trees to help in the prediction of different scenarios, as it is shown in Fig. 1.

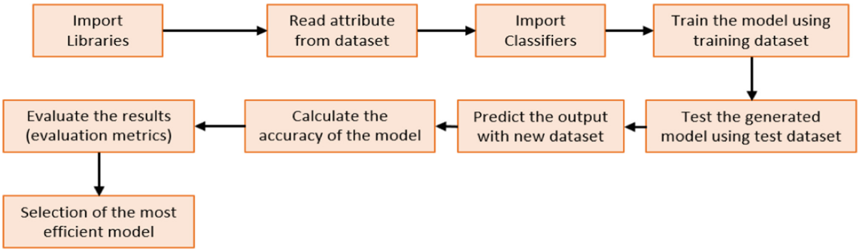


Fig. 1. Block diagram for implementing the proposed method

Based on the required prediction methodologies, the first step includes the implementation of all the required libraries, attributes and inputs from the dataset. The next step includes the implementation of the classifier, and the model is trained with the training data set. After the model is appropriately trained with the specified datasets, the test data is introduced. Then, the model predicts the data based on the training data set. The results are obtained from multiple linear, random forest and decision tree algorithm and the accuracy of each is determined. The method with the highest accuracy rate is selected and deployed in the analysis.

3 Results and Discussion

The model has been built with a total of 54176 items. Various results using several ML algorithms have been analyzed and obtained as it is shown in Fig. 2 and Fig. 3. The graph clearly provides the conclusion that the accurate results are obtained using RFR. Also obtained the yield potential based on several considerations, such as modelled yield potential, experimental yield potential, Maximum farmer yield and Average farmer yield potential. Figure 2 predicts the accuracy of various regressions methods deployed,

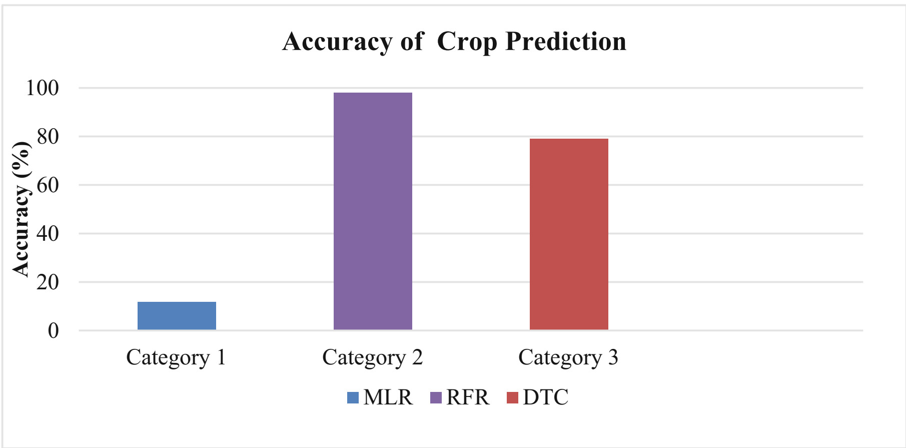


Fig. 2. Accuracy of crop prediction

namely multiple linear regression. RFR and decision tree classifier. The most accurate result is obtained by RFR compared to the other two regression models. An approximate value of 98% is obtained by RFR while the remaining multiple linear regression and decision tree classifier stands at 12% and 79% respectively,

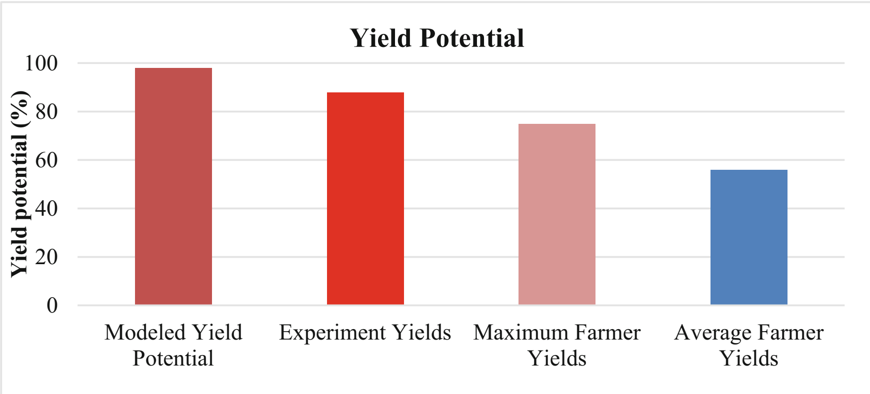


Fig. 3. Yield potential

Figure 3 represents the yield potential of various crops. The modelled yield depicts the planned procedure yield. The experimental yield represents the proximity of the produce. The maximum farmer yield explains the highest produce of the crop, with its most suitable factors. The average yield explains the productivity of any average year's crop. The estimated values are calculated and tabulated for all the three models, as it is shown in Table 1.

Table 1. Estimated accuracy of models

Model	Accuracy	Evaluation metrics	
		RMSE	R^2
Multiple linear regression	11.8	0.1529	0.11844
Random forest regression	99.8	3972.83	0.99825
Decision tree classifier	97.8	3645.79	0.97850

Table 1 shows the accuracy values of all the algorithms applied in this paper. The result accuracy rate is very high for random forest algorithm, providing the highest accuracy of 99.8%. The decision tree classifier stands next with 97.8% of accuracy. Multiple Linear regressions have been provided the least accuracy rate of 11.8%.

4 Conclusion

With the climatic changes and increasing population, novel models are required to estimate the crop yield. This paper explains a model to predict the crop yield for a selected crop given the parameters, such as temperature, rainfall, etc. This model has achieved an accuracy of 98% with random forest algorithm that increases the accuracy of predictions of the expected amount of crop yield, being very useful in the agricultural sector. It is proposed a future work with a web application that will be easy to understand, and users can use it to predict the crop yield in advance. This would improve the estimation of the amount of production that will be obtained by the agricultural sector to verify if it matches with the future demands. This paper includes limited parameters while the actual yield depends on variety of other factors, e.g., type of soil, the size of area on which it is produced, etc. As future research line using these kinds of predictions and data, this model will also include the prediction of the most suitable crop for the given type of soil, area of cultivation, climatic conditions, etc.

References

1. Lekhaa, T.: Efficient crop yield and pesticide prediction for improving agricultural economy using data mining techniques. Int. J. Mod. Trends Eng. Sci. (IJMTES) **3**(10), 11–28 (2016)
2. Tidake, A.H.: Design and implement a novel algorithm to maximize the yield of farming using prescriptive analysis (2019)
3. Khosla, E., Dharavath, R., Priya, R.: Crop yield prediction using aggregated rainfall-based modular artificial neural networks and support vector regression. Environ. Dev. Sustain. **22**(6), 5687–5708 (2019). https://doi.org/10.1007/s10668-019-00445-x
4. McBratney, A., Whelan, B., Ancev, T., Bouma, J.: Future directions of precision agriculture. Precision Agric. **6**, 7–23 (2005). https://doi.org/10.1007/s11119-005-0681-8
5. Pantazi, X.E., Moshou, D., Alexandridis, T., Whetton, R.L., Mouazen, A.M.: Wheat yield prediction using machine learning and advanced sensing techniques. Comput. Electron. Agric. **121**, 57–65 (2016)
6. Chlingaryan, A., Sukkarieh, S., Whelan, B.: Machine learning approaches for crop yield prediction and nitrogen status estimation in precision agriculture: a review. Comput. Electron. Agric. **151**, 61–69 (2018)
7. Veenadhari, S., Misra, B., Singh, C.: Machine learning approach for forecasting crop yield based on climatic parameters. In: 2014 International Conference on Computer Communication and Informatics, pp. 1–5. IEEE (2014)
8. Palanivel, K., Surianarayanan, C.: An approach for prediction of crop yield using machine learning and big data techniques. Int. J. Comput. Eng. Technol. **10**, 110–118 (2019)
9. Pa, R., Gb, B.J.: A review based on secure banking application against server attacks. In: Smart Intelligent Computing and Communication Technology, vol. 38, p. 241 (2021)
10. Marquez, F.P.G., Tercero, D.J.P., Schmid, F.: Unobserved component models applied to the assessment of wear in railway points: a case study. Eur. J. Oper. Res. **176**, 1703–1712 (2007)
11. Acaroğlu, H., García Márquez, F.P.: Comprehensive review on electricity market price and load forecasting based on wind energy. Energies **14**, 7473 (2021)
12. García Márquez, F.P., Peinado Gonzalo, A.: A comprehensive review of artificial intelligence and wind energy. Arch. Comput. Methods Eng. **29**, 2935–2958 (2022). https://doi.org/10.1007/s11831-021-09678-4

13. Jiménez, A.A., Zhang, L., Muñoz, C.Q.G., Márquez, F.P.G.: Maintenance management based on machine learning and nonlinear features in wind turbines. Renew. Energy **146**, 316–328 (2020)
14. Peco Chacón, A.M., Segovia Ramírez, I., García Márquez, F.P.: State of the art of artificial intelligence applied for false alarms in wind turbines. Arch. Comput. Methods Eng. **29**, 2659–2683 (2022). https://doi.org/10.1007/s11831-021-09671-x
15. García Márquez, F.P., García-Pardo, I.P.: Principal component analysis applied to filtered signals for maintenance management. Qual. Reliab. Eng. Int. **26**, 523–527 (2010)

Internet of Things for Construction Project Management: A Systematic Literature Review

Ana Lara Medina, Virginia Herrera-Pérez, Luis Rodriguez-Passolas Cantal, and María Martínez Rojas(✉)

Universidad de Málaga, Málaga, Spain
mmrojas@uma.es

Abstract. The use of technologies based on the Internet of Things (IoT) in the construction sector has recently attracted the attention of many researchers and practitioners. Its use provides many advantages for project management, such as enabling better monitoring of execution, effective control, improved quality, cost and time savings. Also, it allows quick decisions to be made due to the availability of real-time data analysis. In this work, we review the literature through a systematic review of existing documents to explore the current situation of the sector and the different fields in which IoT is applied. In addition, we focus on the safety field to study the different technologies used and their benefits.

Keywords: Project management · Construction · Internet of Things · Systematic review

1 Introduction

The construction industry is undergoing a transformation due to the information and communication technologies [1, 2]. The transformation presents challenges at various levels, and project management is no exception. One of these Technologies is Internet of things, which is essentially a global network of devices that can communicate with one another and end users through the internet [3]. In the beginning, less than two decades ago, this network consisted almost exclusively of computers. But in the last decade, the IoT has exploded thanks to the proliferation of all kinds of devices that share data with each other and the world around them. In the context of project management, IoT may be useful for many purposes. For example, one of the fundamental tasks in the construction phase is related to Health and Safety Management due to the high accident rate in this sector [4]. The use of technologies to monitor or detect potential risks in real time can be of great interest to prevent or reduce the number of accidents.

The aim of this paper is to review the literature to explore the domains in which IoT can provide benefits for project management and related to safety management in construction.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 286–291, 2023.
https://doi.org/10.1007/978-3-031-27915-7_51

2 Methodology

A systematic review is an approach that identifies, selects, and evaluates all literature of a certain established level of quality that is relevant to a research question [5]. Figure 1 shows the main systematic review process carried out in this proposal.

The bibliographic search was limited to scientific publications from any country published in both Spanish and English. The preliminary search was performed in the reference database: ISI Web of Science. The period studied covers from 2008 to December 2021 in order to extract current results following recent trends in the scientific community.

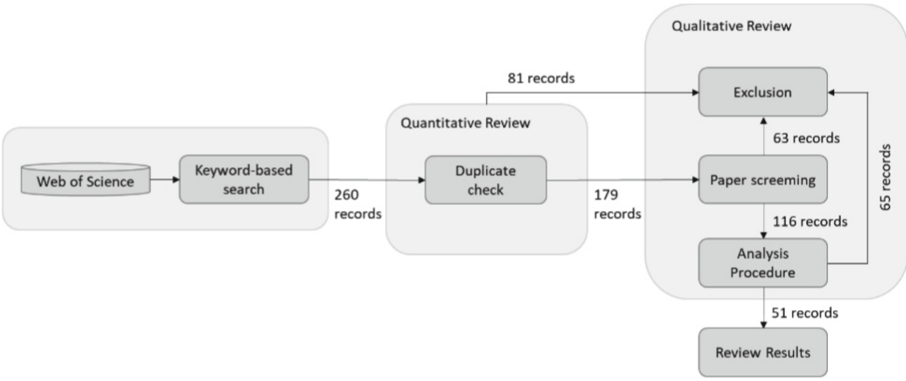


Fig. 1. Flowchart of systematic Literature review methodology

Keywords were combined through several searches using the "title/abstract/keyword" fields of the referenced database. The combined keywords were: "Internet of things", "Construction", "Project Management", "Safety" and "Occupational risk prevention".

As can be seen in Fig. 1, the searches obtained 260 results, which were subjected to a quantitative review in which the duplicates (81 records) were eliminated, obtaining 179 results. This was followed by a qualitative review. As a first step, documents were eliminated by title (63 records) and then the summary of each document was reviewed to eliminate those that did not deal with the subject of this work (65 records). Finally, and after this process, a total of 51 publications were obtained.

3 Results

3.1 Overall Results

The 51 papers obtained can be divided between conferences and journals, of which the majority are journals (69%), as shown in Fig. 2. As can be seen in this figure, in the early years the number of publications in journals is lower and there were a greater number of conferences, this is due to the fact that being a new emerging form of work was only being transmitted by “word of mouth”, through conferences. As knowledge and technologies become more established, more papers are published in reputable journals.

An upward trend line can be observed, as over the years and with new technological discoveries, research and publications have increased. Although during 2019 and 2020, a slight decrease is observed, probably due to the pandemic.

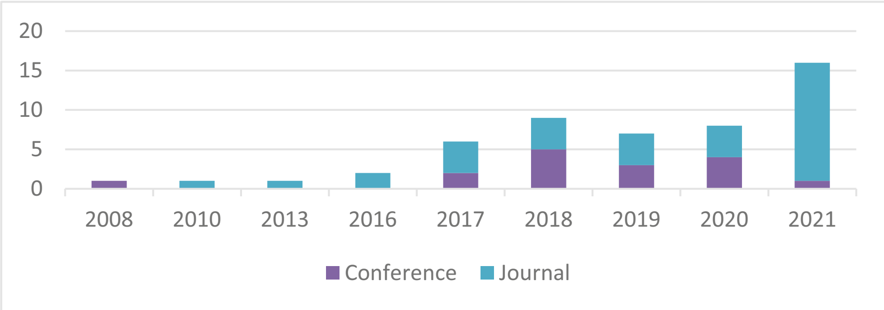


Fig. 2. Distribution of documents per years

The type of publication that can be seen in Fig. 3 are classified into four groups:

- Application (A): in which a theoretical or practical advance is performed.
- Study (S): research on some topic.
- Methodology (M): a roadmap, methodology or framework to follow is proposed.
- Review (R): bibliographic review.

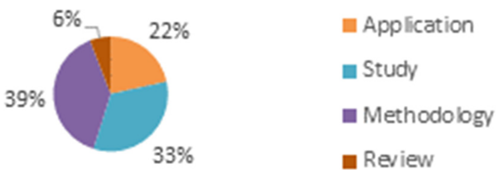


Fig. 3. Distribution of documents per type of publication

A variety of issues were encountered, including the following (Table 1):

Table 1. Topics present and number of documents referring to them

Topic	Quantity
BIM	17
Management	13
Safety	10
News	8
Prefabricated	6
Risks	4
Blockchain	2

The most prominent ones are Safety, the use of BIM (Building Information Management) and Management in general. This is due to the use of IOT as an aid for project management, as a tool to avoid accidents, and it is very useful in the early phases of projects, so it is combined with the use of BIM.

3.2 Specific Results

In this paper we have focused on the documents related to "safety", to which 10 papers belong. As mentioned, safety is one of the most recurrent topics in the papers related to the use of IoT in PM, this is because the technologies developed from the use of IoT are very useful to avoid risks and accidents at work, and they are also combined with other Technologies such as RFID, JGML or BIM (Table 2).

Table 2. Proposals focused on the use of IoT for the management of occupational risk prevention.

Work	Technology	Publication	Objective
[6]		S	Supervision of workers through IoT with the use of a device
[7]	RFID, FBG sensor	A	IOT-based real-time safety early warning system in subway construction
[8]	BIM	A	New smart barrier design method for hazardous energy in petrochemical construction
[9]	RFID	F	Improve safety by preventing unauthorized intrusions on the construction site
[1]	JGML	A	Preventing accidents due to falling objects in construction sites
[10]		S	Study of the use of IoT in construction and possible risks

(*continued*)

Table 2. (*continued*)

Work	Technology	Publication	Objective
[11]		S	Modular integrated construction
[12]	RFID, LoRa, BIM, Cloud Computing	F	Automatically manage real-time information on prefabrication project components
[13]	BIM	F	Analyse the current and future state of IOT in intelligent buildings. Propose the smart building system design and smart manufacturing architecture model based on IoTs technology
[14]	RFID, BIM	A	Platform enabled to solve Modular integrated construction problems

4 Conclusions

The aim of this article is to study the existing research on the use of IoT in construction project management and its evolution. In addition, we explore the different existing technologies used, with a focus on security.

The use of IOT has undergone a great increase in recent years, as we are living a great industrial revolution, giving rise to Industry 4.0. The number of research using IoT has also increased, as work in any industry is facilitated using IoT. But focusing on the construction sector, the possibilities offered using IoT are numerous.

One of the issues that has always been of concern to managers is the management of occupational risk prevention, as the lives of workers depend on it, which is why investment is currently being made in its development and research. The focus of safety management work is on coordinating safety practices, avoiding risks, preventing accidents through the combination of various technologies. The most notable technology, both for safety and for the construction sector in general, is BIM, which has opened a great path in which, together with the application of IoT, will promote the development of Industry4.0.

Acknowledgements. This work has been supported by the Spanish Ministry of Science and Innovation under the project "Complejidad y resiliencia: un enfoque sistémico para la Monitorización y mejora de la gestion de la seguridad en la construcción" (PID2020-114502GB-I00).

References

1. Martínez-Rojas, M., Soto-Hidalgo, J.M., Marín, N., Vila, M.A.: Using classification techniques for assigning work descriptions to task groups on the basis of construction vocabulary. Comput.-Aided Civ. Infrastruct. Eng. **33**(11), 966–981 (2018)
2. Demirkesen, S., Tezel, A.: Investigating major challenges for industry 4.0 adoption among construction companies. Eng. Construct. Architect. Manag. **29**(3), 1470–1503 (2021)

3. Martínez-Rojas, M., Gacto, M.J., Vitiello, A., Acampora, G., Soto-Hidalgo, J.M.: An internet of things and fuzzy markup language-based approach to prevent the risk of falling object accidents in the execution phase of construction projects. Sensors **21**(19), 6461 (2021)
4. Akinlolu, M., Haupt, T.C., Edwards, D.J., Simpeh, F.: A bibliometric review of the status and emerging research trends in construction safety management technologies. Int. J. Constr. Manag. **22**(14), 2699–2711 (2020)
5. Kitchenham, B., Charters, S.: Guidelines for performing systematic literature reviews in software engineering. Technical Report EBSE 2007-001, Keele University and Durham University Joint Report (2007)
6. Abbasianjahromi, H., Sohrab Ghazvini, E.: Developing a wearable device based on IoT to monitor the use of personal protective equipment in construction projects. Iran. J. Sci. Technol. Trans. Civ. Eng. **46**, 2561–2573 (2022). https://doi.org/10.1007/s40996-021-00716-6
7. Ding, L.Y., et al.: Real-time safety early warning system for cross passage construction in Yangtze Riverbed Metro Tunnel based on the Internet of Things. Autom. Constr. **36**, 25–37 (2013)
8. Ding, L., Jiang, W., Zhou, C.: IoT sensor-based BIM system for smart safety barriers of hazardous energy in petrochemical construction. Front. Eng. Manag. **9**, 1–15 (2022). https://doi.org/10.1007/s42524-021-0160-6
9. Jin, R., Zhang, H., Liu, D., Yan, X.: IoT-based detecting, locating, and alarming of unauthorized intrusion on construction sites. Autom. Constr. **118**, 103278 (2020)
10. Rane, S.B., Potdar, P.R., Rane, S.: Development of project risk management framework based on industry 4.0 technologies. Benchmarking Int. J. **28**(5), 1451–1481 (2021)
11. Song, H., Yu, H., Xiao, D., Li, Y.: Real-time warning model of highway engineering construction safety based on Internet of Things. Adv. Civ. Eng. **2021**, 1–10 (2021)
12. Yang, O.: Improved locating algorithm of railway tunnel personnel based on collaborative information fusion in Internet of Things. Trans. Inst. Meas. Control **39**(4), 446–454 (2017)
13. Zou, J., Zhao, Q., Jiao, B., Yang, W., Wang, J.: Integrated management of Internet of Things in Nanhai district and its application to smart city. In: 2017 Chinese Automation Congress (CAC), pp. 2814–2819. IEEE (2017)
14. Zhou, C., Ding, L.Y.: Safety barrier warning system for underground construction sites using Internet-of-Things technologies. Autom. Constr. **83**, 372–389 (2017)

Impact of Backordering on the Demand Forecasting Process

Eugenia Babiloni[1], Ester Guijarro[1], Diego J. Pedregal[2], and Juan R. Trapero[2](✉)

[1] Department of Business Organization, Universitat Politècnica de València, Valencia, Spain
{mabagri,esguitar}@doe.upv.es

[2] Department of Business Administration, University of Castilla-La Mancha, Ciudad Real, Spain
{diego.pedregal,juanramon.trapero}@uclm.es

Abstract. Backorders and lost-sales are two extreme situations that companies have to face when occurring stockouts. This work explores how the forecasting models should be enhanced to include inventory system information to improve their forecasting accuracy when facing backordering. A simulation with a periodic review (*R, S*) system has been carried out to identify the "best" forecasting model in terms of RMSE. The results show that the value of *R* should be included as a seasonality term to improve the results. Particularly, a ETS(A, N, A) provided the best results.

Keywords: Forecasting · Inventory · Sales · Demand · Backorder

1 Introduction

Demand forecasting is a strategic activity of supply chain management. Production planning decisions are usually driven by those forecasts. In this context, one of the first problems we have to face is to determine how demand is going to be measured. Many companies employ sales as a demand estimation. However, sales and demand are not exactly equal and in case of stockouts, sales become a demand biased estimator. Essentially, there exist two extreme situations in the presence of such stockouts. First, complete backordering, the client decides to wait until the product is available again, it is called a backordering context [1]. That situation may occur for example, in an industrial environment [2]. On the other hand, if the client is not willing to wait, then, we have a lost-sales situation [1]. Such a type of situations are typically found in retailing [3]. In practice, a mixed of both situations occurs, where a part of the demand is backordered and another part goes to lost-sales.

Interestingly, when selecting the "best" demand forecasting model/method, usually, the backordering/lost-sales context does not play an important role in that decision. In fact, most of the fundamentals forecasting texts do not explain how the forecasting demand should be modified to properly incorporate the fact that sales are used as a demand estimation. In general terms, forecasting model selection can be done by either identifying unobservable components as trend, seasonality and cycles in past data or

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 292–296, 2023.
https://doi.org/10.1007/978-3-031-27915-7_52

minimizing a loss function or an information criteria [4]. However, how the inventory assumptions (backordering/lost-sales context) influence the forecasting demand model selection has not been clearly investigated.

In the case of lost-sales, several works have been proposed [5, 6]. Note that, such a problem is very related to the censored demand estimation problem.

In this work, we centre on the backordering case. Possibly, the backordering case has attracted less attention because, at the end, the unsatisfied demand is somehow recorded. Nonetheless, how you incorporate the unmet demand into the sales data, which feeds the forecasting system, is not clearly defined and the literature is scarce. In this sense, one possibility is to work in an off-line fashion, i.e., sales series can be post-processed to incorporate excess demand at the right temporal instants, however, to the best of authors knowledge, no publication has dealt with that. Another possibility, which is able to work in an online fashion and/or when backorders are not recorded, is to consider the autocorrelation introduced in the sales because of the backordering process. In this case, when a stockout happens, sales, would underestimate the actual demand at that instant. However, as soon as the replenishment arrives, such orders would be included and sales will overestimate the actual demand. Therefore, the demand has been moved between time periods, what means that sales include demand delays when a stockout happens. Note that, by using the latter alternative, it is not necessary to post-process the sales series. We understand that this option would be easier to automate in case many products should be forecasted very frequently.

The objective of this paper is to explore how the different forecasting models should be modified to incorporate the backordering process when using sales as an input for the demand forecasting support system. To do this, we will explore two well-known forecasting models as ARIMA and Exponential Smoothing expressed in a State Space framework [7]. In addition, the inventory system is simulated by the periodic review, base-stock (*R, S*) system [1].

This paper is organized as follows: Sect. 2 explains the experimental design and explores the simulation results and, finally, Sect. 3 concludes the main findings of this research.

2 Experimental Design

This paper in based on an experiment with three phases: phase 1 is dedicated to simulate a periodic review (*R, S*) system; phase 2 refers to the forecasting process and, finally, phase 3 measures the performance of the different forecasting models.

2.1 Phase 1: Simulation of the (*R, S*) System and Generate Time Series

The periodic review system is one of the most common inventory systems and consists of reviewing the inventory status every R periods and launch a replenishment order to reach the base-stock, S. We run a Monte Carlo simulation with the (R, S) system that considers 500 consecutive periods (instants) with the following considerations: (1) demand process is randomly generated following a independent and identically distributed (i.i.d.) Poisson process with $\lambda = 3{,}000$, which is represented as d_t; (2) the lead time, L, is known and constant; (3) there is never more than one outstanding order which implies that the lead time is strictly less than the review period, i.e. $L < R$; (4) The time between two consecutive deliveries is the replenishment cycle and is equal to R; (5) demand that is not fulfilled immediately is backordered and served as soon as possible; (6) the replenishment order is added to the inventory at the end of the period in which it is received and therefore it is available for the next period. After running the simulation we obtain the following time series:

$d_t \rightarrow$ data generating process (unobserved demand) per period t.
$b_t \rightarrow$ backorders per period t
$B_R \rightarrow$ accumulated backorders per replenishment cycle R
$SB_t \rightarrow S_t + B_R$, if t is the first period of a replenishment cycle, and S_t, elsewhere.

In the simulation exercise, we employed a set of values of $R = 5$; $L = 2$; and $S =$ 20,000. Table 1 shows the first 8 periods of the simulation. Note that Sales is lower than demand in periods 6, 7 and 8 because of stockouts and that, when the replenishment arrives, sales is greater than demand (period 8).

Table 1. Some periods as a result of the inventory system (R, S) simulation.

Period (t)	Demand (d_t)	Backorders per period (b_t)	Backorders per cycle (B_T)	Sales (SB_t)
1	5000	0		5000
2	3000	0	0	3000
3	2000	0		2000
4	5000	0		5000
5	6000	1000		5000
6	1000	1000		0
7	1000	1000	3000	0
8	2000	0		5000

2.2 Phase 2: Forecasting

This phase is dedicated to calculate the forecasts of SB_t. Given that, the actual demand (d_t) is i.i.d. there is not any correlation in the demand data. However, one of the main changes if using sales rather than demand, it is the appearance of autocorrelation as shown in Fig. 1.

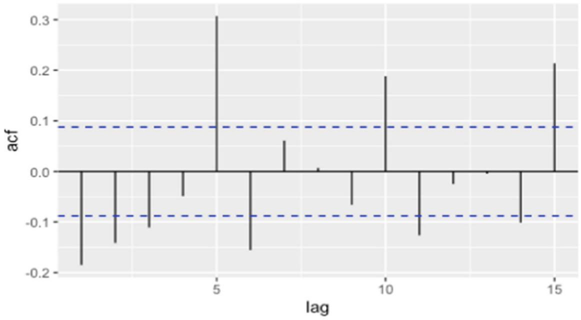


Fig. 1. Sales autocorrelation plot.

Note that, the autocorrelation is mostly significant at lag 5 which corresponds with the *R* value. It means that, when the replenishment arrives, all the past backorders are satisfied at the same time. Since the replenishment arrives periodically because of the periodic review inherent to the system (*R, S*), the sales signal becomes also periodic. Thus, we have verified that the inventory assumption (backordering) and system (*R, S*) provides information that should be considered in the forecasting modeling process to improve the forecasting accuracy.

The next step is to carry out a forecasting exercise with different models to incorporate efficiently the aforementioned autocorrelation. First, a single exponential smoothing will be tested as a benchmark. Then, an ARIMA model and an exponential smoothing model in a State Space format will be proposed, both of them automatically identified by the package fabble in *R* [7]. The automatic identification results in an ARIMA(1, 0, 5) and an ETS(A, N, A). Note that ETS(A, N, A) means an exponential smoothing with additive Error, without Trend and with additive Seasonality, where the seasonal period is 5, which coincides with the review interval *R*. Interestingly, the auto ARIMA also identifies the lag 5 as an important piece of information to be considered in the model.

2.3 Phase 3: Performance of Forecasting Models

To measure the performance of the different forecasting models. Root Mean Squared Error (RMSE) on the hold-out sample are used. The data has been divided in 250 observation for estimation and the rest of data as a hold-out sample. RMSE is a measure related with the size of the safety stock that also relates to the determination of the reorder point. Figure 2 shows the RMSE obtained for the considered forecasting models for different forecasting horizons. Note that, such a figure is the result of a rolling origin forecasting experiment. That figure also shows how the ETS(A, N, A) model achieves the lowest RMSE providing the best performance.

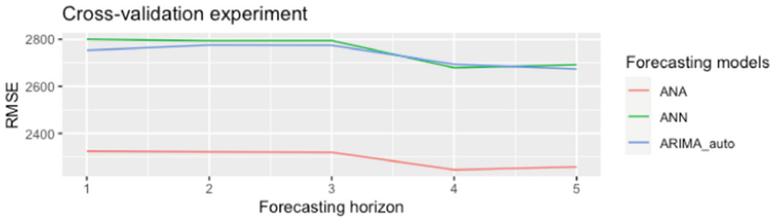


Fig. 2. RMSE vs forecasting horizon obtained by a cross-validation experiment.

3 Conclusion

Sales is a typical record that companies use as an input for its demand Forecasting Support System. Nevertheless, when a stockout happens, sales and demand diverge. This work explores what happens when occurring stockouts and the company uses sales as a demand estimator and works under both a backordering context and a (R, S) stock policy. The simulation results show that, although, the demand is i.i.d., sales is not and a seasonality pattern turns out in sales at lag R that should be included in the candidate forecasting models. In fact, an ETS(A, N, A) which uses an additive seasonality provides the best results in comparison with typical SES and ARIMA models in terms of the RMSE error metric.

Acknowledgements. This research was supported by the European Regional Development Fund and Junta de Comunidades de Castilla-La Mancha (JCCM/FEDER, UE) under the project with reference SBPLY/19/180501/000151.

References

1. Silver, E.A., Pyke, D.F., Peterson, R.: Inventory and Production Management in Supply Chains. Taylor and Francis Group (2017)
2. Bijvank, M., Vis, I.F.A.: Lost-sales inventory theory: a review. Eur. J. Oper. Res. **215**, 1–13 (2011)
3. Gruen, T.W., Corsten, D., Bharadwaj, S.: Retail Out-of-Stocks: A Worldwide Examination of Extent Causes, Rates and Consumer Responses. Grocery Manufacturers of America, Washington, D.C. (2002)
4. Ord, K., Fildes, R.A., Kourentzes, N.: Principles of Business Forecasting, 2nd edn. Wessex Press Inc., New York (2017)
5. Nahmias, S.: Demand estimation in lost sales inventory systems. Nav. Res. Logist. **41**, 739–757 (1994)
6. Lau, H.-S., Hing-Ling Lau, A.: Estimating the demand distributions of single-period items having frequent stockouts. Eur. J. Oper. Res. **92**, 254–265 (1996). https://doi.org/10.1016/0377-2217(95)00134-4
7. Hyndman, R.J., Athanasopoulos, G.: Forecasting: Principles and Practice, 3rd edn. OTexts, Melbourne (2021). OTexts.com/fpp3. Accessed 08 June 2022

Automated Identification of Photovoltaic Panels with Hot Spots by Using Convolutional Neural Networks

Jorge Bernabé Sanjuán[1,3], Carlos Quiterio Gómez Muñoz[1,2,3](✉), and Fausto Pedro Garcia Marquez[2,3]

[1] Universidad Europea de Madrid, 28001 Madrid, Spain
carlosq.gomez@uam.es
[2] HCTLab Research Group, Electronics and Communications Technology Department, Universidad Autonoma de Madrid, 28049 Madrid, Spain
FaustoPedro.Garcia@uclm.es
[3] Ingenium Research Group, Universidad de Castilla-La Mancha, Ciudad Real, Spain

Abstract. The field of artificial intelligence is experiencing a great interest in manufacturing companies for the inspection of parts and verification of images. The current trend in the sector is to implement these novel methodologies in industrial environments because they can benefit from their advantages over traditional systems. Quality and production managers are increasingly interested in replacing the classic inspection methods with this new approach due to its flexibility and precision. In an industrial environment, these disturbances can be changes in lighting during the day the appearance of external elements such as dust or dirt. The use of new convolutional neural network techniques allows training including disturbance scenarios, teaching the artificial neural network to detect non-verse defects influenced by changes in light or by the appearance of dust. This work studies the implementation of a hybrid model based on a cascade detection neural network with a classification neural network in an industrial environment.

Keywords: Neural networks · Fault detection · Vibrations · Riveting machines · Deep learning

1 Introduction

This work explores the use of different artificial intelligence techniques to detect faults in photovoltaic panels. This is generally carried out manually by a technician, which generates high maintenance costs. However, thanks to advances in Artificial Intelligence (AI), these types of challenges can be addressed in a new way [1, 2]. It is possible to teach a machine to recognize panels by indicating which of them is a panel, and which is not using thousands of images [3–5].

The main objective of this study is to detect the appearance of hot spots in solar panels. These hot spots are caused by a malfunction or deterioration by one of the solar cells. This means that the cell does not convert solar radiation into electrical energy [6].

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 297–302, 2023.
https://doi.org/10.1007/978-3-031-27915-7_53

It behaves like a short circuit causing it to overheat. This thermal radiation is easily detectable by infrared cameras or thermal imaging cameras [7]. These cameras can be mounted on drones that fly autonomously, or controlled by a pilot, across the entire surface of the PV farm, capturing images in which these hot cells are shown as bright spots [8]. The images can be used to teach a neural network to recognize those panels with hot spots, and it is possible to obtain the GPS position of these panels [9]. This allows automating the maintenance work of the solar plant (i.e., farm) together with the use of IoT systems [10–12].

The purpose of this work is to identify solar panels with defects automatically from a video or a sequence of images by using neural networks. With the use of a combination of two cascaded neural networks instead of a single one increases the precision of the results because each of them specializes in a single purpose.

Non-destructive tests are tests based on physical principles, and the results needed to diagnose the status, quality, or condition of the inspected object [13–15]. This type of NDT is characterized by low cost and great versatility [16–19]. Failures are caused by the malfunction of the components of the solar cells. When a solar cell degrades, instead of transforming solar radiation into energy, these are short-circuited and consume the energy of that cell and that of neighbouring cells, generating heat and causing a decrease in the panel efficiency [3, 20–23].

Deep learning is a subtype of machine learning that consists of training a model to perform classification tasks from images, texts, sounds, or any dataset [24]. The term "Deep" is a reference to the number of layers [25, 26]. These algorithms have advanced to the point of overcoming human accuracy when it comes to classifying images [27–30]. There is a common problem with a high rate of false positives in detecting hot spots due to glare and reflections from the sun on the PV panel and on its frames. Thereby, the training will be focused to reduce false positives and to be able to differentiate between the brightness of hot spots and those that are simple reflections of the sun, using a small extra neural network.

2 Methology

The methodology contains two different specialized systems. The first of them is responsible for detecting all the panels within an image. Then each panel passes to another system that is responsible for classifying whether the panel is defective or not. The steps to accomplish this are:

- Labelling and segmentation of individual panels
- Panel detector training
- Trimming and manually sorting panels
- Second neural network training for panel classification
- Integration of both networks a single system

The images were obtained by a Workswell WIRIS 640 camera mounted on the drone (UAV), acquire an aerial view of the panels from different angles and heights, with multiple panels at the same time in a frame [31]. However, despite being a thermal camera that captures the images, it shows other bright spots that are not hot spots, but reflections of the sun. Due to the existence of these reflections, it is not possible to use simpler algorithms that filter by tonalities. These bright spots (not hot spots) depend on the position of the drone relative to the position of the sun and the tilt of the panels.

A convolutional neural network (CNN) is one of the most used deep learning algorithms for image and video processing. In order to reduce computational costs, a hybrid combination of limited, but also more specialized, networks is proposed. The output of this neural network are the bounding boxes that each of the detected PV panels continue. New images of individual panels are then cropped and obtained and fed into a second neural network dedicated to the detection of faults within the panels. The use of this hybrid system presents several advantages over a single extremely large neural network. However, the most significant advantage is the computational cost [32]. One of the problems with convolutional neural networks is the limitation of the size of the images to be processed. Since the dataset is made up of thousands of images, training the network with large images would involve several problems. An alternative consists in finding panels and isolating them within a new image. This is done using a deep learning function known as Regions with Convolutional Neural Networks (R-CNN) (see Fig. 1). Therefore, an image of several panels can be read, and broken down into more manageable individual panels.

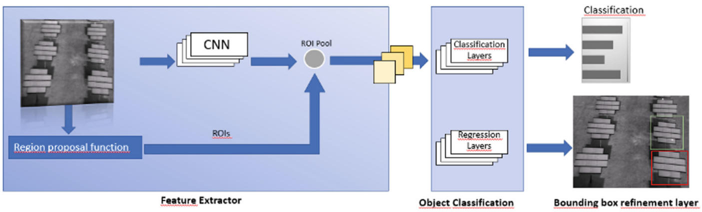


Fig. 1. R-CNN object detector structure.

These regions enter as separate images on the R-CNN. The objective of this network is to classify the cropped panel images created in the previous section into two folders identified by "Defect" and "No Defect". Unlike the previous network where only the panels had to be distinguished from the rest of the image, this network classifies if the panel belongs to one category or another. There are some very powerful pre-trained deep neural networks that have been tested and verified to check which ones have the most suitable characteristics and have a lower computational cost for this task, e.g., Darknet53, Resnet50 and GoogleNet. Once all the images have been manually classified, a test bench has been carried out with different pre-trained networks to empirically verify which of them offers the best accuracy in the classification task. It was experimentally verified that the architecture that gave the best results was GoogleNet (see Fig. 2).

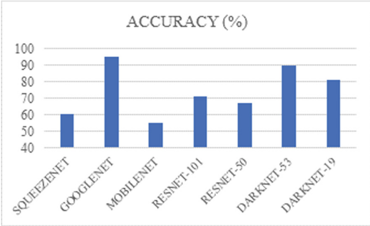


Fig. 2. Accuracy comparison of different artificial neural networks

With an input image resolution of 224 × 224 × 3, it is high enough for that bright spots within the panel to be recognized and powerful enough to distinguish between the false positives of the reflections and the actual hot spots [33]. After training the neural network, it returns a value of "Validation Accuracy" of 99.86%. The neural network has detected and pointed out all the full panels of the image, completely ignoring the partials with a recognition certainty of at least 98.5% and maximum of 99.8%. This certainty is based on how "similar". It is to the database, which it has been trained, being 1 absolute certainty. After the successful identification of the PV panels by the R-CNN, the program can complete the last step: classifying the panels.

3 Conclusıons

In this research work, the following conclusions have been successfully achieved:

- The detection of panels autonomous by convolutional neural networks has been achieved with a high index of validation accuracy
- The classification model of panels by presence of defects has been trained until obtaining a validation accuracy of 99.89%
- A software solution has been created that combines the two methodologies to give an innovative solution incorporating different types of neural networks in a single integral function.
- Due to the panel detector has been created with an R-CNN type, it is designed to be used with any input image size.This would allow to take images at a higher height, covering more terrain and thus optimizing the process of obtaining images.
- With the implementation of this tool combined with the drone and camera would allow solar plants to be more competitive in the energy market and boost the growth of this increasingly necessary renewable energy source.

Acknowledgments. The work reported herewith has been financially supported by the Spanish Ministerio de Economía y Competitividad, under the Research Grant RTC2019-007364-3.

References

1. García Márquez, F.P., Peinado Gonzalo, A.: A comprehensive review of artificial intelligence and wind energy. Arch. Comput. Methods Eng. **29**, 2935–2958 (2022). https://doi.org/10.1007/s11831-021-09678-4
2. Peco Chacón, A.M., Segovia Ramírez, I., García Márquez, F.P.: State of the art of artificial intelligence applied for false alarms in wind turbines. Arch. Comput. Methods Eng. **29**, 2659–2683 (2022). https://doi.org/10.1007/s11831-021-09671-x
3. Gómez Muñoz, C.Q., García Márquez, F.P.: Future maintenance management in renewable energies. In: García Márquez, F., Karyotakis, A., Papaelias, M. (eds.) Renewable Energies, pp. 149–159. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-45364-4_10
4. Márquez, F.P.G., Ramírez, I.S.: Condition monitoring system for solar power plants with radiometric and thermographic sensors embedded in unmanned aerial vehicles. Measurement **139**, 152–162 (2019)
5. Salam, R.A., et al.: An overview on energy and development of energy integration in major South Asian countries: the building sector. Energies **13**, 5776 (2020)
6. Rezazadeh, S., Moradzadeh, A., Pourhossein, K., Mohammadi-Ivatloo, B., García Márquez, F.P.: Photovoltaic array reconfiguration under partial shading conditions for maximum power extraction via knight's tour technique. J. Ambient Intell. Human. Comput. 1–23 (2022). https://doi.org/10.1007/s12652-022-03723-1
7. Segovia Ramirez, I., Das, B., Garcia Marquez, F.P.: Fault detection and diagnosis in photovoltaic panels by radiometric sensors embedded in unmanned aerial vehicles. Prog. Photovoltaics Res. Appl. **30**, 240–256 (2022)
8. Ramírez, I.S., Chaparro, J.R.P., Márquez, F.P.G.: Unmanned aerial vehicle integrated real time kinematic in infrared inspection of photovoltaic panels. Measurement **188**, 110536 (2022)
9. Segovia, I., Pliego, A., Márquez, F.P.G.: A novel approach to optimize the positioning and measurement parameters in photovoltaic aerial inspections. Renew. Energy **187**, 371–389 (2022)
10. Jiménez, A.A., Muñoz, C.Q.G., Marquez, F.P.G., Zhang, L.: Artificial intelligence for concentrated solar plant maintenance management. In: Xu, J., Hajiyev, A., Nickel, S., Gen, M. (eds.) Proceedings of the Tenth International Conference on Management Science and Engineering Management. AISC, vol. 502, pp. 125–134. Springer, Singapore (2017). https://doi.org/10.1007/978-981-10-1837-4_11
11. Gómez, C.Q., Villegas, M.A., García, F.P., Pedregal, D.J.: Big data and web intelligence for condition monitoring: a case study on wind turbines. In: Handbook of Research on Trends and Future Directions in Big Data and Web Intelligence, pp. 149–163. IGI global (2015)
12. Marquez, F.P.G.: An approach to remote condition monitoring systems management. In: 2006 IET International Conference on Railway Condition Monitoring, pp. 156–160. IET (2006)
13. Gomez Munoz, C.Q., Garcia Marquez, F.P.: A new fault location approach for acoustic emission techniques in wind turbines. Energies **9**, 40 (2016)
14. Jiménez, A.A., Márquez, F.P.G., Moraleda, V.B., Muñoz, C.Q.G.: Linear and nonlinear features and machine learning for wind turbine blade ice detection and diagnosis. Renew. Energy **132**, 1034–1048 (2019)
15. Ramirez, I.S., Muñoz, C.Q.G., Marquez, F.P.G.: A condition monitoring system for blades of wind turbine maintenance management. In: Xu, J., Hajiyev, A., Nickel, S., Gen, M. (eds.) Proceedings of the Tenth International Conference on Management Science and Engineering Management. AISC, vol. 502, pp. 3–11. Springer, Singapore (2017). https://doi.org/10.1007/978-981-10-1837-4_1
16. Gómez Muñoz, C.Q., García Marquez, F.P., Hernandez Crespo, B., Makaya, K.: Structural health monitoring for delamination detection and location in wind turbine blades employing guided waves. Wind Energy **22**, 698–711 (2019)

17. Jiménez, A.A., Muñoz, C.Q.G., Márquez, F.P.G.: Dirt and mud detection and diagnosis on a wind turbine blade employing guided waves and supervised learning classifiers. Reliab. Eng. Syst. Saf. **184**, 2–12 (2019)
18. Muñoz, C.Q.G., Márquez, F.P.G.: Wind energy power prospective. In: Márquez, F.P.G., Karyotakis, A., Papaelias, M. (eds.) Renewable Energies, pp. 83–95. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-45364-4_6
19. Gómez, C.Q., García Márquez, F.P., Arcos, A., Cheng, L., Kogia, M., Papaelias, M.: Calculus of the defect severity with EMATs by analyzing the attenuation curves of the guided waves (2016)
20. Hantula, R.: How do Solar Panels Work? Infobase Publishing (2009)
21. Jiménez, A.A., Gómez, C.Q., Márquez, F.P.G.: Concentrated solar plants management: Big data and neural network. In: Márquez, F.P.G., Karyotakis, A., Papaelias, M. (eds.) Renewable Energies, pp. 63–81. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-45364-4_5
22. Montoya, J.C., Muñoz, C.Q.G., Márquez, F.P.G.: Remote condition monitoring for photovoltaic systems. In: Non-Destructive Testing and Condition Monitoring Techniques for Renewable Energy Industrial Assets, pp. 133–142. Elsevier (2020)
23. Ramirez, I.S., Marquez, F.P.G.: Fault detection and identification for maintenance management. In: Jiuping, Xu., Duca, G., Ahmed, S.E., Márquez, F.P.G., Hajiyev, A. (eds.) ICMSEM 2020. AISC. vol. 1190, pp. 460–469. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-49829-0_34
24. Jiménez, A.A., Zhang, L., Muñoz, C.Q.G., Márquez, F.P.G.: Maintenance management based on machine learning and nonlinear features in wind turbines. Renew. Energy **146**, 316–328 (2020)
25. García Márquez, F.P., Segovia Ramírez, I., Pliego Marugán, A.: Decision making using logical decision tree and binary decision diagrams: a real case study of wind turbine manufacturing. Energies **12**, 1753 (2019)
26. Chacón, A.M.P., Ramirez, I.S., Márquez, F.P.G.: Support vector machine for false alarm detection in wind turbine management. In: 2021 7th International Conference on Control, Instrumentation and Automation (ICCIA), pp. 1–5. IEEE (2021)
27. Herraiz, Á.H., Marugán, A.P., Márquez, F.P.G.: Optimal productivity in solar power plants based on machine learning and engineering management. In: Jiuping, Xu., Cooke, F.L., Gen, M., Ahmed, S.E. (eds.) ICMSEM 2018. LNMUINEN, pp. 983–994. Springer, Cham (2019). https://doi.org/10.1007/978-3-319-93351-1_77
28. Herraiz, Á.H., Marugán, A.P., Márquez, F.P.G.: Photovoltaic plant condition monitoring using thermal images analysis by convolutional neural network-based structure. Renew. Energy **153**, 334–348 (2020)
29. García Márquez, F.P., Segovia Ramírez, I., Mohammadi-Ivatloo, B., Marugán, A.P.: Reliability dynamic analysis by fault trees and binary decision diagrams. Information **11**, 324 (2020)
30. Sadeghian, O., Moradzadeh, A., Mohammadi-Ivatloo, B., Abapour, M., Garcia Marquez, F.P.: Generation units maintenance in combined heat and power integrated systems using the mixed integer quadratic programming approach. Energies **13**, 2840 (2020)
31. Bemposta Rosende, S., Sánchez-Soriano, J., Gómez Muñoz, C.Q., Fernández Andrés, J.J.E.: Remote management architecture of UAV fleets for maintenance, surveillance, and security tasks in solar power plants. Energies **13**, 5712 (2020)
32. Saponara, S., Elhanashi, A., Gagliardi, A.: Exploiting R-CNN for video smoke/fire sensing in antifire surveillance indoor and outdoor systems for smart cities. In: 2020 IEEE International Conference on Smart Computing (SMARTCOMP), pp. 392–397. IEEE (2020)
33. Pliego Marugán, A., García Márquez, F.P.: Advanced analytics for detection and diagnosis of false alarms and faults: a real case study. Wind Energy **22**, 1622–1635 (2019)

Energy Communities in Spain: Challenges in the Transition to Institutionalisation

Sara Romero-Muñoz[1](✉), Teresa Sánchez-Chaparro[2], Ruth Carrasco-Gallego[2], and Carlos Sánchez[3]

[1] Innovation and Technology for Development Centre, Universidad Politécnica de Madrid, Avenida Complutense, s/n, 28040 Madrid, Spain
sara.romero@upm.es

[2] Department of Industrial Engineering, Business Administration and Statistics, Escuela Técnica Superior de Ingenieros Industriales, Universidad Politécnica de Madrid, c/José Gutiérrez Abascal, 2, 28006 Madrid, Spain

[3] Climate and Energy Municipal Foundation, Valencia City Council, c/Joan Verdeguer, 16, 46024 Valencia, Spain

Abstract. European energy regulation from 2019 introduces a new legal figure in the energy supply chain: the "citizen energy community". It has been translated into the Spanish regulation as Local Energy Communities and Renewable Energy Communities. This allows agents not previously involved in the production and distribution of electricity to be integrated into the energy system beyond their role as consumers (prosumers). Several challenges have been identified in this paper for institutionalization of niches of energy co-production into the energy regimen configuration.

Keywords: Local energy communities · Energy policy · Co-production · Prosumer · Sustainable development goals

1 Introduction

The production and distribution of energy in Spain has been managed by the public sector since the beginning of the industrial electrification process in the country, in 1876. Since the late 1990s, a process of privatisation of the sector began, which has continued up to the present day. Recently, the European Union has developed new energy regulation, EU Directives 2018/2001 and 2019/944 [1, 2], introducing a new legal figure in the energy supply chain: the "citizen energy community", translated into the Spanish regulation [3] as Local Energy Communities (Comunidades Ciudadanas de Energía) and Renewable Energy Communities (Comunidades de Energías Renovables). This allows agents not previously involved in the production and distribution of electricity to be integrated into the energy system beyond their role as consumers. They can be natural persons—individuals—or legal entities—municipalities, local public bodies, SMEs or cooperatives. This regulation and its transposition to Spain is altering the configuration of the energy supply chain in our country, giving rise to a new agent: the prosumer [4],

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 303–308, 2023.
https://doi.org/10.1007/978-3-031-27915-7_54

who produces and self-consumes his own energy, and sells the rest of his production to the established energy system.

It is worth noticing that practices of co-production of energy in Europe and particularly in Spain are not new. They started in the decade of 1960 in the UK promoted by citizen initiatives. In Spain, the development of bottom-up practices of energy co-production started decades later, in the 2000s. To date, in Spain there are 21 initiatives related to local Energy Communities (EC), according to the interactive map developed by IDAE[1], the National Institute for Energy Diversification and Saving. However, with the new regulatory framework from 2018–2019, we are witnessing a process of institutionalisation of this kind of initiatives. At this moment, some municipalities in Spain are participating in ECs either as promoters or participants.

The following section exposes the objectives of this paper. Third section exposes the analytical framework or the analysis. The next section introduces the methodology applied. Results are presented in the fifth section, and the final section concludes with points to discuss and consider the prospects for more transition analysis.

2 Objectives

Up to our knowledge, the process of institutionalisation of EC from a socio-technical transition perspective has not been studied so far in Spain. Our research intends to contribute to this gap by addressing the following questions: *What are the challenges posed by this institutionalisation?, and what strategies are being adopted to ensure their sustainability at all levels, i.e., that the innovation tested in bottom-up practices becomes part of the regime in a sustainable way?*.

Our research adopts a case-study methodology and focuses on the ECs developed in the city Valencia. It is worth noticing that while focusing on a single case, our research also considers the interrelationship between local policy and national and European strategies and policies in the energy field, which requires an inter-scale approach to policies.

3 Theoretical Framework

The theoretical framework of this research is the socio-technical transitions perspective, and particularly the multi-level perspective [5, 6]. From this theoretical angle, the process of institutionalization of EC initiatives taking place since 2018–2019, could be conceptualized as an evolution in transition from niche innovations—bottom-up initiatives, driven by citizens, small companies and cooperatives without public intervention—to more hybrid emerging models—under the energy market and policy "regimes"[2] with public intervention.

[1] IDAE map of EC in Spain: https://cutt.ly/nGxPPcU.

[2] Energy 'regimes': the actors, networks, and institutions that understand energy as the commodity provision of gas and electricity; dominated by a regulated market of a handful of multinational utilities operating centralised energy systems; distributed to relatively passive energy consumers (cf. Active energy citizens); and where political preoccupation focuses on coaxing investment in energy security and decarbonisation of supplies (6).

In Spain, contemporary researchers are applying the transitions perspective to analyse niche innovations in the agro-industrial and energy sector [6–8]. Its conclusions are relevant to this article because of its understanding of the tensions between niches and regimes.

4 Methods

The methodological approach is qualitative, based on a case study methodology [9]. The case study explores how the EC emerged in the city of Valencia, in Spain, with the support of the Valencia City Council. Nowadays there are two ECs producing renewable energy ("Castellar-l'Oliveral" and "l'Illa y Aiora"). The Valencia case is particularly relevant for the purposes of our research as Valencia ECs has been recognized as a reference case of social innovation for climate neutrality at European scale by the European Platform Net Zero Cities[3]—an EU-funded initiative to support cities facing climate neutrality objectives until 2030[4].

The following sources of information were used during the investigation: focus group with energy experts, semi-structured interview, and key document analysis. In particular, the objective of the focus group[5] was to identify what opportunities and barriers to scalability of EC. Attendance was a success, with 40 energy experts in total, with the following representativeness: 14 professionals from energy private services, from multinational energy companies to energy cooperatives; 18 civil servants from City Councils and National Business Entity of the Ministry of Science and Innovation; 5 professors from two Spanish technical universities; 3 professionals in legal and financing services. The focus-group was developed in February 2021 in a virtual format because of the pandemic restrictions.

Personal semi-structured interview was conducted with the main promoter agent of ECs in the city of Valencia, the Director of the Climate and Energy Foundation of the Valencia City Council, to contrast the reflections from the focus-group.

Finally, key documents analysis reviewed were: energy policies at different scales (EU Directives, PNIEC, IDAE Guidebook); documents produced by Valencia ECs (statutes and procedures); Spanish local energy cooperatives documentation (as La Corriente Cooperative or Pylon Energy Community). News and public statements are also being considered to update the understanding of the Spanish energy regime.

5 Results: Challenges in the EC Transition from Niche Practices to Regimen Configuration

Table 1 summarises the main challenges linked to the institutionalization and scaling-up of ECs according to the seven dimensions that characterise a transition process from the socio-technical transitions perspective [5]: technology, user practices and markets,

[3] Net Zero Cities website: https://netzerocities.eu/.
[4] EU Mission: Climate-Neutral Cities by 2030, by and for citizens: https://cutt.ly/uGxPT1z.
[5] Detail information and video recorded: https://cutt.ly/MGxPRrg.

symbolic meaning and culture, infrastructure, industry structure, policy and techno-scientific knowledge.

This allows us to analyse in which dimensions the institutionalisation process is being underpinned. It has also facilitated the identification of two new dimensions contributed by the focus-group and case study participants, added to the table.

Table 1. Challenges linked to institutionalization of ECs (source: own elaboration)

Dimension	Challenges of the institutionalization and scaling-up of ECs
Prosumers practices and preferences. *Renamed by the authors*	- Take advantage of lessons learned, successes and failures, from the co-production energy niches generated since the 1960s in Europe, and since the 2000s in Spain - Generate incentives to accelerate members' adherence to ECs by contagion from nearby successful cases
Market conditions and competing incentives. *It has been divided from the category above and renamed it*	- To compete with the high penetration of gas as an energy source in our country - Possible negotiation with the distribution companies for the discharge of surplus energy from ECs into the general grid - Generation of quality and new economic employment in depopulated areas - Development of training programmes to generate local capacities in energy management
Technology	No challenges are collected
Infrastructure	- Potential technological problems due to possible overloading of the power grid due to surplus energy from ECs - Limitations of available space in large cities to install renewable energy systems
Industry structure	Tensions in the process of opening up the current oligopolistic centralised energy market in Spain to a potential decentralised market, under fair and competitive conditions
Techno-scientific knowledge	No challenges are collected
Policy	- Pending the transposition of the EU Directives into more specific Spanish regulations (IDAE's Guidebook[6] are not sufficient as a regulatory instrument) - Adjust some requirements regulated by Europe (such as the maximum radius of 500 m to involve the neighbourhood) - Solve inconsistencies between regulations (e.g., between the Royal Decree on renewable energies and the EU Directive)

(*continued*)

6 IDAE's Guidebook: https://cutt.ly/7GcGIbA.

Table 1. (*continued*)

Dimension	Challenges of the institutionalization and scaling-up of ECs
Governance, management and financing model. *New category added by the authors*	- Need for a one-stop shop procedure, which reduces administrative hurdles and facilitates internal coordination between different public administrations -Mechanisms for public-private collaboration (e.g., transfer of public land/infrastructure to private agents and vice versa, management of hybrid financing models, etc.) - Offering financing models according to the socio-economic level (subsidies for low incomes, credit options, etc.) - Provide a flexible and quality support service ("turnkey solution") easily accessible from a network of energy service offices distributed in the districts (technical, legal and economic advice) - Develop open tools for monitoring by EC members and non-members - Relying on potential prescribers such as Property Administrators (key agents for dialogue with neighbourhood communities)
Symbolic meaning and culture	- The restrictive narrative of the previous regulation persists, more restrictive about energy self-consumption and colloquially known as the "sun tax" - Crisis of trust and legitimacy between the public administration and citizens - Democratisation of energy production, increased power of the prosumer role - Narrative focused on socio-economic benefits: reduction in electricity bills, tax benefits, other co-benefits, etc. - Managing resistance in the transition from a centralised supply chain model to a decentralised model

6 Discussion and Conclusion

The results of this analysis reveal that the process of institutionalisation of ECs is "nudging" the emergence of new ECs. Indeed, the new EC legal figure could be explained as a "nudge" in Thaler's sense [10 p. 6]: an aspect of the "choice architecture" that could alter people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives. Public administration intervention ensures universal and equitable access to energy services for the most vulnerable households. The introduction of new elements in a supply system/network changed the incentive structures and situation of other elements. New opportunities opened up which guided actors in different directions. In this paper, we have shown that the 'breaking out' of radical innovations in energy co-production can be understood as a process of "niche-cumulation", in terms of Geels [5]. Scaling is usually far from a linear inevitability and the development of a product, service or practice innovation may be just the beginning of a process of generating impact.

It is necessary to indicate that the reflections expressed in this paper should be taken as exploratory, due to the novelty of the topic. What can be concluded is that the energy supply chain is at the beginning of a deep reconfiguration if prosumers and co-production practices scale-up. Institutionalisation of ECs can accelerate the emergence of multi-actor collaborations in Spain and Europe, and with it, the energy transition to renewable sources in a more granular way.

References

1. Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources. https://www.boe.es/doue/2018/328/L00082-00209.pdf
2. Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 concerning common rules for the internal market in electricity and amending Directive 2012/27/EU. https://www.boe.es/doue/2019/158/L00125-00199.pdf
3. Plan Nacional Integrado de Energía y Clima (PNIEC) 2021–2030. [Gobierno de España]. https://www.miteco.gob.es/images/es/pnieccompleto_tcm30-508410.pdf
4. Toffler, A.: The Third Wave, vol. 484. Bantam Books, New York (1980). https://doi.org/10.1016/0016-3287(80)90006-3
5. Geels, F.W.: Technological transitions as evolutionary reconfiguration processes: a multilevel perspective and a case-study. Res. Policy **31**(8–9), 1257–1274 (2002). https://doi.org/10.1016/S0048-7333(02)00062-8
6. Smith, A., Hargreaves, T., Hielscher, S., Martiskainen, M., Seyfang, G.: Making the most of community energies: three perspectives on grassroots innovation. Environ. Plan. A **48**(2), 407–432 (2016). https://doi.org/10.1177/0308518X15597908
7. Pellicer-Sifres, V., Belda-Miquel, S., Cuesta-Fernández, I., Boni, A.: Learning, transformative action, and grassroots innovation: insights from the Spanish energy cooperative Som Energia. Energy Res. Soc. Sci. **42**, 100–111 (2018). https://doi.org/10.1016/j.erss.2018.03.001
8. Isern, S.R.: Reapropiación popular de la energía en los albores de una transición incierta. Una contribución a partir del análisis de caso de Som Energia. Doctoral dissertation, Universitat de Barcelona (2015). http://www.ub.edu/cdub/publicacions/reapropiacion-popular-energia-los-albores-transicion-incierta-contribucion-partir
9. Yin, R.K.: The case study as a serious research strategy. Knowledge **3**(1), 97–114 (1981). https://doi.org/10.1177/107554708100300106
10. Thaler, R.H., Sunstein, C.R.: Nudge: Improving Decisions About Health, Wealth, and Happiness. Yale University Press (2008). https://doi.org/10.1016/j.soscij.2008.09.003

Gamification for Decision-Making When Facing Disruptive Events in the Supply Chain

Marco Arias-Vargas[1,2](✉), Raquel Sanchis[2], and Raúl Poler[2]

[1] Industrial Engineering School, University of Costa Rica, San José, Costa Rica
marco.ariasvargas@ucr.ac.cr
[2] Research Centre on Production Management and Engineering (CIGIP), Universitat Politècnica de València, Valencia, Spain
{rsanchis,rpoler}@cigip.upv.es

Abstract. During the last five years, supply chains around the globe have been stressed by significant disruptive events. Consequently, companies have been incurring in high inventory stockouts, which affects significantly companies performance. As a result, enterprise and supply chain resilience must be considered as an essential component in companies strategies in order to make the right decisions when facing disruptive events. The decision-making process can be costly and risky if decisions are made by trial and error, misleading the course of organizations. The objective of this work is to obtain a robust methodology for testing a decision-making process by means of a simulation game that takes into account people, products and disruptive events.

Keywords: Gamification · Enterprise resilience · Supply chain resilience · System dynamics · Simulation

1 Introduction

The occurrence of disruptive events in the business environment is increasing, and that is why companies must start balancing their strategic goals, considering Enterprise and Supply Chain Resilience (ESCR).

A valuable method to train people about strategic and tactical decision-making is gamification. It does not require putting at-risk companies by testing learners with real situations; instead, it can often work through simulation games that model real-life situations. Gamification has been implemented in several fields such as Supply Chain (SC) management, information security, demand management, and strategic decision-making. It has been proven to be an effective and efficient method for people to learn and test their skills in different situations.

An ESCR systems dynamics simulation game, inspired in the Beer Distribution Game, is proposed in this work to test people skills in the presence of multiple disruptive events.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 309–314, 2023.
https://doi.org/10.1007/978-3-031-27915-7_55

2 Literature Review

Authors in [1] define disruptive events as as foreseeable or unforeseeable events that directly affect an enterprise's usual operation and its stability. Since there is a wide variety of these events, as stated by [2], organizations need people with solid knowledge in ESCR, awareness of the possible presence of those events, and high decision-making skills. In this sense, building an ESCR strategy can lead to a competitive advantage, but this requires several investments; from a proactive perspective, companies must choose in which actions to invest to be prepared in advance to face disruptive events.

According to [1], Enterprise Resilience (ER) is the capability to anticipate and be prepared to face disruptive events, and if their occurrence is inevitable, the capacity to recover as soon and efficiently as possible [2].

Since predicting disruptive events is a complex task, organizations must ensure the decision-making capabilities of their decision-makers. Moreover, it is risky and expensive to train people in ESCR with disruptive events occurring in real scenarios since the related decisions can have significant consequences for the organization. Real-time training has little room for repetitiveness because disruptive events do not happen all the time and are usually not predictable. In this sense, gamification is accessible; represents less risk and cost; and it can replicate certain events to learn how to make the right decisions when they occur.

Evaluating and training people through gamification has been successfully applied in different fields, such as SC management, information technology (IT), health, new product development, marketing, and demand management. In [3], the authors analyze if Enterprise Resource Planning (ERP) simulation games can be applied to other management disciplines, and they conclude that this type of games can be used to guide decision-making in an entertaining way with realistic practices. Additionally, authors in [4] study the implementation of game mechanics to increase motivation and learning outcomes in security awareness and training programs, and they find that gamification has potential for these programs.

These games have also been developed to shape customers' behavior; in [9], they present a system that motivates customers to reduce peak and overall energy consumption through competition and collaboration using gamification. There are additional contributions to increase sustainability through gamification; [5] promote the creation of efficient and sustainable business processes; a green Business Process Management (BPM). They describe a tool that combines the concepts of gamification, sustainability, and BPM.

Moreover, Sterman [6] believes in using flight simulators to teach critical ideas in several fields, such as business, strategy, and sustainability. These simulators enable players to learn experientially, exploring the consequences of different decisions, so they can learn from themselves about the complex dynamics of complicated issues. These flight simulators for management have been tested over the last decades and have been successful because they can turn events into procedures when repeatedly trained [7].

Significant opportunities arise for organizations when formal training programs in ESCR are in place, and gamification can add value by implementing specialized simulation games. This paper aims to present a game that has been designed based on relevant research about ESCR to help organizations qualify and quantify the decision-making skills of their workers regarding this field.

3 Enterprise and Supply Chain Resilience Simulation Game

It is highly recommended to challenge people's decision-making skills in every organization. This can be accomplished by implementing the simulation game proposed in this work. In this game, the player faces several disruptive events for a recommended horizon of 52 weeks (although the player can change this setting), and the player has to make decisions to minimize their effects and to maximize the profits. This simulation game is inspired in the Beer Distribution Game which is a role-playing simulation of a SC to introduce students to the concepts of system dynamics and computer simulation [7]. The SC in the Beer Distribution Game has 4 sequential components: a retailer, a wholesaler, a distributor, and a factory, where each company is the only client of the preceding company, except for the retailer, which receives orders from the final consumers. In such a game, the only events that occur are changes in the customer‘s demand. However, in the simulation game proposed in this work, the player must choose between 2 suppliers and the 3 entities can face multiple events, not only customer's demand changes.

The proposed game simulates a distribution company (Comala) managing one product delivered in cardboard boxes and two suppliers (S1 and S2) with different prices, lead times, replenishment policies, and resilience factors. In [8], the authors define the resilience factors in terms of 3 types of resilience capabilities: absorbing, adaptative and restorative. During each week of the game, the player must decide how many boxes to purchase from each supplier considering the suppliers' capabilities and prices, and the internal variables: inventory carrying costs, backorder cost, lost sales costs, selling price, fill rate, operating expenses, and insurance expenses. The goal is to maximize the Earnings Before Interests and Taxes (EBIT) for the playing period. The types of disruptive events that the player can face are high demand fluctuations due to customer behavior, economic slowdown that affects customers' demand, and temporary facilities closures due to natural or human-driven disasters. The game is designed using system dynamics in VENSIM software, and further developments will deploy a web application. System dynamics is recommended because it considers business dynamics, with oscillations, amplification of disturbances, feedback loops, stocks, flows, and nonlinearities created by the interaction of the physical and institutional structure of a system with the decision-making processes of the agents acting within it [9]. Figure 1 shows a supplier's replenishment logic, expressed with causal loops.

As stated by [7], causal loop diagrams are an important tool for representing the feedback structure of systems and they consist of variables connected by arrows denoting the causal influences among the variables. In Fig. 1, each supplier receives orders from the distribution center of Comala, and the player must define the order quantities for both suppliers. The inventory replenishment model that both suppliers use is based on a reorder point (calculated automatically as a function of the demand during the lead time and a probabilistic safety stock) and an order up to level (QSn - a function of the lead time demand) quantity that their manufacturing facility delivers to their distribution center, from where they ship the orders to Comala. They can accumulate BackOrders

(BO) if they cannot fulfill the incoming orders on time. When on-hand inventory in the supplier's distribution center reaches a reorder level, the manufacturing facility will supply the number of boxes defined in the variable QS1.

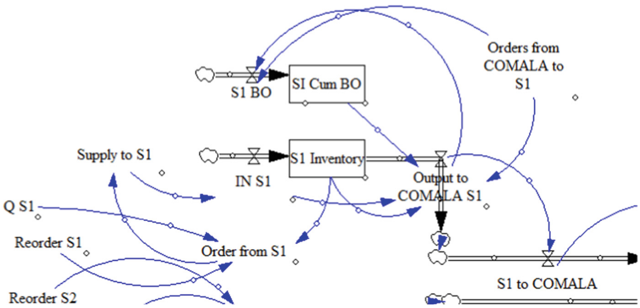


Fig. 1. Supplier's logistics

Figure 2 shows a diagram with the other variables that directly affect Comala.

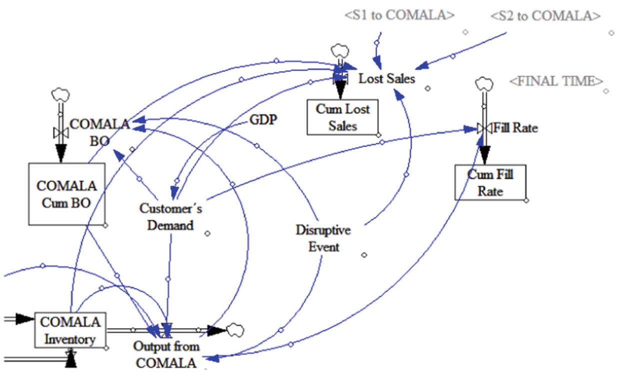


Fig. 2. Example of Comala's causal relations

Comala receives boxes from their suppliers, and then they will try to fulfill their customer's demand. This demand is influenced by the macroeconomic situation, represented by the Gross Domestic Product (GDP); if the increase rate of the GDP is less than 3%, the demand will be severely reduced. The outputs from distribution center depend on the on-hand inventory, the BOs, the customer's demand, and the appearance of a disruptive event that causes the temporal closure of the distribution center. While playing the game, the simulator will calculate Comala's fill rate and all the financial indicators addressed to obtain the EBIT. The player can monitor the leading indicators directly from a control panel during the game. This panel includes three input sliders that the player must use when making decisions; two sliders are for selecting the quantity to purchase from each supplier. The other slider is for selecting the amount to spend in insurances for disaster coverage. In Fig. 3, there is an example of the control panel.

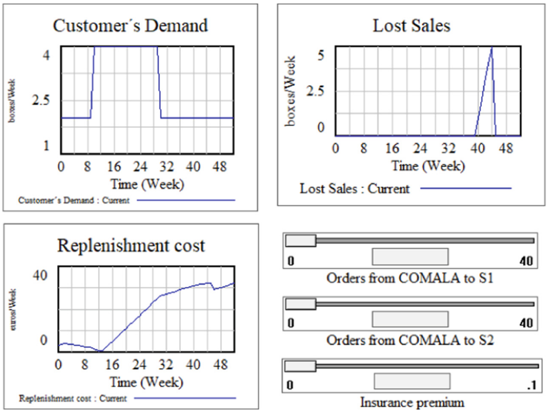


Fig. 3. Control panel (partial)

Currently, the game is as a prototype version, for this reason, next step is focused on implementing it in a real company to assess if people are appropriately prepared to make the right decisions related to the variables included in the game what leads to a resilient decision-making process.

4 Conclusions

Organizations can add value to their performance and strategies by evaluating the decision-making skills of their people with an ESCR specialized simulation game, like the one proposed in this paper. This game is focused on resilient scenarios where players make tactical decisions to overcome different disruptive events in a SC environment; thus, it is proper training for the real world.

This simulation game can be complemented with other types of games, for instance, trivia games, to enhance awareness of the impact of disruptive events. In this sense, this is a future research line to be developed. Moreover, with knowledge and decision-making enhanced through gamification, further research will focus on developing and implementing tools for monitoring and predicting disruptive events. One potential mechanism to consider is artificial intelligence for disruptive events prediction depending on their origin.

Acknowledgements. This work was supported in part by the European Commission under the Project Reference No. 2021-1-IT01-KA220-VET-000033287.The authors would like to acknowledge the support of the researchers from the project "Business Continuity Managers Training Platform" (CONTINUITY) (business-continuity-project.eu).

To the Industrial Engineering School at the University of Costa Rica.

References

1. Sanchis, R., Canetta, L., Poler, R.: A conceptual reference framework for enterprise resilience enhancement. Sustainability. **12**, 1464 (2020). https://doi.org/10.3390/su12041464
2. Sanchis, R., Poler, R.: Evaluación de la resiliencia empresarial: Marco de categorización de disrupciones Enterprise resilience assessment: a categorisation framework of disruptions. Dirección y Organización **54**, 45–53 (2014)
3. Dick, G.N., Akbulut, A.Y.: Innovative use of the erpsim game in a management decision making class: an empirical study. J. Inf. Technol. Educ. Res. **19**, 615–637 (2020). https://doi.org/10.28945/4632
4. Gjertsen, E.G.B., Gjære, E.A., Bartnes, M., Flores, W.R.: Gamification of information security awareness and training. In: ICISSP 2017 - Proceedings of the 3rd International Conference on Information Systems Security and Privacy, pp. 59–70. SciTePress (2017). https://doi.org/10.5220/0006128500590070
5. Mancebo, J., Garcia, F., Pedreira, O., Moraga, M.A.: BPMS-game: tool for business process gamification. In: Carmona, J., Engels, G., Kumar, A. (eds.) BPM 2017. LNBIP, vol. 297, pp. 127–140. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-65015-9_8
6. Sterman, J.: Interactive web-based simulations for strategy and sustainability: the MIT Sloan LearningEdge management flight simulators, part I flight simulators for management education. Syst. Dyn. Rev. **30**, 89–121 (2014). https://doi.org/10.1002/sdr.1513
7. Sterman, J.: Business dynamics. Systems thinking and modeling for a complex world, pp. 137–695. Irwin McGraw-Hill (2000)
8. Hosseini, S., Khaled, A.A.: A hybrid ensemble and AHP approach for resilient supplier selection. J. Intell. Manuf. **30**(1), 207–228 (2016). https://doi.org/10.1007/s10845-016-1241-y
9. Sterman, J., Oliva, R., Linderman, K., Bendoly, E.: System dynamics perspectives and modeling opportunities for research in operations management. J. Oper. Manag. **39**, 40 (2015). https://doi.org/10.1016/j.jom.2015.07.001

A Study on the Correlation of Workload and Distance with the Success of Last Mile Logistics

Antonio Lorenzo-Espejo(✉), Jesús Muñuzuri, Luis Onieva, and María-Luisa Muñoz-Díaz

Departamento de Organización Industrial y Gestión de Empresas II, Escuela Técnica Superior de Ingeniería, Universidad de Sevilla, Cm. de los Descubrimientos, s/n, 41092 Seville, Spain
alorenzo@us.es

Abstract. Given the growth in online sales experimented in the past years, which has been accentuated by the health crisis in 2020 and 2021, B2C (*business to consumer*) distribution has gained even more importance in the operation of most firms in the retail sector. As a result, there has been an increase in the academic and practice interest in last mile logistics optimization. In this work, we analyze the correlation between couriers' workloads and their ability to successfully carry out their assigned services. Additionally, we assess the correlation between the distance from the warehouses to the delivery points and the completion rate of the couriers' workloads. Through the analysis of a dataset corresponding to deliveries and pickups performed in Madrid in 2021, we identify significant and moderate correlations between the couriers' workloads and performances. However, the correlations between the performances and both the distance and the visit frequency to each area are weak, yet significant.

Keywords: Logistics · Last mile · B2C · Distance · Workload · Service fulfillment

1 Introduction

The movement restrictions enforced by many governments due to the COVID-19 pandemic gave way to an unprecedented increase in the use of e-commerce and, thus, to last mile deliveries and pickups. Villa and Monzón [1] estimate that the number of parcels delivered in the city of Madrid increased by 98% from the second quarter of 2019 to the second quarter of 2020. This growth has fostered academics and retailers' research attention on last mile logistics. Nevertheless, even before the health crisis, there had already been an increase in academic interest in the field given the surge in omni-channel retailing, the growing urbanization, the changes in consumer behavior, and the increasing interest in sustainability [2].

The growth in the number of deliveries and pickups required has entailed an increasing demand for couriers and a significant surge in couriers' workloads. Wang et al. [3] argue that excessive workloads impact couriers' quality of life, which leads to a low

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 315–320, 2023.
https://doi.org/10.1007/978-3-031-27915-7_56

courier retention rate, a circumstance that needs to be addressed by companies in an increasingly competitive workforce market.

In our work, we focus on analyzing the relation between workload and the failure of the last mile services, that is, the percentage of attempted services unfulfilled. Additionally, we examine whether the distance between the warehouse and the service point is correlated with the outcome of the service. To the best of our knowledge, there is no previous research on the correlations of these variables and last mile delivery or pickup effectiveness.

2 Methodology

In this section, the materials and methods used in the study are described. For this research, we have gathered the operational data of a logistics operator based in Madrid, Spain. The dataset comprises information regarding deliveries and pickups performed between January and September of 2021. The available data includes records of the courier performing the service, the GPS coordinates of the service point, the location of the warehouse and information on whether the service was successfully completed or not.

While there is a plethora of disruptions that can impede the completion of a service, in this work we only consider as "failed services" those that have not been completed due to a lack of time, as specified by the couriers themselves.

Regarding the characteristics of the couriers' routes, it must be noted that the workers alternate deliveries and pickups without a specific pattern. For the purpose of this analysis, we consider both deliveries and pickups as services, without making distinctions between them.

Two main analyses are performed in this work. First, we study the correlation between the daily assigned workloads and the couriers' performances. To do so, we have calculated the average daily workload for each worker in the second and third quarters of the year, that is, from April up to June (Q2) and from July up to September (Q3). Additionally, we obtain the percentage of failed services due to a lack of time (to which we refer as the incompletion rate, IR), computed as the ratio between the number of failed services due to a lack of time and the total amount of delivery/pickup attempts performed for each worker. Clearly, the IR must refer to the failed attempts and not to the failed services, since the overwhelming majority of services are bound to be completed at some point.

Next, the analysis of the correlation between distance and the IR is performed. In order to analyze this relation, we have grouped the deliveries and pickups performed from January to September in each postal code. In this way, we can calculate the distance between the centroid of each postal code and the corresponding logistics operator warehouse and then collate it to the couriers' performance records in each day.

The centroid is a point inside each postal code calculated as the mean of the coordinates of the points in the perimeter of the area. To calculate the distance between said centroids and the corresponding warehouse, the Euclidean distance between their coordinates is used. Admittedly, this measure is not fully representative of the road distance covered between said points. To account for this issue, we have applied a coefficient obtained as the ratio between the actual on-road distance and the linear distance in a sample of postal codes. The calculations used in this study were performed using SPSS Statistics version 26.

3 Results and Discussion

As mentioned previously, our analysis is two-fold: first, we investigate the correlation between the daily assigned workloads and the couriers' performances (Sect. 3.1); next, the correlation between distance and the IR is analyzed (Sect. 3.2).

3.1 Correlation Between Workloads and Incompletion Rates

For the analysis of the correlation between the assigned workloads and the couriers' performances, we consider the data of the second and third quarters of 2021 (Q2 and Q3). The general data regarding these periods is summarized in Table 1.

Table 1. Summary of service attempts and incompletions in Q2 and Q3.

Quarter	Total attempts	Total incompletions	IR	# of couriers	Mean # of days worked per courier
Q2	104,780	1,110	1.06%	40	46.82
Q3	167,859	1,675	1.00%	45	58.11

Table 1 shows that, despite a 60.2% increase in the service volume of the logistics operator from Q2 to Q3, the IR has remained almost constant. This volume increase can be explained by the fact that, even as the workforce has only grown by 5 couriers, the average number of days worked by each courier has significantly increased from Q2 to Q3.

Figure 1 shows a dispersion graph presenting the average daily workload against the IR for each worker in Q2 and Q3. Additionally, the trendlines for each cloud of points are shown in their respective colors.

From Fig. 1 it can be drawn that there is in fact a direct correlation between the daily workload that each courier must sustain and their performances in term of unfulfilled services. To further strengthen this claim, we have calculated the Pearson's correlation coefficient between the average daily workloads and the IRs for Q2 and Q3 and for both of them combined. To combine the two quarters, the incompletion rate is obtained as the number of incomplete services in the two quarters divided by the number of days worked in the full six months. Similarly, the average daily workload refers to said period. The results are shown in Table 2, along with the P-values calculated through a two-tailed significance test:

The results shown in Table 2 indicate a significant (with a confidence level of 95%) and moderate direct correlation between the average daily workload and the IR for Q2, Q3 and combining the data for both quarters. The findings suggest that a higher IR can be expected if couriers are assigned heavier workloads.

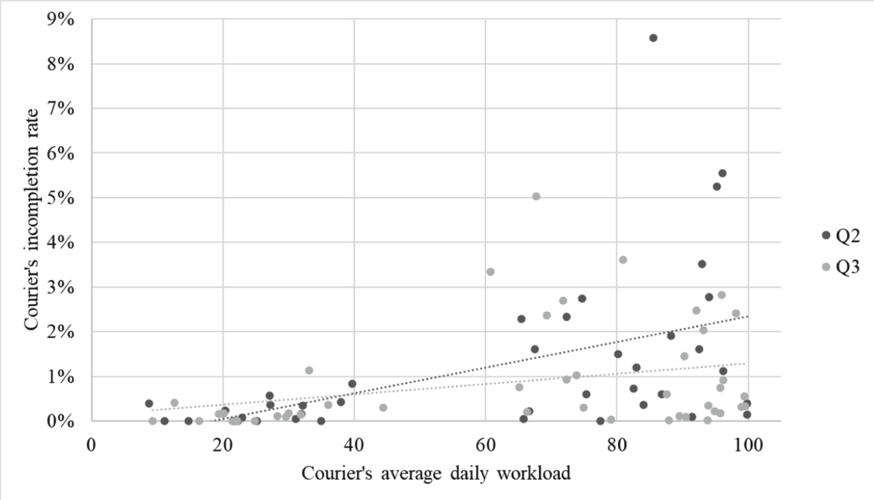


Fig. 1. Average daily workload vs. IR in Q2 and Q3.

Table 2. Pearson's correlation coefficients between average daily workload and IR in Q2, Q3 and overall.

Quarter	Pearson's correlation coefficient (ρ)	P-value
Q2	0.487	0.001
Q3	0.305	0.041
Q2+Q3	0.398	0.003

3.2 Correlation Between Distances and Incompletion Rates

As discussed in Sect. 2, the second analysis presented in this work addresses the correlation between the distance and the IR. Additionally, we analyze if the frequency with which postal codes are visited is correlated to the IR. It must be noted that the dataset contains 121 postal codes that held at least 1,000 deliveries or pickups. First, these trends can be examined in Fig. 2:

Figure 2 shows that most of the postal codes sustaining an IR below 5% are located at less than 20 km from their corresponding warehouses. Conversely, almost the entirety of the postal codes showing an IR over 15% are located at more than 20 km from the warehouses. However, it can be hard to infer strong trends from these findings, given that the postal codes sustaining IRs between 5 and 15% are seemingly evenly dispersed.

To further analyze this potential correlation, we have obtained Pearson's correlation coefficient (along with the significance test P-values) for the IR with both the distances between warehouses and postal codes and the average number of daily attempts at the postal code. These results are shown in Table 3:

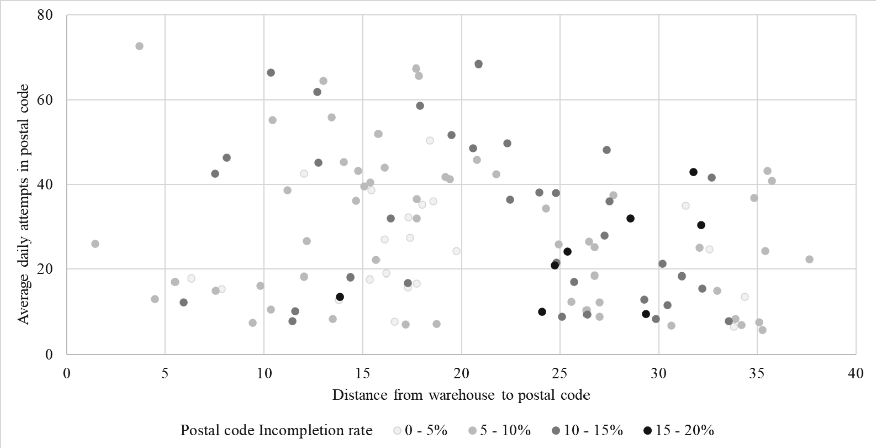


Fig. 2. IR per postal code. Distance from warehouse to postal code vs. mean daily attempts.

Table 3. Pearson's correlation coefficients between distance and IR, and average daily attempts and IR.

Variable pair	Pearson's correlation coefficient (ρ)	P-value
IR – distance	0.140	0.062
IR – daily attempts	0.170	0.031

As can be expected by observing Fig. 2, the correlation between the IR and the distance is weak and only significant with a 90% confidence level. However, the results outline a slightly higher correlation between the IR and the daily attempts, which is also significant with a greater confidence level (95%). These results suggest that the services of a postal code may be unfulfilled due to a lack of time in a higher degree if the postal code is farther away from the warehouse or if the postal code receives less services per day (this could also stem from the postal code being visited less often). Nevertheless, the correlations of both pairs of variables are admittedly weak and, thus, the findings must be interpreted with caution.

4 Conclusion

The results of this study suggest that there are significant direct correlations between the incompletion rates in last mile delivery and pickup routes and three operational variables: the workload sustained by the courier, the number of service attempts in the postal code and the distance between the postal code and the warehouse. However, the results only detect a moderate correlation between the assigned workloads and the incompletion rates. For the two other pairs of variables, the coefficients indicate weak correlations.

The findings highlight the necessity of improving the estimation of the workload attainable by each courier as well as the importance of calculating and accounting for the additional costs sustained when servicing locations situated far from the warehouse or belonging to areas with low service volumes.

Acknowledgements. This research has been funded by the Consejería de Economía, Conocimiento, Empresas y Universidad of Andalusia (project TRACSINT, P20_01183) within Programme FEDER 2014–2020. The research was also supported by the Ministry of Universities of Spain through a grant for the Training of University Researchers (Ayuda para la Formación del Profesorado Universitario, reference FPU20/05584).

References

1. Villa, R., Monzón, A.: Mobility restrictions and e-commerce: holistic balance in madrid centre during COVID-19 lockdown. Economies. **9**, 57 (2021)
2. Olsson, J., Hellström, D., Pålsson, H.: Framework of last mile logistics research: a systematic review of the literature. Sustainability **11**, 7131 (2019)
3. Wang, Y., Zhao, L., Savelsbergh, M., Wu, S.: Multi-period workload balancing in last-mile urban delivery. Transp. Sci. **56**(5), 1348–1368 (2022)

Maturity Model for Analysis of Machine Learning Operations in Industry

Miguel Ángel Mateo-Casalí[1](✉), Francisco Fraile[1], Andrés Boza[1], and Artem Nazarenko[2]

[1] Research Centre on Production Management and Engineering (CIGIP), Universitat Politècnica de València (UPV), Camino de Vera s/n, 46022 Valencia, Spain
{mmateo,ffraile}@cigip.upv.es, aboza@omp.upv.es

[2] Faculty of Science and Technology & UNINOVA, Nova Uniersity of Lisbon, Monte Caparica, 2829-516 Lisbon, Portugal
a.nazarenko@campus.fct.unl.pt

Abstract. The next evolutionary technological step in the industry presumes the automation of the elements found within a factory, which can be accomplished through extensive introduction of automatons, computers and Internet of Things (IoT) components. All this seeks to streamline, improve, and increase production at the lowest possible cost and avoid any failure in the creation of the product, following a strategy called "Zero Defect Manufacturing". Machine Learning Operations (MLOps) provide a ML-based solution to this challenge, promoting the automation of all product-relevant steps, from development to deployment. When integrating different machine learning models within manufacturing operations, it is necessary to have a good understanding of what functionality is needed and what is expected. This article presents a maturity model that can help companies identify and map their current level of implementation of machine learning models.

Keywords: Machine learning · Manufacturing execution system · Zero-defect manufacturing · Manufacturing operations · CMM · ISA-95 · MLops

1 Introduction

More than four decades ago, Phillip Crosby coined the concept of zero defects. It was just a vision at that time, but the rise of Artificial Intelligence (AI) in manufacturing has made it achievable [1]. AI can be defined as the process by which, by means of different techniques, cognitive skills can be generated and thus endow machines with intelligence. To achieve this, AI must be provided with the ability to learn tasks, which is where the concept of machine learning (ML) comes in [2]. ML is one of the most important concepts for Industry 4.0 that aims to provide analytical data modelling and outcome prediction [3]. ML uses computer algorithms that receive and analyse real-time data to predict output values within an acceptable range. As new data come in and are introduced, these algorithms "learn" and optimise their output to improve performance

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 321–328, 2023.
https://doi.org/10.1007/978-3-031-27915-7_57

and enhance their "intelligence" over time [4]. ML can also be focused on finding patterns in data that are seemingly difficult to forecast and supporting the implementation of zero defects manufacturing (ZDM) concept [5]. ZDM is a strategy followed to minimize, mitigate, or eliminate failures and defects during the production process [6]. It is based on the evidence that they will always exist and will eventually affect production and its output, but recognizing that (i) faults and defects can be detected and minimized more quickly online; (ii) any production output that deviates from specifications should not be allowed to pass to the next step in the value chain or, eventually, to an end customer; (iii) any production output that deviates from specifications should not be allowed to pass to the next step in the value chain or, eventually, to an end customer [7]. The ZDM concept can be used in any manufacturing environment that seeks to reduce costs and increase the quality of its products [8]. Conventional manufacturing facilities are equipped with a manufacturing execution system (MES) to enable automated production beyond automatic control of individual pieces of equipment [9]. This article will propose a maturity model to measure the state of ZDM readiness within a company. This model or approach addresses both tactical aspects, at the horizontal level, and operational aspects, at the vertical level. All of this is based on the Zero Defects philosophy, such as the optimisation of the production chain through MLOps, avoiding errors in the final product. This paper will provide the definition and details of the proposed model consisting of vertical and horizontal axis.

2 Vertical Axis

The use of information technologies has generated software development needs in manufacturing companies. This phenomenon is known as Computer Integrated Manufacturing (CIM). CIM is a philosophy of approaching an integrated organisation of the factory and its management [10]. The CIM standard is divided into 5 levels [11]: (i) first level is formed by the industrial processes and their machinery; (ii) second level defines the integration between the physical part and the control systems; (iii) third level corresponds to the interaction between man and the production chain; (iv) fourth level where the measurements are stored; (v) fifth level where the human management by means of tools, such as ERPs, happens.

When integrating different machine learning models within manufacturing operations, it is necessary to have a good understanding of what functionality is needed and what is expected. If this integration is in the requirements that reside in the manufacturing operations domain, the standard that can be used is provided by "International Society of Automation" (ISA-95) [13], especially Part 3 of this standard. ISA-95 is based upon the hierarchical structure presented in the "The Purdue Enterprise Reference Architecture (PERA)". This standard separates the functionality of the enterprise by dividing it into three layers (Fig. 1): Planning or level 4 (top layer with business and logistics information), Execution or level 2 (middle layer with manufacturing operations and control information) and Control (inner layer with the rest of the CIM levels) [11].

ISA 95 Part 3 focuses on activities within manufacturing operations; this part specifies a generic activity model that applies to different types of manufacturing operations

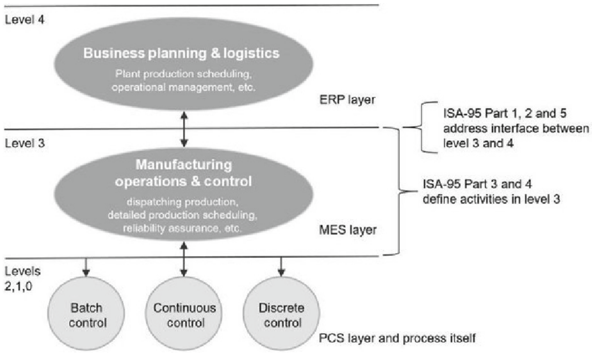


Fig. 1. ISA-95 functional hierarchy model [12].

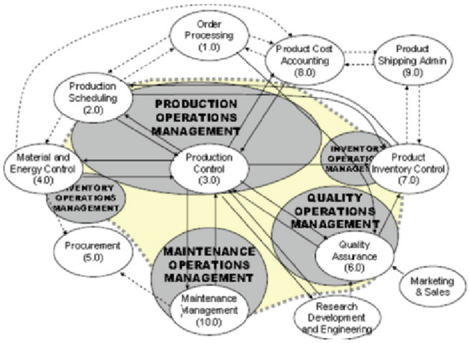


Fig. 2. Production management activities according to ISA 95 standard [12].

[14] (Fig. 2). These manufacturing operations management activities are those that coordinate personnel, material, and equipment in the conversion of raw material into components or finished products and include activities that can be carried out by human effort, equipment or information systems controlled by scheduling, usage, capacity, definition, history, and resource status [14]. Considering these levels of activities, we try to group them into 5 categories, which will form the levels to be measured in our maturity model:

- **Management of production operations** defines the functions associated with the operations of a factory, such as product definition management, production resource management, data collection, etc.
- **Management of maintenance operations;** those activities that ensure the availability of personnel, equipment, or tools for manufacturing operations.
- **Management of laboratory operations** are the set of activities related to quality measurement and reporting (both quality operations and quality operations management).
- **Management of materials handling and storage** are the set of activities that manage the inventory of products and materials.

- **Support activities**, including security, information, configuration, documentation, compliance, and incident/deviation management.

3 Horizontal Axis

The Capability Maturity Model Integration (CMMI) presents a model for the appraisal of an organisation's processes, developed by Carnegie-Mellon University (USA) in 1986 for software implementation processes [15]. It consists of a set of key practices in processes that are grouped into five "maturity levels". [16] Thus, a company or organisation that complies with all the practices intrinsic to the corresponding level and the levels below is considered to have reached that level of maturity. These levels are: Initial, Repeatable, Defined, Managed and Optimised. This CMM model allows progress assessment as maturity levels advance. To conform with each level, several conditions must be fulfilled. These are identified by the satisfaction or dissatisfaction of several clear and measurable objectives. The description of the horizontal axis levels is provided below:

i. **Initial.** This is the starting point of any company or organisation, as it has no ML process or strategy in place. ML development processes are not designed and implemented within an architecture or have no structure at all. On the other hand, the ML processes in the organisation are not standardised and lack a correct management approach.
ii. **Repeatable.** At this point, the company, or organisation, has an idea of what ML is and has established a scope for its implementation. However, at this point the company does not have sufficient data to apply ML and the ML development architecture is centralised and only applied for independent processes. In summary, the company has taken the first steps to implement ML.
iii. **Defined.** The company has a defined plan and architecture for implementing ML. On the other hand, it has data to train the models. The company has a department or assigned workers that are focused on implementing and improving ML. The integration of ML processes within the company has been automated and monitoring and tracking tools have been included. In summary, the company has implemented and has some experience in implementing ML.
iv. **Managed.** At this point the company/organisation has already implemented different ML strategies, which have been properly configured and are constantly analysed. All the company's ML models are highly integrated with the company's subsystems. Moreover, it clouds solutions are the part of a ML development strategy facilitating distributed computing. Thus, the company at this level can be considered advanced in the industrial ML implementation and will be one step away from being able to generate ML-related standards.
v. **Optimisation.** At this point, the company or organisation has implemented a complete ML strategy, has strong support and monitoring of all models, within a well-defined architecture. The company's products and services are regularly updated with the help of ML to improve their value.

The CMM model establishes a measure of progress as maturity levels advance. To pass each level, several process areas must be accomplished. That are identified by the satisfaction or dissatisfaction from several clear and quantifiable goals. These goals are known in the CMM documentation by the acronym KPA, which stands for Key Process Area. Each KPA identifies a set of interrelated activities and practices, that when carried out collectively, allow the fundamental goals of the process to be achieved.

4 Maturity Model

The measurement matrix (Table 1) is used to determine the status of machine learning implementation at the different levels of activities within the manufacturing operations and will be the basis for identifying all the steps needed to move from the traditional factory to an automated one. As mentioned above, we will use the CMI model as a basis, establishing five levels of scale, to specify its status within the factory. This snapshot will be the means for the user to identify the necessary steps to adopt the use of machine learning models in a smooth and stepwise manner. In this way, the matrix provides a brief and clear form of the current state and desired conditions, showing different alternatives.

Table 1. Maturity model

	Initial	Repeatable	Defined	Managed	Optimised
Management of production operations	There is no control of production operations	Control of production operations has begun to be established	The company has a defined plan and architecture for implementing ML in production operations management	It has included cloud solutions, such as cloud computing, for better integration and use of MLOps	A full MLOps strategy has been implemented and everything is managed automatically
Management of maintenance operations	There is no monitoring or control of maintenance operations	Data collection has started to try to control maintenance operations	An ML has been developed for degradation analysis of parts, to predict their changeover and cumulative effect	The company or organisation has already implemented different MLOps strategies to manage storage operations	A full MLOps strategy has been implemented to manage warehousing operations automatically

(*continued*)

Table 1. (*continued*)

	Initial	Repeatable	Defined	Managed	Optimised
Management of laboratory operations	There is no quality control operation	Quality starts to be an important point for product development	The organisation has ML quality control measures in place that are implemented in accordance with industry standards and best practices	Models have been introduced to analyse appropriate configurations to measure quality and are constantly monitored	ML is used to control all elements of quality in the company automatically
Management of materials handling and storage	There is no control of the warehouse or procurement of materials	Basic warehouse control tools have been introduced and a history of data is kept	The integration of ML processes within the company has been defined and material monitoring and tracking tools have been included within the company	Models have been introduced that manage information on storage and existing materials. The model is trained to give warnings of material procurement	The company's products and services are regularly updated with the help of MLOps to improve its warehousing control automatically
Support activities	There are no standards in place to assist operations management	The preparation of materials to manage, explain and help workers has been considered	The company has a department or assigned workers focused on implementing and improving ML	The company at this level can be considered advanced in the industry and will be one step away from being able to generate standards	The company has strong support and monitoring of all models, within a well-defined architecture. It is a reference in the sector and can support other companies

5 Practical Application

To define the level of implementation of machine learning models in industry, a questionnaire will be developed according to each of the characteristics listed in the matrix

(Table 1). A company will be able to say that it has a level of implementation, if it fulfils all the questions positively referred to on the horizontal axis. It will not be able to move up a level without having positively completed all the questions associated with the previous level. This result of the matrix provides the integrators of learning models in manufacturing operations with an overview of the implementation status of the models (Table 2) and will allow them to know where they need to improve. Following the analysis of the current state of the implementation of learning models within the factory. Our maturity model would return a report with the points to be improved in order to reach better levels within this maturity model.

Table 2. Example of a measurement matrix

	Initial	Repeatable	Defined	Managed	Optimised
M1		x			
M2		x			
M3			x		
M4		x			
M5				x	

6 Conclusions

Throughout this article, a proposal for a Machine Learning Maturity assessment model covering various levels of activities within the manufacturing operations aspects has been made. To this end, a maturity model has been developed using the CMM background for the ML implementation stage analysis in relation to the activities that take place in the manufacturing operations management system addressed by ISA-95. It allows obtaining an image of the state of a factory at a specific moment within the digital transformation process to the automation. This matrix will be used to measure the implementation of machine learning models in the Zero-Defect Manufacturing Platform (ZDMP) or Industrial Data Services for Quality Control in Smart Manufacturing (i4Q) projects, which have several solutions that deploy algorithms as a service (AaaS) and encourage the use of machine learning models.

Acknowledgements. The research leading to these results received funding from the European Union H2020 programs with grant agreements No. 825631 "Zero-Defect Manufacturing Platform (ZDMP)" and No. 958205 "Industrial Data Services for Quality Control in Smart Manufacturing (i4Q)".

References

1. Escobar, C., Arinez, J., Morales-Menendez, R.: Process-monitoring-for-quality-a step forward in the zero defects vision. SAE Technical Papers, pp. 1–8, April 2020. https://doi.org/10.4271/2020-01-1302

2. El Naqa, I., Li, R., Murphy, M.J. (eds.): Machine Learning in Radiation Oncology. Springer, Cham (2015). https://doi.org/10.1007/978-3-319-18305-3
3. Frank, A.G., Dalenogare, L.S., Ayala, N.F.: Industry 4.0 technologies: Implementation patterns in manufacturing companies. Int. J. Prod. Econ. **210**, 15–26 (2019). https://doi.org/10.1016/j.ijpe.2019.01.004
4. Ongsulee, P.: Artificial intelligence, machine learning and deep learning. In: Fifteenth International Conference on ICT and Knowledge Engineering, pp. 1–6 (2017). https://doi.org/10.1109/ICTKE.2017.8259629
5. Psarommatis, F., Prouvost, S., May, G., Kiritsis, D.: Product quality improvement policies in industry 4.0: characteristics, enabling factors, barriers, and evolution toward zero defect manufacturing. Front. Comput. Sci. **2**, 1–15 (2020). https://doi.org/10.3389/fcomp.2020.00026
6. Serrano-Ruiz, J.C., Mula, J., Poler, R.: Smart manufacturing scheduling: a literature review. J. Manuf. Syst. **61**, 265–287 (2021). https://doi.org/10.1016/j.jmsy.2021.09.011
7. Lindström, J., Kyösti, P., Birk, W., Lejon, E.: An initial model for zero defect manufacturing. Appl. Sci. **10**(13), 4570 (2020). https://doi.org/10.3390/app10134570
8. Calvin, T.W.: Quality control techniques for 'zero defects'. Tech. Pap. Soc. Manuf. Eng. **C**(3), 323–328 (1983). https://doi.org/10.1016/0026-2714(84)90075-1
9. Jürgen, K.: Manufacturing Execution System – MES. Springer, Heidelberg (2007). https://doi.org/10.1007/978-3-540-49744-8
10. Barbuceanu, M., Fox, M.S., Chionglo, J.F.: The integrated supply chain management project, p. 13, May 1993.https://www.researchgate.net/publication/239033756_The_Integrated_Supply_Chain_Management_Project
11. Unver, H.O.: An ISA-95-based manufacturing intelligence system in support of lean initiatives. Int. J. Adv. Manuf. Technol. **65**(5–8), 853–866 (2013). https://doi.org/10.1007/s00170-012-4223-z
12. Scholten, B.: The Road to Integration - A Guide to Apply the ISA-95 Standard in Manufacturing (2007)
13. Junín Durán de Leon, A., Cruz Rentería, J.R., Muñoz Zamora, G., Garcia-alva, S., Gutierrez-torres, L., Sanchezz Hernández, Z.: Desarrollo de Software basado en el estándar ISA-95, March 2016
14. Johnsson, C.: ISA 95 - how and where can it be applied? Technical Papers of ISA, vol. 454, pp. 399–408, October 2004
15. Galan Manuel, J., de la fuente, S., Alonso de Armiño, C., Alcalde Delgado, R.: 15th International Conference on Industrial Engineering and Industrial Management, July 2021. https://pressbooks.com/app/uploads/sites/132093/2021/07/Proceedings-of-the-15th-International-Conference-on-Industrial-Engineering-and-Industrial-Management-and-XXV-Congreso-de-Ingenieria-de-Organizacion.pdf
16. Finkelstein, A.: A software process immaturity model. SIGSOFT Softw. Eng. Notes **17**(4), 22–23 (1992)

Mapping Science Related to Competitive Intelligence

Alfredo Garcia-Varona[1(✉)], Izaskun Alvarez-Meaza[1], Rosa Maria Rio-Belver[2], and Ernesto Cilleruelo-Carrasco[1]

[1] Industrial Organization and Management Engineering Department, Faculty of Engineering Bilbao, University of the Basque Country, Paseo Rafael Moreno "Pitxitxi" nº3, 48013 Bilbao, Spain
agarcia298@ikasle.ehu.eus

[2] Industrial Organization and Management Engineering Department, Faculty of Engineering Vitoria, University of the Basque Country, Nieves Cano 12, 01006 Vitoria-Gasteiz, Spain

Abstract. Competitive Intelligence has become the most important technique to provide firms' with competitor analyses to aid in decision making. At the same time, the scientific community's interest in researching and developing competitive intelligence and its influential fields has substantially increased in the last two decades. The aim of this paper is to map science using the bibliometric analysis to show the most relevant authors, countries, organizations and keywords related to the field of study. A proper query to accurately select the existing CI related articles and a later phase to clean, classify and map the obtained dataset, show that USA and China are the most productive countries and the main fields of research are grouped into three main groups.

Keywords: Competitive intelligence · Bibliometric analysis · Network analysis

1 Introduction

Nowadays, after five decades since intelligent gathering and competitors' analysis have emerged as a recognized discipline and a tool for corporate decision-making, it is safe to say that every large company or small business is engaging in Competitive Intelligence (CI) and Market Intelligence activities [1]. Parallel to this need and experience of information gathering and analysis in order to define strategies or identify competitive gaps, the scientific community has been publishing their development studies related to CI tools, criteria, algorithms, methodologies, models and, above all, scientific knowledge about CI. One can assume that every scientist involved in developing CI related research would previously check existing literature related to CI scientific development [2, 3].

This paper is intended to show and better interpret published state-of-the-art CI research work by collecting, classifying, and analyzing the existing CI related literature using techniques related to bibliometric analysis and network analysis. Therefore, the objective of the work is to analyze the main fields linked to the scientific development of the area, identifying the academic performance, such as, where research is produced,

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 329–334, 2023.
https://doi.org/10.1007/978-3-031-27915-7_58

who leads it and which research topics are the most important. The results will reveal the scientific trends of CI with the dual purpose of providing future researchers with valuable information for deeper scientific investigations into CI, and supplying future CI implementers with key information to aid in decision making.

2 Methodology

To achieve the objective of this article, first of all, Web of Science (WOS) [4] was selected as the search engine to provide scientific publications about CI. The following step was to ensure the data accuracy by selecting a proper query related to Competitive Intelligence. That accuracy required two characteristics of the dataset results: high precision and high recall. To this end, two main blocks were defined: unconditional set terms and conditional set terms. In this way, a final cross search between the two blocks defined the query to obtain the definitive study dataset (see Fig. 1).

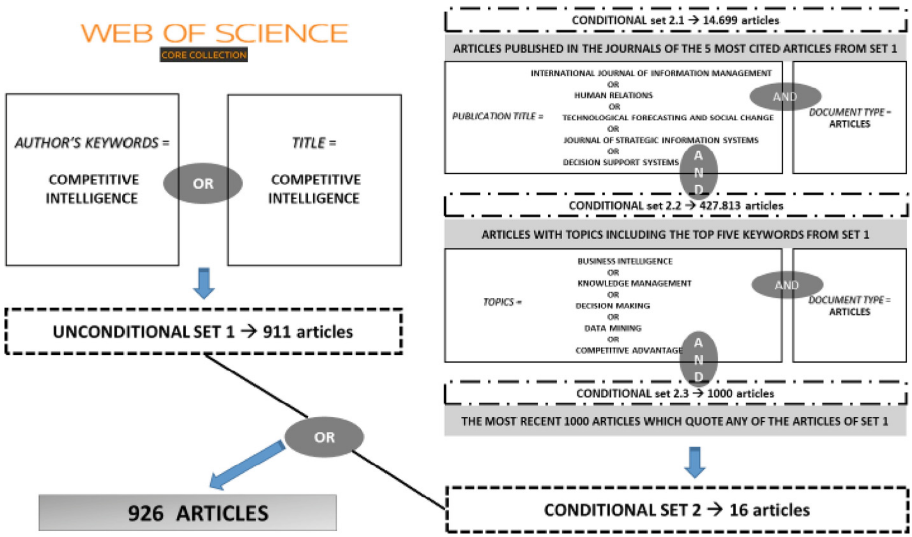


Fig. 1. Search query performed in web of science database.

The following phase involved applying data mining techniques through the software Vantage Point (VP) [5]. This software uses fuzzy matching techniques that could then be used to clean and classify these raw data. The dataset generated in previous phase is imported into the software. After data cleaning, the results obtained are analyzed, generating the necessary graphs to identify the objectives set. In addition, the network analysis will allow to improve the results, including the identification of the main relationships and the main knowledge hubs. The networks are generated, visualized and analyzed by Gephi software [6].

3 Results

3.1 Academic Performance

CI research scientific literature starts after the mid 80s. As shown in Fig. 2, the number of publications remained low level for the first twenty years, until 2004, achieving the highest output in 2009 and continuing at an almost constant level to the present day. However, the scientific development related to CI is being the origin of new scientific publications, as shown by the growing evolution of the number of citations per year, thus demonstrating its influence on new scientific developments in this area.

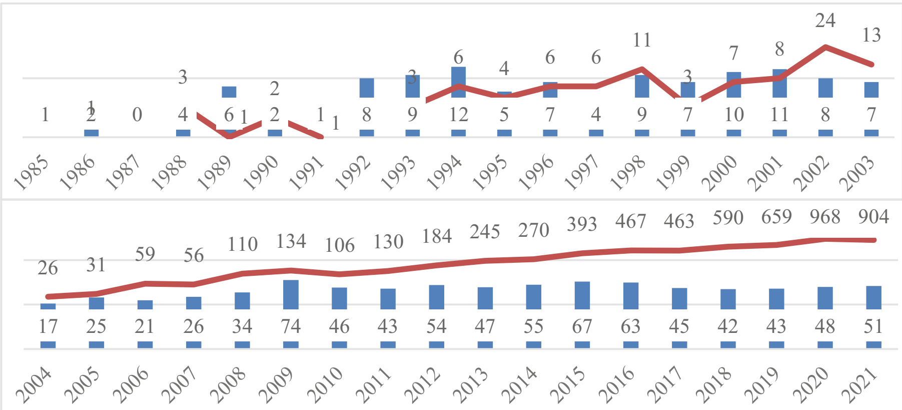


Fig. 2. Number of publications and citations per year.

Relating to the countries, USA appears at the top of the three measured rankings (number of publications, collaboration and intermediation degree). China, the second most prolific CI scientific literature producer, however, does not interact with other countries, either in terms of collaboration or intermediation (see Fig. 3 and Table 1).

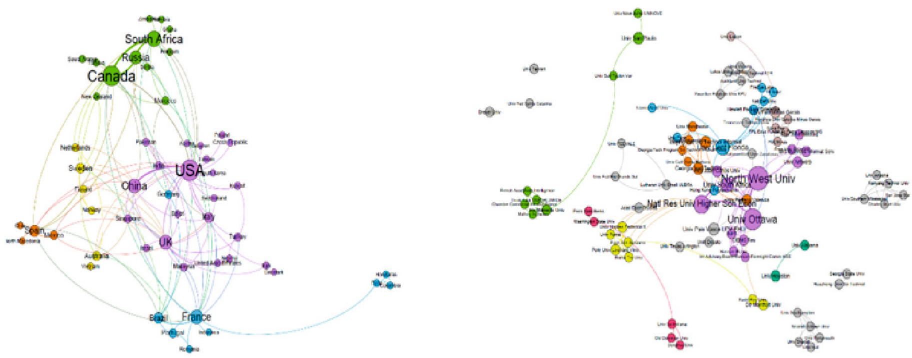


Fig. 3. Countries and organizations co-occurrence network.

Regarding organizations, the North West University (South Africa) and University Ottawa (Canada) show the highest levels in terms of publication numbers (together with IBIS) and also in collaboration and intermediation (see Fig. 3 and Table 2).

Table 1. Most productive, collaborative and intermediary countries.

Ranked	Nº of Publications (Productive)		Weighted degree (Collaborative)		Betweenness centrality (Intermediary)	
1	USA	165.0	USA	49.0	USA	544.37
2	China	142.0	Canada	46.0	France	300.55
3	Brazil	68.0	South Africa	31.0	UK	269.24
4	South Africa	68.0	China	26.0	Canada	258.69
5	Spain	59.0	UK	26.0	South Africa	182.94

Table 2. Most productive, collaborative, and intermediary organizations

Ranked	Nº of publications (Productive)		Weighted degree (Collaborative)		Betweenness centrality (Intermediary)	
1	IBIS Business Informat Serv	18	North West Univ	38	Hewlett Packard Enterprise	1218
2	North West Univ	17	Univ Ottawa	32	North West Univ	1211.66
3	Univ Ottawa	17	Natl Res Univ Higher Sch Econ	25	Univ Ottawa	1188.16
4	Univ South Africa	15	Univ Cent Florida	19	Univ Cent Florida	1168.5
5	Acad Econ Studies	13	Univ South Africa	16	Rey Juan Carlos Univ	706

3.2 Research Topics

Regarding research topics, the network has a low modularization, which means that few clusters are generated, implying research centralized around three major research areas. These are represented by the colors green, brown and purple, the latter being the main group, which is led by Competitive Intelligence, accompanied by fields related to "business intelligence" and "knowledge management" (see Fig. 4 and Table 3).

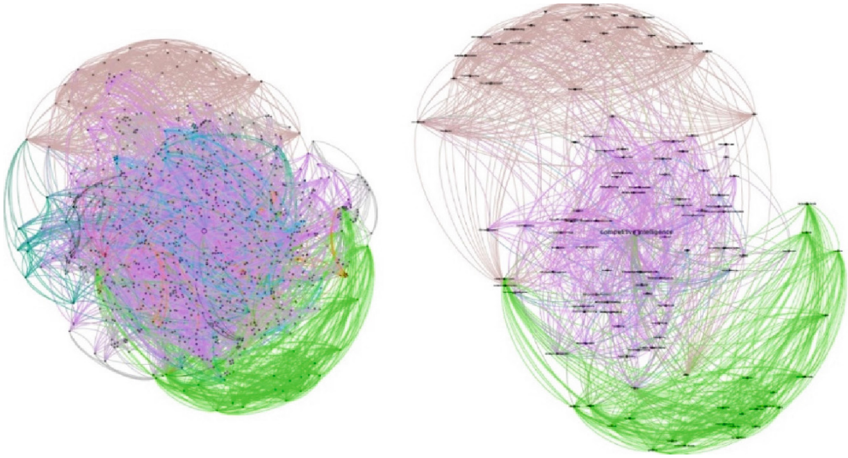


Fig. 4. Authors' keyword interaction network.

Table 3. Most relevant authors' keywords.

Ranked	Nº of publications		Weighted degree (Collaborative)		Betweenness centrality (Intermediary)	
1	Competitive intelligence	596	Competitive intelligence	2352	Competitive intelligence	1203322.72
2	Business intelligence	60	Business intelligence	272	Business intelligence	21469.41
3	Knowledge Management (KM)	58	Knowledge Management (KM)	264	Competitive intelligence system	12848.89
4	Competitiveness	31	Strategy	143	Marketing intelligence	12158.48
5	Marketing intelligence	30	Competitiveness	129	Knowledge Management (KM)	11559.12
6	Competitive advantage	28	Marketing intelligence	121	Text mining	11308.45
7	Innovation	28	Text mining	120	Innovation	11177.77
8	Small and medium-sized enterprises	26	Innovation	116	Intelligence	9816.22
9	Strategy	25	Competitive advantage	114	Competitiveness	9198.55
10	Text mining	25	Decision making	107	Small and medium-sized enterprises	8628.78

4 Conclusions

The bibliometric analysis of CI shows the scientific community's progressive interest in this intelligent gathering technique. While the keyword "competitive intelligence" itself, together with "business intelligence" and "knowledge management" dominate the interactions with a clear cluster behavior, the source countries and organizations are far more atomized, with USA and China as the top producers, together with South Africa as one of the most influential ones, and North West University (South Africa) and University Ottawa (Canada) as leaders in terms of collaboration and intermediation. It can be concluded that, the generated knowledge is not geographically concentrated, but are rather located in the tri-polar world (North America, Asia-Pacific, and Europe) and the universities are very important in the scientific development. As for the research topics, the main conclusion is that there are three main groups in which research on CI is conducted. All this leads us to future research to identify, among others: the main fields of work of the organizations that lead research in CI; to determine the most cited articles in order to know the origin of the main knowledge generated; and to analyze the new topics generated each year, thus identifying the scientific evolution.

References

1. Niu, Y., Ying, L., Yang, J., Bao, M., Sivaparthipan, C.B.: Organizational business intelligence and decision making using big data analytics. Inf. Process. Manage. **58**(6), 102725 (2021). https://doi.org/10.1016/J.IPM.2021.102725
2. van der Pol, J.: Collaboration network analysis for competitive intelligence. J. Intell. Stud. Bus. **11**(3), 17–26 (2021). https://ojs.hh.se/
3. Purnomo, A., Firdaus, M., Sutiksno, D.U., Putra, R.S., Hasanah, U.: Mapping of business intelligence research themes: four decade review. In: 10th IEEE International Conference on Communication, Networks and Satellite, Comnetsat 2021 - Proceedings, July 2021, pp. 32–37 (2021). https://doi.org/10.1109/COMNETSAT53002.2021.9530790
4. Clarivate Analytics. Web of Science Core Collection – Clarivate 2019 (2019). https://clarivate.com/products/web-of-science/web-science-form/web-science-core-collection/ Accessed 22 Feb 2022
5. Search Technology: The VantagePoint (2022). https://www.thevantagepoint.com/. Accessed 22 Feb 2022
6. Bastian, M., Heimann, S., Jacomy, M.: Gephi: an open source software for exploring and manipulating networks. In: Proceedings of the Third International Conference on Weblogs and Social Media, ICWSM 2009, San Jose, California, USA, 17–20 May 2009 (2009)

Value Chain Approach in Biotechnology Companies: A Bibliometric Analysis

Onailis Oramas-Santos(✉), Lourdes Canós-Darós, and Eugenia Babiloni

Universitat Politècnica de València, 46022 València, Spain
oorasan@doctor.upv.es

Keywords: Bibliometric · Value chain · Biotechnology

1 Introduction

In economics, value is perceived as a client's willingness to pay for a good provided by a company. Value theory is recognized as a strategic competitive analysis tool by Porter. He offers the seminal definition of Value Chain (VC further on), understanding it as an instrument to configure and link company activities to create a product or service [1]. The VC approach aligns with the new industrial policy's goal [2] to create global competitiveness, value-adding, and innovative industries to generate more productive jobs and reduce poverty towards shared prosperity [3].

Nowadays, one of the five most innovative sectors is the Biotechnology (biotech in short) industry [4], which is considered one of the critical technologies of the 21st century for the production of knowledge, goods, and services [5]. Biotech applications are differenced using indexes such as color index; e.g., companies developing health applications are also called "red" biotech companies [6]. From a VC perspective, this study selects red biotech for several reasons. First, the products or therapies resulting from research aim to improve patients' quality of life and are valued for the value-added. Also, it is a sector in which researchers are constantly generating new knowledge, and their contributions to science are measured by the value of this knowledge or social impact. Namely, it is a strongly science-based sector, within which innovations and cutting-edge technologies are crucial to their success.

The main objective of this study is to perform an analysis of the VC approach in the red biotechnology sector from a bibliometric perspective. To fulfill it, we use Scopus and WoS databases and VOSviewer and R studio software to show the results and highlight findings and conclusions. This is the first bibliometric study that addresses this specific topic to the best of our knowledge.

According to our main objective, the research questions posed by this study are: (1) Which are red biotech VC publications trends and citation networks? (2) Who are the most influential and productive authors, affiliations, countries, and years? (3) Which are the most relevant reasons to use the VC approach in red biotech? (4) What are the research gaps in this field?

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 335–340, 2023.
https://doi.org/10.1007/978-3-031-27915-7_59

2 Methodology

The pursued methodology is shown in Fig. 1 and developed following [7, 8].

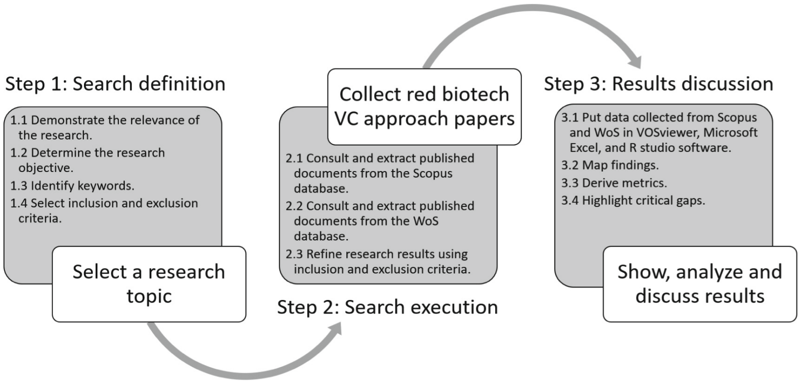


Fig. 1. Methodological research process of this study

The keywords identified and selected are: "value chain"; "biotechnology"; "health biotechnology"; "disease biotechnology"; "medical biotechnology"; "red biotechnology"; "biopharmaceutical"; and "biopharmacy". The selected inclusion and exclusion criteria are keyword combination, period analysis, document type, and communications language. The time-period of the research is from 2011 to 2021 what is justified according to [7, 9, 10]. Additionally, the publications before 2011 are not significant either in number or citations. The final date of data collection is February 15, 2022. After eliminating duplicate papers, the results from the first step are 30 and 52 papers from Scopus and WoS, respectively.

3 Results and Discussions

This section specifically: (1) identifies the most influential authors, their affiliations, and also the most productive publication's year and countries; (2) reveals current research trends; (3) highlights the main reason to adopt the biotech VC approach, and (4) maps and summarizes results.

Figure 2 summarizes the number of publications in Scopus and WoS, where a positive trend can be appreciated clearly. However, it is not an intensive research topic by Scopus´s authors, who commonly have published only one publication over the period analyzed. WoS's authors evidence a more stable behavior about year publications.

According to Scopus' records, Van Montagu, M. ranks first in productivity, followed by Giacca, M. and Singer, P.A. Fevre, E.M. ranks first in WoS with eleven published papers about red biotech VC, seconded by Alarcon, P., and Rushton, J.

H-index and G-index have been calculated according to the time cited in Scopus and WoS. The results show that at least 12 papers have been cited 12 times in Scopus and 14 in WoS, and the G-index results in 5 papers for both databases.

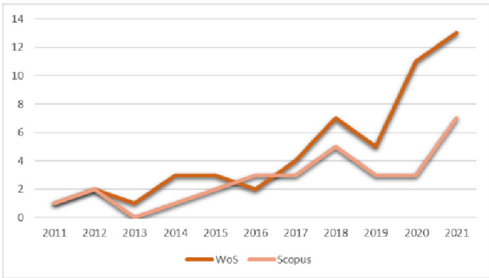


Fig. 2. Red biotech VC approach's yearly publications between 2011 and 2021

3.1 Network and Content Analysis

For network analysis (co-authorship, co-citation analysis, and bibliographic coupling), we use VOSviewer. Scopus authors are not connected, but Fig. 3 shows the author's network in WoS.

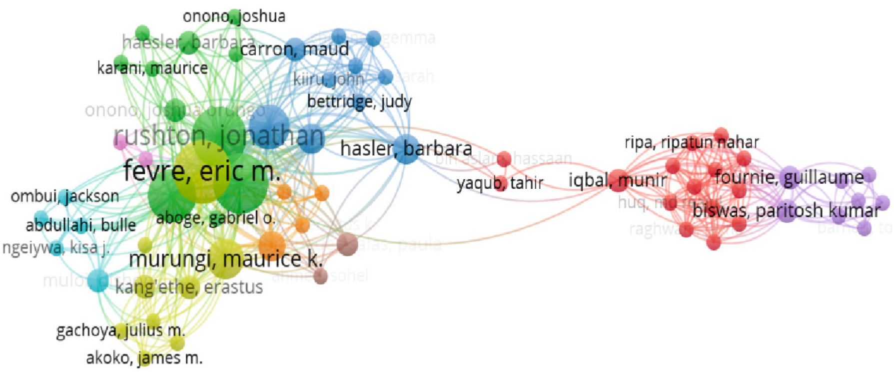


Fig. 3. Co-authorship network visualization in WoS (Source: VOSviewer software maps)

Authors in the WoS conform 65 links in 7 clusters. Therefore, there is a weak network of authors investigating VC in the red biotech sector. Fevre, E.M. is a vital author that connects other researchers, mainly due to his productivity. The authors of the sample of papers in both databases come from a few countries: the United States (USA), the United Kingdom, France, and Netherland. In the same way, the authors´ affiliations are also not extensive.

A co-citation source map for papers in both databases is inexistent. According to the co-citation reference map, the situation with Scopus is the same, and only two articles in the WoS form a network: [11] and [12]. This result is in line with the dispersion of authors and the few quantities of clusters.

The content analysis offers a general overview of the nature of the topic studied in this research. We use R studio to draw the words cloud based on authors' keywords in Fig. 4.

Fig. 4. Authors´ keywords word cloud in Scopus and WoS (Source. R studio software map)

In Fig. 4, we can visualize how in papers coming from the WoS (Fig. 4a.) and the Scopus (Fig. 4b.) databases, the most frequent keywords and, therefore, most studied topics are: (1) value chain as a strategic tool, (2) innovation in the value chains, (3) the impacts and applications of the VC approach in a biobased economy and the biotechnology industry, (4) the sustainability of VCs, (5) the risk in the pharmaceutical sector, (6) the governance in VC, (7) mapping a VC, and (8) the impacts in the society's health.

4 Conclusions and Highlights

This study provides the first bibliometric analysis of the value chain approach in the red biotech sector. It was developed to answer four initial research questions, presented in Sect. 1 and following a three-step methodology with data collected from the Scopus and the WoS databases. We summarize five relevant findings as follows:

(1) Once we examined the performance of the VC publications in red biotech and its current trends, it is possible to affirm that it is not an extended studied area (only 82 documents have been published during the last ten years). Publications are increased over the years, but each author's low number of publications demonstrates that publications in red biotech are more focused on health topics than in the industry. Networks do not extensively link research. Co-citation analysis of articles is impossible because papers do not compound networks.

(2) According to productivity from Scopus, Van Montagu, M. is the most productive author, while Fevre, E.M. distinguishes in WoS. Highlighted institutions are Wageningen University and the University of Liverpool. More productive years and countries are 2021 and the USA, respectively. H-index and G-index have been calculated, but these metrics are inconclusive because authors in different databases are incomparable. After all, the indexes depend on where you get the publication and citation data.

(3) The most relevant reasons for using the VC approach in this industry are the government's implication given its social impact and the possibility of linking activities in a technological sector and global environment.

(4) This research demonstrates the existence of some gaps that shapes the future agenda. Firstly, the modern VC concept, which analyses a business's complex network, including international relationships, is not extensively studied and applied in the

red biotech sector. Secondly, and related to red biotech and its business model, no published works analyze the initial step of a biotech product, that is, when the product is a project. The value created in this process is as significant as the impact of the future product, or even more given that if the project cannot beat this step, it never becomes a product. In third place, we show that nowadays' topics such as the impact of Industry 4.0 on the red biotech VC were not extensively investigated. Industry 4.0 applications such as Blockchain Technology and the Internet of Things [13–15] could favor business efficiency and provide better economic, social, and environmental results.

(5) Finally, future research could be directed to map VC for products in less developed countries, applying techniques to minimize or reduce the incertitude and the risk present in those regions. All actors, including governments, funding institutions, universities, and regulatory agencies, should be considered.

References

1. Porter, M.E.: Towards a dynamic theory of strategy. Strateg. Manag. J. **12**, 95–117 (1991). https://doi.org/10.1002/smj.4250121008
2. Kaplinsky, R., Morris, M.: A Handbook for Value Chain Research. University of Sussex, Institute of Development Studies, Brighton (2000)
3. Terzi, A., Singh, A., Sherwood, M.: Industrial policy for the 21st century: lessons from the past. Eur. Econ. Discuss. Pap. **157** (2022). https://economy-finance.ec.europa.eu
4. Ideascale: 5 Industries with the Most Innovative Companies. https://innovationmanagement.se/2017/03/30/5-industries-with-the-most-innovative-companies/
5. Uecke, O.: How to Commercialise Research in Biotechnology? Springer Gabler, Wiesbaden (2012)
6. DaSilva, E.J.: The colours of biotechnology: science, development and humankind. Electron. J. Biotechnol. **7**, 01–02 (2004)
7. Carrizo, D., Moller, C.: Estructuras metodológicas de revisiones sistemáticas de literatura en Ingeniería de Software: un estudio de mapeo sistemático. Ingeniare Rev. Chil. Ing. **26**, 45–54 (2018). https://doi.org/10.4067/S0718-33052018000500045
8. Choudhri, A.F., Siddiqui, A., Khan, N.R., Cohen, H.L.: Understanding bibliometric parameters and analysis. Radiographics **35**, 736–746 (2015). https://doi.org/10.1148/rg.2015140036
9. Gómez-Cedeño, M., Castán, J.M.[a], Guitart-Tarrés, L.: La importancia de los recursos humanos en la cadena de suministro (2014)
10. Codina, L.: Taller de bases de datos académicas Scopus, WoS y Mendeley. 91p (2019)
11. Alarcon, P., et al.: The broiler meat system in Nairobi, Kenya: using a value chain framework to understand animal and product flows, governance and sanitary risks. Prev. Vet. Med. **147**, 90–99 (2017). https://doi.org/10.1016/j.prevetmed.2017.08.013
12. Gereffi, G., Humphrey, J., Sturgeon, T.: The governance of global value chains. Rev. Int. Polit. Econ. **12**, 78–104 (2005). https://doi.org/10.1080/09692290500049805
13. Khan, S.A.R., Godil, D.I., Jabbour, C.J.C., Shujaat, S., Razzaq, A., Yu, Z.: Green data analytics, blockchain technology for sustainable development, and sustainable supply chain practices: evidence from small and medium enterprises. Ann. Oper. Res. (2021). https://doi.org/10.1007/s10479-021-04275-x

14. Meseguer-Sánchez, V., Gálvez-Sánchez, F.J., López-Martínez, G., Molina-Moreno, V.: Corporate social responsibility and sustainability. A bibliometric analysis of their interrelations. Sustain. Switz. **13**, 1–18 (2021). https://doi.org/10.3390/su13041636
15. Zhang, C., Chen, Y.: A review of research relevant to the emerging industry trends: Industry 4.0, iot, blockchain, and business analytics. J. Ind. Integr. Manag. **5,** 165–180 (2020). https://doi.org/10.1142/S2424862219500192

Optimisation Modeling for Lean, Resilient, Flexible and Sustainable Supply Chain Planning

John Reyes[1,2], Josefa Mula[1], and Manuel Díaz-Madroñero[1](✉)

[1] Research Centre on Production Management and Engineering (CIGIP), Universitat Politècnica de València, Alcoy, Spain
jreyvas@doctor.upv.es, {fmula,fcodiama}@cigip.upv.es
[2] Universidad Técnica de Ambato, Ambato, Ecuador
johnpreyes@uta.edu.ec

Abstract. This article provides an analysis of existing mathematical models for supply chain planning (SCP) with an emphasis on lean manufacturing that consider aspects of flexibility, resilience and sustainability to manage demand in today's changing and disruptive industrial environments. The incorporation of Industry 4.0 technologies to obtain a more autonomous supply chain (SC) is also considered. For this purpose, several reference models that can be used as a basis for new mathematical developments to improve the performance of SCs are analyzed. Finally, the problem to be addressed is described and the possible inputs, outputs, objectives, constraints, modeling and solution approaches are identified.

Keywords: Lean manufacturing · Resilience · Sustainability · Flexibility · Supply chain · Optimisation · Mathematical programming

1 Introduction

In today's world, combining the concepts of lean, agile, sustainable, resilient and flexible manufacturing is one of the most strategic and attractive concerns in today's industrial environments that seek to achieve maximum performance [1]. Also, organizations are under varied and increasing pressures from a broad spectrum of stakeholders to manage their supply chain (SC) functions in more efficient and effective ways from a sustainability standpoint. Definitions, characteristics of SCs and supply chain planning (SCP) also appear frequently in the literature. Existing scientific literature discusses, among others, the following most important objectives for SC optimization: cost, profit, lead time and customer service level. Lean manufacturing-based systems include practices and tools that have the potential to facilitate an organization to be economically, environmentally and socially sustainable. In this sense, given their importance and close relations, as well as the high costs involved, production planning and logistics activities require the optimization of manufacturing processes and the movement of materials in multi-level SC.

There are multiple contributions in the literature that have addressed the development of mathematical programming models for the tactical planning of lean SCs [2].

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 341–345, 2023.
https://doi.org/10.1007/978-3-031-27915-7_60

Also, a smaller body of work allows the generation of conceptual models for production and logistics planning of lean SCs in an Industry 4.0 (I4.0) context [1]. Apart from these initial classifications, scientific literature can also be evaluated using the planning decision level and modeling approach. The trade-off between waste cost and process performance has been an important objective in SC strategic decision making. Such modeling approaches may include: lean infrastructure, through lean tools; supply network design; as well as studies with a more limited scope on specific operations, such as supplier selection and/or lean procurement transportation planning oriented contributions. However, the integration of tactical and operational considerations into these modeling approaches is relatively recent. Similarly, integration in optimization models of I4.0 digital technologies with lean tools, such as internet of things (IoT), big data, cloud computing, cyber-physical systems (CPS), additive manufacturing (AM), and artificial intelligence (AI). Here, the main contribution of this article is the identification and analysis of the most representative works that could serve as the reference for the development of new optimization models for lean SCP in an I4.0 context.

The remainder of this article is structured as follows. Section 2 describes the analysed works and Sect. 3 presents the conclusions and identifies future research lines.

2 Comparative Analysis

The selection of reference models was based on the novelty aspect of the works [3–11]. Thus, regarding the lean SCP formulated as a multi-objective mathematical programming problem, a systematic protocol for the review of scientific literature available in Web of Science was used, employing the identification, screening, eligibility and inclusion of literature based on a PRISMA methodology [12]. The selected mathematical models that have been previously identified and analyzed by state of the art and conceptual proposals present validated planning alternatives for all SC processes considering lean, resilient and sustainable tools, in addition to considering, in some cases, I4.0 technological aspects [1, 13].

The elements of comparison of the fundamental aspects considered in Table 1 for each model studied have been extracted based on some of those identified in Table 1, to which some additional significant elements have been added to facilitate the comparison among them. To begin the discussion of how these models contribute to the development of new mathematical programming proposals, the main contributions and limitations detailed in the scientific references consulted are described. All models present combinations or integrated planning to reduce waste in terms of SC costs, such as production costs, procurement, inventory, among others.

First, a detailed production plan is presented to reduce manufacturing, transportation and inventory holding costs [4]. Flexibility is focused on warehouse inventory management capabilities and finished goods lead times. In addition, the authors contribute with an intervention of lean tools to minimize environmental degradation, including carbon emissions, energy consumption and waste generation. The limitations are oriented to the analysis of SC material sourcing processes, use of technologies and resilience aspects.

The modeling approach of [5] also has a lean and sustainable objective, but is strengthened by the application of 11 lean practices to improve organizational performance through the planning of SC-wide processes such as suppliers, production,

Table 1. Comparison of reference models.

Elements of comparison		[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
Type of problem	Sourcing planning	•	•	•	•	•		•	•	•
	Production planning	•	•	•			•	•	•	•
	Inventory planning		•						•	•
	Transportation planning	•	•	•	•	•		•		•
	Distribution planning	•		•	•	•		•	•	
	Supply network planning				•				•	
	Integration of the entire SC			•	•				•	
	Real case studies		•	•	•				•	
	I4.0 digital technologies							•	•	
Objective	Lean		•	•	•	•	•		•	•
	Agile					•		•		•
	Sustainable		•	•	•		•	•	•	
	Resilient				•				•	
	Flexible		•					•		
Decision level	Strategic			•	•	•				•
	Tactical		•				•	•	•	
	Operational		•				•		•	
Modeling approach	Nonlinear programming		•							•
	Entire model			•			•			
	Mixed-integer linear programming	•		•					•	
	Mixed-integer nonlinear programming							•		

procurement, transportation but with an emphasis on product distribution to improve environmental sustainability in terms of energy consumption generation of harmful emissions, pollution and waste; and social sustainability in terms of safety, employee empowerment, knowledge sharing and the provision of training. Also, resilience developments in a lean approach integrated into SCP to address uncertainty and related risks have not been addressed [4].

Regarding resilience criteria as determinant factors for performance improvement [14], an analysis of proactive measures with supply shortage risk scenarios in integrated warehouses with lean practices in food SCP as criteria to achieve economic sustainability by maximizing organizational profitability is shown [6]. This is done with a multiple objective, firstly to reduce waste; and, secondly with the selection of suppliers and location of distributors to meet market demand with minimal cost and environmental impact. The limitations of this model for our study are focused on the non-use of I4.0 technologies.

On the other hand, considering the main structural and technological elements of a lean SC for production and operations planning in an I4.0 environment, SCP integrated with I4.0 information and communication technologies is considered to provide flexibility to the SC demand forecasting process, minimize product delivery time, and maximize the total profit rate over time [9]. This model contributes in the area of flexibility with tactical planning, especially, for logistics and distribution processes in terms of connection, collaboration and customization to meet a known demand while complying with safety inventory policies. The perspective of the proposed solution does not contemplate the use of lean tools and scenarios to manage crisis environments.

Finally, the integration of the lean manufacturing system into a sustainable and resilient SC is examined. The flow of materials and finished products at four levels of the SC for suppliers, manufacturers, distribution centers and regional outlets is considered by [10]. This mathematical programming model provides integrated criteria for production planning and lean inventories and is strengthened in the analysis for procurement by prioritizing backup suppliers based on sustainability and resilience criteria in likely risk scenarios. The limitations of this model for our study focus on the use of I4.0 digital technologies.

3 Conclusions

In this article, five mathematical programming models have been analyzed in the field of SCP: multidimensional lean and environmentally sustainable model [4]; lean and sustainable model [5]; lean, environmentally sustainable and resilient model [6]; flexible model integrating I4.0 technologies [9]; as well as the lean, resilient and sustainable model with selection of alternative suppliers [10]. From the detailed and comparative analysis of the characteristics of the different reference models (see Table 1), we will extract possible inputs, outputs, modeling and solution approaches that could serve for the development of new optimization proposals for LSCP 4.0 that improve the performance of organizations. In this sense, a forthcoming work is a novel optımısatıon model for lean SCP. The theoretical and practical implications of this research work are aimed at guiding future research by academics and practitioners to build mathematical models for lean SCP in an I4.0 context, as well as industrial applications based on simulation optimization algorithms where the flow of physical and digital values is key to successful management.

Acknowledgments. The research leading to these results received funding from the: European Union H2020 Program under grant agreement No. 958205 “Industrial Data Services for Quality Control in Smart Manufacturing (i4Q)”; Regional Department of Innovation, Universities, Science and Digital Society of the Generalitat Valenciana entitled “Industrial Production and Logistics Optimization in Industry 4.0” (i4OPT) (Ref. PROMETEO/2021/065) and “Resilient, Sustainable and People-Oriented Supply Chain 5.0 Optimization Using Hybrid Intelligence” (RESPECT) (Ref. CIGE/2021/159); and PhD grant from Technical of Ambato University.

References

1. Reyes, J., Mula, J., Díaz-Madroñero, M.: Development of a conceptual model for lean supply chain planning in industry 4.0: multidimensional analysis for operations management. Prod. Plan. Control. (2021, in press). https://doi.org/10.1080/09537287.2021.1993373
2. Díaz-Madroñero, M., Mula, J., Peidro, D.: A review of discrete-time optimization models for tactical production planning. Int. J. Prod. Res. **52**, 5171–5205 (2014). https://doi.org/10.1080/00207543.2014.899721
3. Alavidoost, M.H., Jafarnejad, A., Babazadeh, H.: A novel fuzzy mathematical model for an integrated supply chain planning using multi-objective evolutionary algorithm. Soft. Comput. **25**(3), 1777–1801 (2020). https://doi.org/10.1007/s00500-020-05251-6
4. Fahimnia, B., Sarkis, J., Eshragh, A.: A tradeoff model for green supply chain planning: a leanness-versus-greenness analysis. Omega-Int. J. Manag. Sci. **54**, 173–190 (2015)
5. Das, K.: Integrating lean systems in the design of a sustainable supply chain model. Int. J. Prod. Econ. **198**, 177–190 (2018)
6. Das, K.: Integrating lean, green, and resilience criteria in a sustainable food supply chain planning model. Int. J. Math. Eng. Manag. Sci. **4**, 259–275 (2019). https://doi.org/10.33889/ijmems.2019.4.2-022
7. Malmir, B., Zobel, C.W.: An applied approach to multi-criteria humanitarian supply chain planning for pandemic response. J. Humanit. Logist. Supply Chain Manag. ahead-of-print (2021). https://doi.org/10.1108/JHLSCM-08-2020-0064
8. Vafaeenezhad, T., Tavakkoli-Moghaddam, R., Cheikhrouhou, N.: Multi-objective mathematical modeling for sustainable supply chain management in the paper industry. Comput. Ind. Eng. **135**, 1092–1102 (2019). https://doi.org/10.1016/j.cie.2019.05.027
9. Oh, J., Jeong, B.: Tactical supply planning in smart manufacturing supply chain. Robot. Comput. Integr. Manuf. **55**, 217–233 (2019). https://doi.org/10.1016/j.rcim.2018.04.003
10. Shafiee, M., Zare Mehrjerdi, Y., Keshavarz, M.: Integrating lean, resilient, and sustainable practices in supply chain network: mathematical modelling and the AUGMECON2 approach. Int. J. Syst. Sci. Oper. Logist. **9**(4), 451–471 (2022). https://doi.org/10.1080/23302674.2021.1921878
11. Rabbani, M., Aghamohamadi-Bosjin, S., Manavizadeh, N.: Leagile supply chain network design through a dynamic two-phase optimization in view of order penetration point. RAIRO - Oper. Res. **55**, S1369–S1394 (2021). https://doi.org/10.1051/ro/2020041
12. Moher, D., et al.: Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. Ann. Intern. Med. **151**, 264–269 (2009). https://doi.org/10.7326/0003-4819-151-4-200908180-00135
13. Reyes, J., Mula, J., Díaz-Madroñero, M.: The potential of Industry 4.0 in Lean Supply Chain Management. In: 15th International Conference on Industrial Engineering and Industrial Management and XXV Congreso de Ingeniería de Organización, pp. 153–154. Burgos (2021)
14. Llaguno, A., Mula, J., Campuzano-Bolarin, F.: State of the art, conceptual framework and simulation analysis of the ripple effect on supply chains. Int. J. Prod. Res. **60**(1), 1–23 (2020)

Gamification for Awareness of the Importance of Enterprise and Supply Chain Resilience

Marco Arias-Vargas[1,2](✉), Raquel Sanchis[2], and Raúl Poler[2]

[1] Industrial Engineering School, University of Costa Rica, San José, Costa Rica
marco.ariasvargas@ucr.ac.cr
[2] Research Centre on Production Management and Engineering (CIGIP), Universitat Politècnica de València, Valencia, Spain
{rsanchis,rpoler}@cigip.upv.es

Abstract. Enterprise and supply chain resilience has become a must in the business world due to the increasing number of disruptive events that have modified companies' environments. To cope with this strategic must, organizations must evaluate their workers' knowledge and awareness about this matter. In this work, these attributes are assessed using gamification: a trivia game to measure essential knowledge and awareness. Strengthening these attributes is a strong starting point for organizations to enhance their resilient capacity as a key goal in their strategy.

Keywords: Gamification · Trivia · Enterprise resilience · Supply chain resilience · Knowledge · Awareness

1 Introduction

Over the last decade, enterprise performance has been influenced by the degree of resilience that a company and its supply chain have due to the high impact of crisis and threats in the business world. Based on the definition of enterprise resilience (ER) from [1], we define enterprise and supply chain resilience (ESCR) as the capability of an enterprise and its supply chain to anticipate and be prepared to face disruptive events (DEs), and, if their occurrence is inevitable, the capacity to recover as soon and efficiently as possible. Currently, and due to the recent DEs, defined as foreseeable or unforeseeable events that directly affect an enterprise's usual operation and its stability [1], strategic plans must change; from the efficient perspective to the efficiency/resilience perspective to face these events and achieve success in the long term. Gamification is a robust method to test and train people in the business world about specific matters. Gamification is widely used for educational purposes, and it can be implemented within an organization to drive knowledge achievement. It has proven to be an effective and efficient method for people to learn how to be aware of potential situations in organizations. It has also proven to drive learning competitions to faster learning.

In this work, a trivia game, based on recent research, is proposed to quantify people's knowledge and awareness about DEs and ESCR.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 346–351, 2023.
https://doi.org/10.1007/978-3-031-27915-7_61

2 Literature Review

Companies and organizations must turn their strategic plans into actions. While doing that, they must ensure that these plans are flexible due to the dynamism of the business environment, with significant DEs occurrence. This situation has driven companies to be aware of such events and, thus, to increase resilient capabilities. In the last decade, researchers have made significant contributions to companies in their quest for resilience, developing several frameworks and mathematical models to achieve resilience. In this sense, [2] present an ER conceptual reference framework that helps companies understand and manage ER.

The use of games as learning tools have been extensively studied [3], and it has been confirmed that educational games are an effective and attractive way to improve the learning process. Also, in [3], the authors present 12 arguments in favor of games and their effects on the learning process; such as enjoyment, motivation, learning evidence, gratification, and player's resilience.

Gamification has been applied to train people in different fields, such as general education, engineering education, management, cyber security, manufacturing, and health. Gamification can help companies reduce their information and cyber security breaches as game-based learning methods can be more effective in learning to avoid fraudulent phishing and, in general, security awareness [4]. Also, in [5], they conclude that several breach catalysts are consequences of human error that they expose as the leading cause of data breach. Companies need workers to be aware of data breaches when using company devices or even personal devices. They conclude that training is critical to prevent future breaches.

Regarding the pharma business, in [6], they propose adopting gamification to improve product quality, effectiveness, and efficiency. They state that gamification is related to employee motivation; key to achieving company's goals.

These gaming models can be applied to manufacturing; in [7], they argue that gamification mechanics can support manufacturing education and training, especially in the sustainability aspect of the transition to Industry 4.0. Gamification has been applied to teach, learn, and train different business themes. Still, although the recent proliferation of research works in the ESCR field, literature about gamification on this subject is scarce. As far as we know, specifically, the awareness of ESCR has not been addressed through gamification.

3 Enterprise and Supply Chain Resilience Trivia Game

Some games can be used for individual learning or competitive learning purposes; several games have been used for evaluation and training [3]. In this case, a trivia game has been developed to cover all those objectives. It can be played individually, showing the results in a global ranking, or several persons from a specific organization can register, play it, and compare their results with each other in the organization's rank. Both rankings try to promote healthy competition. The main goal of this game is to enhance awareness of the importance of ESCR for organizations and to identify the specific aspects in which companies should offer training to their employees since it keeps track of the lowest rating concepts. Training is a solid starting point to be more resilient.

The trivia game presented in this paper is based on recent academic research studies in ESCR. One of the main features is that it can be accessible for educational purposes. It was developed in an open-source language (Python, using the PyWebio library for web publishing), and it uses a free database (MARIA DB). This game contains more than 300 single selection questions (still in progress), which are classified based on the origin of the DEs; "Production," "Inventory," "Environmental," "Social," "Financial," or "Customers". All the questions and answers are related to recent research in this field [8, 9]. This trivia game is based on the conceptual framework for enterprise resilience enhancement developed by [1], consisting of more than 70 DEs identified as endangerments for organizations (through an exhaustive literature review using Scopus and Web of Science databases and reports issued by consulting firms that perform annual surveys to study the most worrisome DEs) and more than 400 preparedness actions (validated through a Delphi Study) to deal with each DE.

This game shows the player the questions randomly, and since they all have the same weight in the final results, the game is balanced concerning the origin of the DEs. Moreover, the game provides feedback about the correct and wrong answers with a summary report and information about each player's performance.

This trivia game allows a wide variety of people to play it, since it is user-friendly and easy to play; after filling up the registration form, random questions will show. The players only have to choose the answer they think is the correct one. Figure 1 presents an example of one of the questions.

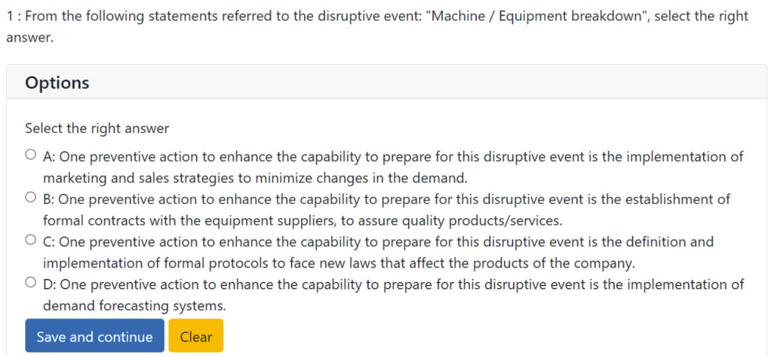


Fig. 1. Example of the questions included in the trivia game

All the questions in this trivia game are simple selection questions, and thus, only one of the four answers displayed for each question is correct. All the questions have the same weight in the final score, and they are internally categorized by disruption event origin.

After the player answers all the questions, the game will display a report showing the current score and several related statistics, as is shown in Fig. 2.

In the upper section of the status report, the player's performance indicators are displayed; they include the current game score, the maximum and average historical scores, and the rank position within a company and in the global ranking, which considers

Status Report

100.0%

Name	Company	Score	Max	Average	Global Ranking	Competitors	Company Ranking	Company Competitors
Marco Arias Vargas	Macrologistica	80.0	100.0	91.0	1	4	1	2

Disruptive event origin	Score	Average
Production	0.0	42.86
Inventory	100.0	71.43
Environmental	100.0	85.71
Social	100.0	100.0
Finance	100.0	85.71
Customers	No questions asked	71.43

Continue

Fig. 2. Individual achievement report

all the players, regardless their company. Each player can find scores related to each DE origin in the lower section of this report.

The game also has a detailed report of the results, which is very important to enhance the learning process. Figure 3 shows an example of this report.

DETAILED REPORT

Participant: Marco Arias Vargas

Question
From the following statements referred to the disruptive event: "Machine / Equipment breakdown", select the right answer.
Your answer
One preventive action to enhance the capability to prepare for this disruptive event is the implementation of demand forecasting systems.
Correct answer
One preventive action to enhance the capability to prepare for this disruptive event is the establishment of formal contracts with the equipment suppliers, to assure quality products/services.

Fig. 3. Example of the final report

The feedback from this report is essential to learn from all the questions the player failed to answer since it shows the correct answers to those questions.

This specialized trivia application tests the players' knowledge and awareness about ESCR, since it is based on DEs that every company should be aware of to enhance resilience. Also, it promotes healthy competition; if a player wants to achieve a higher position in the ranking, he/she can play again. Since the trivia application status is as an initial prototype, the next step is to implement it in a company to validate it and test if the awareness about ESCR increases after playing the game. Based on [3], to compare the results about the degree of knowledge and awareness before and after playing the game, the experiment will allow for repetitiveness, giving the players the option to play several times and then, comparing the initial scores with the late ones. If this method concludes that this trivia game is suitable for enhancing ESCR awareness, the game, that has been defined as generic as possible to cover as many companies as possible, should be applied to companies from different sectors to compare their results and obtain a specific homogeneous analysis for each sector. In addition, it is worth mentioning that it is difficult to estimate the improvement in the level of knowledge and awareness that the game will provide. However, in other research related to trivia games, the improvement has been quantified at 15.8% in the number of right answers [10].

4 Conclusions

The first step to successfully enhance ESCR is to ensure that the staff in the company has sufficient knowledge and understanding of ESCR concepts and is aware of all the implications, risks, and opportunities surrounding the company. This can be accomplished by evaluating their knowledge and awareness level using a focused trivia to quantify those levels before and after playing the game. With this evaluation, organizations will identify the weak areas that will support them in developing and implementing a formal and fine-tuned training process. Future research should address gamification applied to the specific areas where knowledge gaps have been identified, to implement specific training programs. This can be accomplished by implementing ESCR simulation games like the one that authors are currently designing.

All these diagnoses and further training will enhance ESCR. Organizations will be better prepared to include these topics in their strategic plans and recover more efficiently when the occurrence of a DE is unavoidable.

Acknowledgements. This work was supported in part by the European Commission under the Project Reference No. 2021-1-IT01-KA220-VET-000033287.The authors would like to acknowledge the support of the researchers from the project "Business Continuity Managers Training Platform" (CONTINUITY) (business-continuity-project.eu).

To the Industrial Engineering School at the University of Costa Rica.

References

1. Sanchis, R., Canetta, L., Poler, R.: A conceptual reference framework for enterprise resilience enhancement. Sustainability **12**, 1464 (2020). https://doi.org/10.3390/su12041464
2. Sanchis, R., Duran-Heras, A., Poler, R.: Optimising the preparedness capacity of enterprise resilience using mathematical programming. Mathematics **8**, 1596 (2020). https://doi.org/10.3390/math8091596
3. Angles, R., Silvestre, L., Pincheira-Orellana, G., Galarce-Miranda, C., Gormaz-Lobos, D.: Improving the teaching-learning process in engineering through a game-based web support system: Edutrivias. In: Auer, M.E., Rüütmann, T. (eds.) ICL 2020. AISC, vol. 1328, pp. 487–498. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-68198-2_45

4. Filipczuk, D., Mason, C., Snow, S.: Using a game to explore notions of responsibility for cyber security in organisations. In: Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems, pp. 1–6. ACM (2019). https://doi.org/10.1145/3290607.3312846
5. Cole, J.R., Pence, T., Cummings, J., Baker, E.: Gamifying security awareness: a new prototype. In: Moallem, A. (ed.) HCII 2019. LNCS, vol. 11594, pp. 115–133. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-22351-9_8
6. Marcao, R.P., Pestana, G., Sousa, M.J.: Gamifying the product quality reviews in the pharmaceutical ındustry. In: European Conference on Knowledge Management, pp. 724–731 (2019). https://doi.org/10.34190/KM.19.183
7. Paravizo, E., Chaim, O.C., Braatz, D., Muschard, B., Rozenfeld, H.: Exploring gamification to support manufacturing education on industry 4.0 as an enabler for innovation and sustainability. Procedia Manuf. **21**, 438–445 (2018). https://doi.org/10.1016/j.promfg.2018.02.142
8. Sanchis, R., Poler, R.: Origins of disruptions sources framework to support the enterprise resilience analysis. IFAC-PapersOnLine **52**, 2062–2067 (2019). https://doi.org/10.1016/j.ifacol.2019.11.509
9. Sanchis, R., Poler, R.: Evaluación de la resiliencia empresarial: Marco de categorización de disrupciones Enterprise resilience assessment: a categorisation framework of disruptions. Dirección y Organización **54**, 45–53 (2014)
10. Bocchino, A., et al.: Trivial como método didáctico alternativo para fomentar el aprendizaje en los estudiantes de enfermería (2014)

Development and Application of a Specialized Set of Engineering Tools to Enhance Enterprise and Supply Chain Resilience

Marco Arias-Vargas[1,2](✉), Raquel Sanchis[2], and Raúl Poler[2]

[1] Industrial Engineering School, University of Costa Rica, San José, Costa Rica
marco.ariasvargas@ucr.ac.cr

[2] Research Centre on Production Management and Engineering (CIGIP), Universitat Politècnica de València, Valencia, Spain
{rsanchis,rpoler}@cigip.upv.es

Abstract. Complexity, dynamism, sudden changes, and disruptive events (COVID-19, Ukraine war, etc.) have become the norm in the current business world. Companies and their related supply chains are trying to adapt to a business reality fed by disruptive events to try to guarantee their survival in the long term. It is essential to highlight that some disruptive events are more predictable than others. However, even for the non-predictable events, early symptoms will facilitate their detection. Thus, it is critical to provide quantitative tools to identify patterns and warn companies to activate resilience plans and preventive actions. These tools should include features such as multivariate analysis for pattern recognition, disruptive events prediction, and prioritization of the preventive actions related to each disruptive event to support companies in enhancing their resilience capacity. In addition, the entire organization must be committed and convinced of the benefits that improved resilience will bring. For this reason, it is also critical to develop mechanisms to make workers aware of the importance of being resilient and promote the implementation of the resilience dimension in their quality systems, which is an opportunity for an organization to get formally certified in this area.

Keywords: Enterprise and supply chain resilience · Artificial intelligence · Disruptive events · Awareness · Gamification · Predictability

1 Introduction and Background

Enterprise and Supply Chain Resilience (ESCR) is not a new topic. Still, it was not until the beginning of century XXI that researchers and practitioners started to work consistently in this field due to the increasing presence of unexpected events. These disruptive events (DEs) have created awareness among researchers, managers, and business people that this topic is of common interest and should be a component of the organizations' strategy.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 352–357, 2023.
https://doi.org/10.1007/978-3-031-27915-7_62

The concept of resilience has its origins in disciplines like ecology, phycology, and mechanics. In recent years, definitions have emerged in the business and industrial fields [1]. In this research, the selected definition of enterprise resilience (ER) is the capability to anticipate and be prepared to face DEs and, if their occurrence is inevitable, the capacity to recover as soon and efficiently as possible [2].

The lack of ER is exposed when DEs occur, these are incidents that cause expected or unexpected disturbances that have adverse effects on the company and in its supply chain [3]. There are several types of DEs; some occur inside the companies or their supply chain, and their impact is within this supply chain, but others are external, and they have higher outreach and effects. Three known examples of the most recent and critical DEs are: (i) The financial crisis from 2007 to 2009 brought economic losses in different countries and the shutdown of several highly recognized companies [4]. (ii) The pandemics of the Covid-19 have impacted the economy globally, causing raw materials and components scarcity that affected the supply chains [5]. (iii) The invasion of Russia to Ukraine, which consequences on the global economy, will be harmful but are still unquantified.

Regarding the DEs that have their origin and impact inside a company or its supply chain, some examples are low supplier fill rate, significant demand fluctuations, machine breakdowns, and others. These events could be predictable by analyzing their behavior with transactional data to identify patterns. Recent studies have consolidated concepts, methodologies, and conceptual frameworks to measure resilience capacity. In [2], the authors define a framework that involves 71 DEs grouped by 11 disruption sources and develop tools to calculate resilience indexes based on optimization techniques. Some include a list of preventive actions and event logs to support ER [6].

There are quantitative models based on mathematical programming that aim to support organizations in the selection of the preventive actions for each DE [7]. However, this can be complemented with other models, for example, predictive models for DE with origins inside the organization. The predictability of an event depends on several factors [8], such as: (i) How well are the factors that contribute to the event understood?; (ii) How much information is available? and (iii) Can the prediction affect the event we are trying to predict?

The right combination of predictive models with the current tools would support organizations in implementing continuous processes to enhance ER.

The main contributions that this research proposal aims for: (i) To increment the awareness about the importance of companies being resilient; (ii) To incorporate predictive models in the company's transactional systems to take advantage of pattern recognition to warn about the potential presence of DEs before their occurrence; and (iii) To guide companies toward a path to achieve a formal certification in ER.

2 Research Objectives

This doctoral research aims to add value to this field by developing and implementing engineering tools to enhance awareness about the importance of ESCR, predict DEs, and include ESCR in the organizations' quality systems and strategy. This Ph.D. thesis will answer the following research questions:

RQ1. How to make companies aware of the importance of ESCR?
RQ2. Which type of engineering tools could warn companies about the potential occurrence of DEs?
RQ3. Which DEs' detection and prediction tools could complement current tools to enhance ESCR?
RQ4. How to encourage companies to implement resilience plans?
RQ5. Could a standard hallmark be created for companies' resilience, similar to the current quality certificates?

Thus, the main objective of this doctoral thesis is to enhance and strengthen resilience in companies, firstly promoting awareness, then with the development of DEs' prediction models along with techniques to prioritize preventive actions, and finally, with the design of a seminal work toward a certification in enterprise resilience. Therefore, the specific objectives are:

O1. To develop "resilience mechanisms" to promote awareness about the importance of ESCR, measure workers' knowledge about ESCR, and assess workers' decision-making skills in simulated scenarios with the occurrence of DEs.
O2. To validate the usefulness of the "resilience mechanisms" through their implementation in an actual company.
O3. To develop a prediction tool for DEs that continuously warn the company about DEs' potential occurrence. It is expected that this tool will also provide prioritization of preventive actions for the detected DEs.
O4. To test the usefulness of the prediction tool for DEs through its implementation in a company.
O5. To propose a set of indicators to enhance enterprise resilience's control and continuous improvement.
O6. To propose a certification program in ER for companies; to promote the early adoption of the current methodologies and tools for ESCR enhancement.

To answer the research questions and to achieve the objectives, the expected results of this doctoral thesis are:

- Development of the "resilience games". Two gamification applications, "resilience mechanisms," to measure users' knowledge and awareness about ESCR. The first will be a trivia game with more than 300 questions regarding more than 70 DEs to evaluate the knowledge and awareness in ESCR. The second one will be a system dynamics simulation game where participants will be challenged to make intelligent decisions in a company that faces different DEs. This game aims to assess knowledge and decision-making skills.
- Development of a DEs' prediction tool: Since recent studies identified the most important DEs, this tool will aim to predict the ones that a company chooses to monitor, applying artificial intelligence (AI) techniques to the company's transactional data, generating warnings when the probability of a DE is high. Once the DEs have been identified, this tool will prioritize the preventive actions the company should implement.

- Definition of a structured compendium of resilience indicators to continuously monitor and control the degree of resilience in a company, considering the findings of recent research studies and, complemented by a market study of companies' affinity with the main DEs and preventive actions.
- A seminal work defining the basics of a certification program in ESCR. During the last decades, companies have experimented with several certifications to improve their processes and competitiveness, for example, certifications in environmental and quality issues. If a certification program and an ER hallmark fulfill the expectation of companies, this could facilitate and accelerate the implementation of methodologies, tools, and techniques to improve resilience. This hallmark could drive ER into the strategic plans.

Figure 1 shows the relationship among the components of this thesis.

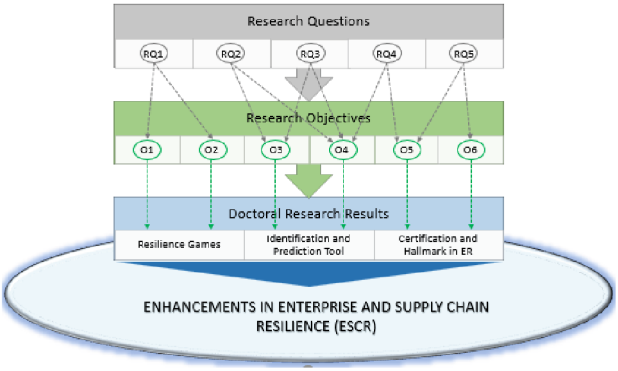


Fig. 1. Relationship among research questions, objectives, and expected results

3 Methodology

This doctoral research will have the following stages:

Problem Definition and Objectives Formulation. This stage aims to define, justify and highlight the importance and the positive impacts of the solutions of the research problem. Additionally, this stage includes the research questions and the derived research objectives.

State of the Art. This stage consists of developing a detailed literature review about the enhancements in ESCR due to the use of AI techniques. It aims to find opportunities to go beyond the current state of the art in topics with low coverage and evaluate the use of AI techniques in monitoring and predicting DEs.

Development of Gamification Applications. The third stage focuses on gamification to improve people's knowledge and awareness regarding ESCR. It includes the development of a web-based trivia application that contains the main concepts of this topic. This game promotes competition comparing scores for people from different companies. The second application is a simulation game where the participants have to manage the company for one year, making decisions about order quantities and suppliers' selection in a business environment containing several DEs. This game assesses decision-making skills.

Development of a Monitoring and Predictive Tool for DEs. This stage focuses on developing a tool that helps companies identify, monitor, and predict DEs. This tool will work with several techniques, ranging from classical statistical models to machine learning and other AI models. This tool will search for patterns and signals to identify and predict DEs using the company's transactional data. After this identification, this tool will prioritize the preventive actions required to minimize adverse effects of the DEs and thus, enhance resilience. Since these preventive actions have already been determined in another tool, SATIER [6], the predictive tool will communicate with it.

Development of a Proposal for Companies' Certification in ESCR. This stage aims to propose the seminal basis for an enterprise certification program in ESCR, where a potential collateral effect would be the incentive for companies to early adopt and implement methodologies and tools to improve resilience. This program and hallmark will create awareness about the inclusion of ESCR in the companies' strategies, adjusting value propositions and critical resources.

Validation of Tools and Proposals. It is critical for the success of this research thesis to implement in real companies all the tools developed. This stage aims to test their functionality, ease of use, and acceptance from the users, considering their feedback to improve these tools. Additionally, this stage includes the review of the certification proposal with the company managers to fine-tune it before presenting it to other organizations.

Conclusions, Limitations, and Future Lines of Research. After doing the analyses and gathering information from the results, the conclusions will show all the findings and a description of the tools implemented. In this stage, results will be presented considering the achievement of the research objectives and the new contributions to the ESCR field. Also, this phase will explain the limitations of the doctoral research, the contributions and the proposal for future research lines.

Acknowledgements. This work was supported in part by the European Commission under the Project Reference No. 2021-1-IT01-KA220-VET-000033287.The authors would like to acknowledge the support of the researchers participating in the project "Business Continuity Managers Training Platform" (CONTINUITY) (business-continuity-project.eu).

To the Industrial Engineering School at the University of Costa Rica, for their support to this work.

References

1. Sanchis, R., Poler, R.: Medición de la Resiliencia Empresarial ante Eventos Disruptivos. Una Revisión del Estado del Arte *. In: V international Conference on İndustrial Engineering And İndustrial Management. pp. 104–113. Cartagena (2011)
2. Sanchis, R., Canetta, L., Poler, R.: A conceptual reference framework for enterprise resilience enhancement. Sustainability **12**, 1464 (2020). https://doi.org/10.3390/su12041464
3. Sanchis, R., Poler, R.: Evaluación de la resiliencia empresarial: Marco de categorización de disrupciones Enterprise resilience assessment: a categorisation framework of disruptions. Dirección y Organización **54**, 45–53 (2014)
4. Taleb, N.: The Black Swan: The Impact of the Highly Improbable. Random House Inc., New York (2010)
5. McLain, S.: Auto Makers Retreat From 50 Years of 'Just in Time' Manufacturing (2021)
6. Sanchis, R.: Propuesta de una Herramienta y Metodología para el Análisis y Mejora de la Resiliencia Empresarial (2017)
7. Sanchis, R., Duran-Heras, A., Poler, R.: Optimising the preparedness capacity of enterprise resilience using mathematical programming. Mathematics **8**, 1596 (2020). https://doi.org/10.3390/math8091596
8. Hyndman, R.J., Athanasopoulos, G.: Forecasting: Principles and practice. OTEXTS (2018)

A Methodology to Reduce the Costs of Water Distribution Networks Design

Alicia Robles-Velasco(✉), María Rodríguez-Palero, Jesús Muñuzuri, and Luis Onieva

Dpto. De Organización Industrial y Gestión de Empresas II, Escuela Técnica Superior de Ingeniería, Universidad de Sevilla, Seville, Spain
arobles2@us.es

Abstract. Due to the population growth and the consequent rapid extension of urban areas, water distribution networks have to be redesigned and adapted to new layouts and water demands. As the design of these networks require the use of discrete variables and non-linear equations, it is a complex problem, being metaheuristics the most suitable techniques to solve them. In this study, simulated annealing is used to solve two well-known networks, Alperovits and Hanoi. Additionally, the installation of valves in some of the pipe sections is analysed from an economical and operational point of view. The results demonstrate that the integration of these two approaches, metaheuristics and valves introduction, allows a significant reduction of the design costs.

Keywords: Water distribution networks · Design · Metaheuristics · Simulated annealing · Valves

1 Introduction

Water distribution networks are responsible for transporting water from source nodes to different supply points. They are mainly composed of pipes, but other elements like tanks, valves or pumps are also typical in these infraestructures. When designing a water distribution network, parameters such as flow, water pressure and velocity must be taken into account in order to assure hydraulic conditions.

Several studies in the exiting literature have already addressed this problem using different metaheuristics [1, 2]. Some of them include additional objectives as the network energy sustainability [3]. Others directly employ a computer-based applications in the field that integrate hydraulic analysis, evolutionary algoritms and Geographic Information System (GIS) [4].

In a previous study developed by the authors, a Tabu Search algorithm is implemented to estimate the pipe diameters that minimize the design costs [5]. The present study proposes a different metaheuristic, concretely, simulated annealing, and the introduction of valves in some pipe sections to optimize the costs of water distribution network design. This metaheristic has been previously used to find solutions for network design problems obtaining very optimistic results [6, 7]. However, we extend the approach by including

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 358–363, 2023.
https://doi.org/10.1007/978-3-031-27915-7_63

valves in the network, seeking to reduce costs while ensuring hydraulic feasibility. Valves are mechanical elements that can control and close the flow inside pipes [8]. They are very useful for maintenance tasks, whether preventive or corrective, since they allow the supply to be interrupted to correct problems and quickly have water available again.

2 Problem and Methodology

In this section, the problem is mathematically defined by a model that seeks for minimizing the desing costs. Then, the methodology that consists of a metaheuristic and the installation of valves in some pipes is presented.

2.1 Model Definition

Two facts make the design of water distribution networks becomes a non-linear mixed-integer problem. Firstly, the variables to be estimated are integer, the design of water distribution networks consists of calculating the pipes diameters, while the network layout is typically established in advance. Secondly, the operation of the system is governed by several hydraulic conditions regarding the flow, the water velocity and the water pressure, which are included as non-linear constrains in the model.

As previously said, the objective of the model is to find the optimal diameters $\varnothing_{kj}$ of each network pipe that minimize the total costs (Eq. (1)). The contrainsts given by Eqs. (2) and (5) represent the flow balance and the minimum operating pressure (p_{min}) of each node i. Meanwhile, the energy conservation is ensured by Eqs. (3) and (4). In the model, N is the set of nodes, A the set of arcs, M the set of loops, E_i and S_i the set of input and output arcs of node i, and K the set of commercial diameters.

$$\min \sum_{j \in A} \mathrm{C}\left(\varnothing_{kj}\right) L_j \tag{1}$$

$$\sum_{j \in E_i} q_j - \sum_{j \in S_i} q_j = d_i, \forall \mathrm{i} \in N \tag{2}$$

$$\sum_{j \in m} P_j = 0, \forall m \in M \tag{3}$$

$$p_i = p_{i-1} - P_j, \forall \mathrm{i} \in N, j \in E_i \tag{4}$$

$$p_i \geq p_{min}, \forall i \in N \tag{5}$$

$$\varnothing_{kj} \in K, q_j \in R, p_i \in R \tag{6}$$

2.2 Simulated Annealing

Metaheuristics are techniques that try to find the global optimum of a problem in a search space. They are suitable to solve complex models as the one presented here.

Simulated annealing (SA) is the metaheuristic used to search for the optimum combinations of diameters that minimize the costs. This metaheuristic is based on the process of cooling a very hot material slowly so that the material solidifies in the state of minimum energy. The algorithm starts with an initial solution, and a neighbouring solution is iteratively generated. In each iteration, the objective function of the new solution is calculated and compared to the previous one. Contrary to the traditional local search, the worsen of solutions is allowed in order to escape from local optima.

2.3 Introduction of Valves

The valves have been included in the network following Algorithm 1. The number of valves to introduce, the initial pipe diameters and the commercial catalogue of diameters needs to be established in advance. If there is two or more pipes with the same diameter, one of them is randomly chosen.

Algorithm 1. The introduction of valves in water distribution networks.

For $i = 1$ to Total_Number_of_Valves **do**
    Order the pipes according to their diameter (from the largest to the smallest):
    $\emptyset = \{\emptyset_1, \ldots, \emptyset_n\}$
    For $j = 1$ to n **do**
        If valve i has not been installed **and** pipe section j does not have a valve **do**
            Install valve i in the pipe section j
            For $k = j + 1$ to n **do**
                If pipe k exists **and** pipe k does not have a valve **do**
                    Reduce the diameter $\emptyset_k$
                    Evaluate hydraulic parameters of the network
                If technical evaluation is admisible **do**
                    Store the solution and calculate the design cost of the network

The introduction of valves allows limiting pipes flows, consequently, some pipe diameters can be reduced without causing loss of admissibility. This action seeks for reducing the the design costs of the network.

3 Case Study

Two well-known networks have been utilised as case studies of this work. On the one hand, the Alperovits and Shamir's network [9] counts with 7 nodes, 8 pipe sections and 2 loops. On the other hand, the Hanoi network [10] is more complex, having 32 nodes and 34 pipe sections. In both cases, the layout of the networks is totally defined, including the nodes elevation, the water demand and the pipes length. Furthermore, a list of commercial diameters is given with their corresponding costs measured in monetary units (u.m.).

Figure 1 shows the definition of the Hanoi network in the software EPANET [11], which is used to simulate its operation when valves are introduced.

4 Results

The software Python, and specifically, the library WNTR [12] are used to solve the model. We have tested the introduction of one valve in each of the studied networks.

The results demonstrate that the combination of metaheuristics and the introduction of valves is an ideal strategy since the costs are reduced to 9% of the initial costs in the case of Alperovits and Shamir network, and to 58% of the original costs in the case of the Hanoi networks (see Table 1).

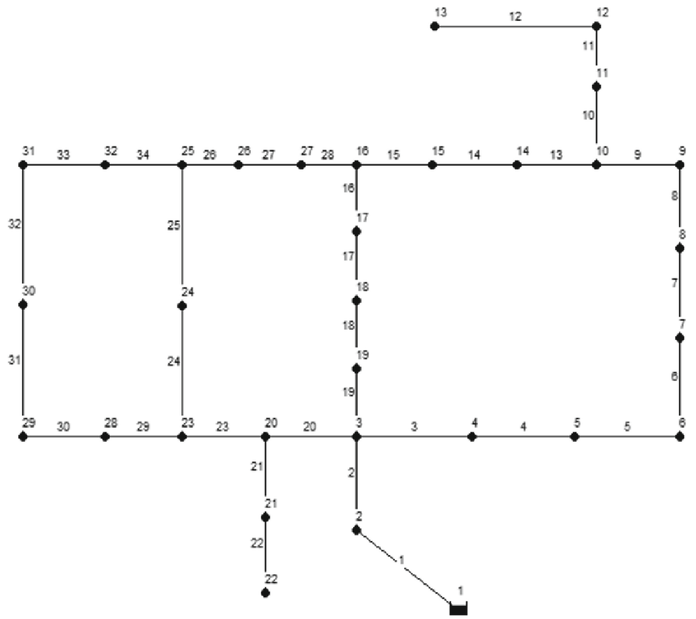


Fig. 1. Simulation of the Hanoi network in EPANET.

In fact, thanks to the inclusion of valves, the final costs of both networks are reduced in 22% in the case of Alperovits and Shamir and 8% in the case of Hanoi, with respects to those costs obtained after implementing the metaheuristic (these costs do not include valve prices, however, they are substantially lower than the design savings achieved). The final solutions obtained are admisible from an operational point of view, i.e., the pressures in the nodes are higher than the minimal operating pressure, and the water velocity does not exceed 2m/s nor is less than 0.5m/s. As Alperovits network is smaller, it requires less iterations in the introduction of valves than Hanoi network.

Table 1. Design costs (u.m.) in the different stages of the proposed methodology.

Water network	Design costs (u.m.)		
	Initial solution	SA solution	Valve inst. Solution
Alperovits	4,400,000.0	488,000.0	382,000.0
Hanoi	10,969,796.6	6,879,260.7	6,352,526.6

5 Conclusions

The main conclusions of this study are:

- The rapid growth of population and, specifically, urban areas is forcing water distribution networks to expand in the same way.
- Simulated annealing is a suitable option since this metaheuristic is able to escape from local optima, achieving excellent results.
- The introduction of valves in some specific pipe sections reduces the design costs of the two cases studies with respecto to those obtained by using only the metaheuristic in 22% and 8% respectively.

As future lines of research, it would be interesting to perform a deeper study of valves inclusion by adding more valves. Moreover, the proposed methods should be tested with larger networks to demostrate their capabilities and usefulness.

Acknowledgements. The authors wish to acknowledge to the *Consejería de Economía, Conocimiento, Empresas y Universidad (Junta de Andalucía)* and the European Regional Development Fund (ERDF) because of their financial support through the *Actuaciones de Transferencia* UNIVERSIDADES-CEI-RIS3 of the project "*Gestión de redes de abastecimiento y saneamiento de agua mediante técnicas de Inteligencia Artificial (GRIAL)*".

References

1. Cunha, M.D.C., Ribeiro, L.: Tabu search algorithms for water network optimization. Eur. J. Oper. Res. **157**, 746–758 (2004). https://doi.org/10.1016/S0377-2217(03)00242-X
2. Reca, J., Martínez, J., Gil, C., Baños, R.: Application of several meta-heuristic techniques to the optimization of real looped water distribution networks. Water Resour. Manag. **22**, 1367–1379 (2008). https://doi.org/10.1007/s11269-007-9230-8
3. Meirelles, G., Brentan, B.M., Luvizotto, E.: Optimal design of water supply networks using an energy recovery approach. Renew. Energy. **117**, 404–413 (2018). https://doi.org/10.1016/j.renene.2017.10.080
4. Ayad, A., Awad, H., Yassin, A.: Integrated approach for the optimal design of pipeline networks. Alexandria Eng. J. **57**, 87–96 (2018). https://doi.org/10.1016/j.aej.2016.10.008
5. Robles-Velasco, A., Cortés, P., Muñuzuri, J., Escudero-Santana, A.: Optimization of water supply network design based on a Tabu search algorithm. In: De la Fuente, D., Pino, R., Ponte, B., Rosillo, R. (eds.) ICIEOM 2018. LNMIE, pp. 61–69. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-67708-4_7

6. Zoppou, C., Reed, M.: Water distribution network design optimization: simulated annealing approach. J. Water Resour. Plan. Manag. **127**, 69–70 (2001)
7. Cunha, M.D.C., Sousa, J.: Water distribution network design optimization: simulated annealing approach. J. Water Resour. Plan. Manag. **125**, 215–221 (1999)
8. Salcedo-Ballestero, C.A.: Localización y ajustes óptimos de válvulas reductoras de presión (VRP) en RDAP para minimizar el índice de agua no contabilizada (IANC) (2014), https://repositorio.uniandes.edu.co/bitstream/handle/1992/17109/u703518.pdf?sequence=1
9. Alperovits, E., Shamir, U.: Design of optimal water distribution systems. Water Resour. Res. **13**, 2637 (1977). https://doi.org/10.1029/WR013i006p00885
10. Fujiwara, O., Khang, D.B.: A two-phase decomposition method for optimal design of looped water distribution networks. Water Resour. Res. **26**, 539–549 (1990). https://doi.org/10.1029/WR026i004p00539
11. Rossman, L.A.: EPANET 2.0 User Manual. Water Supply and Water Resources Division, National Risk management Laboratory, USEPA (2000)
12. Klise, K.A., et al.: Water Network Tool for Resilience (WNTR) User Manual (2017)

Single Station MILP Scheduling Models Using Continuous and Discrete Approach

María-Luisa Muñoz-Díaz[1,2](✉), Alejandro Escudero-Santana[1], Roel Leus[3], and Antonio Lorenzo-Espejo[1]

[1] Departamento de Organización Industrial y Gestión de Empresas II, Escuela Técnica Superior de Ingeniería, Universidad de Sevilla, Seville, Spain
mmunozd@us.es

[2] Andalusia, Alentejo and Algarve University Innovation Centre (CIU3A), Seville, Spain

[3] Research Group ORSTAT, Faculty of Economics and Business, KU Leuven, Leuven, Belgium

Abstract. This paper presents two mixed linear programming models (MILP) for single-station production scheduling. These models use the two classical forms of time representation, continuous and discrete. Both models solve the sequencing and assignment of tasks for the same set of non-identical parallel machines. The two MILP models are solved using Gurobi Optimizer for different problem configurations and their results are displayed in a table showing the value of the objective function and its runtimes.

Keywords: Scheduling · MILP · Single station · Continuous · Discrete

1 Introduction

Mathematical programming, especially Mixed Integer Linear Programming (MILP), due to its rigorousness, flexibility and extensive modelling capabilities, has become one of the most widely explored methods for production scheduling processes [1]. In this field, there are often real scenarios in which the planning of the entire production system is focused on one single station [2, 3].

This paper presents two MILP models to solve the same production planning problem for a single station. The results of these models, applied to the same database, will be presented. Both the solved problem and the database come from a real scenario in a wind tower plant in Seville, Spain.

2 Problem Description

The problem can be classified according to Graham et al. [4] as an $R|prec|C_{max}{}^{*}$, where R refers to unrelated parallel machines, *prec* refers to the fact that precedence relations are specified and $C_{max}{}^{*}$ refers to the optimality criterion chosen to minimize the maximun completion time.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 364–368, 2023.
https://doi.org/10.1007/978-3-031-27915-7_64

In addition, according to the literature review of single-station MILP models by Muñoz-Díaz et al. [5], there are three ways to represent the time domain: continuous, discrete and hybrid formulation. However, no papers were found that develop both options to solve the same problem. This paper presents a single-station MILP model formulated in continuous time and one formulated in discrete time to solve the same problem.

The modelled problem consists of a single station with non-identical parallel machines. All of them can process all the possible tasks. In addition, the model includes the possibility that some tasks must be processed on the same machine consecutively. The information for both models is shown below:

Parameters and indexes:

i,j Task index; $i,j \in \{0,1,2,\ldots,T\}$ in the continuous model and $i,j \in \{1,2,\ldots,T\}$ in the discrete model

T Number of tasks

k Machine index $k \in \{1,2,\ldots,M\}$

M Number of machines

p_{ik} Processing time of task i on machine k

z_{ij} Binary parameter, $z_{ij} = 1$ if task i has to precede task j, otherwise 0

E A large number

Variables:

$Cmax$ Maximun completion time

Ci Completion time task i

2.1 Continuous Model

This section presents the mixed linear programming model in continuous time. Before that, the variables that are used exclusively in this formulation are shown:

y_{ijk} Binary variables, $y_{ijk} = 1$ if task i is scheduled immediately before task j on machine k, otherwise 0

$$\text{Min} \quad Cmax \tag{1}$$

$$sa : Cmax \geq C_i \ \ \forall \text{i} = 1, 2, \ldots, \text{T} \tag{2}$$

$$\sum_{j=1}^{T} y_{0jk} = 1 \quad \forall k \tag{3}$$

$$\sum_{k=1}^{M} \sum_{\substack{i=0 \\ \backslash\{j\}}}^{T} y_{ijk} = 1 \quad \forall j = 1, 2, \ldots, T \tag{4}$$

$$\sum_{\substack{i=0 \\ \backslash\{j\}}}^{T} y_{ijk} = \sum_{\substack{l=0 \\ \backslash\{j\}}}^{T} y_{jlk} \quad \forall j = 1, 2, \ldots, T; \forall k \tag{5}$$

$$\sum_{k=1}^{M} y_{ijk} \geq z_{ij} \quad \forall i, j = 1, 2, \ldots, T \tag{6}$$

$$C_j \geq C_i + p_{jk} - \mathrm{E}\left(1 - y_{ijk}\right) \quad \forall j = 1, 2, \ldots, T; \forall i; \forall \mathrm{k} \tag{7}$$

$$C_0 = 0 \tag{8}$$

$$y_{ijk} \in \{0, 1\} \forall i, j, k \tag{9}$$

$$C_i \geq 0 \quad \forall i \tag{10}$$

$$Cmax \geq 0 \tag{11}$$

The objective function to minimize is stated in Constraint (1) and the Makespan is obtained in Constraints (2). A dummy task is introduced in Constraints (3), which indicate that the dummy task 0 is placed at the beggining of each machine. Constraints (4) ensure that each task has only one immediately previous task, only one immediately subsequent task and is assigned to only one machine, except task 0, the dummy task. Balance equations are included through constraints (5). Constraints (6) are enforced to guarantee that the mandatory sequences between certain pairs of tasks are fulfilled. Constraints (7) and (8) define the completion time of all tasks. Finally, constraints (9), (10) and (11) are the basic restrictions on the decision variables.

2.2 Discrete Model

This section presents the mixed linear programming model in discrete time. This formulation relies on a discretization of the planning horizon, for the lenght of which we use a practical upper bound W_{max}. In addition, let time period u be the time interval [u-1,u], which in this research corresponds to 30 min. Before presenting the model, the indexes, parameters and variables that are used exclusively in this formulation are shown:

u Period index, $u \in \{1,2,\ldots,W_{max}\}$

W_{max} Parameter that delimits the length of the planning horizon

W_{ik} Parameter that defines the time window of task i on machine k. $W_{ik} = \{1,2,..., W_{max}\text{-}p_{ik}+1\}$

y_{iuk} Binary variable, $y_{ijk} = 1$ if task i is scheduled to start in period u on machine k, otherwise 0

$$\text{Min} \quad Cmax \tag{12}$$

$$\text{s.a}: \quad Cmax \geq C_i \ \ \forall i \tag{13}$$

$$\sum_{k=1}^{M} \sum_{u \in W_{ik}} y_{iuk} = 1 \ \ \forall i \tag{14}$$

$$\sum_{i=1}^{T} \sum_{v=u-p_{ik}+1}^{u} y_{ivk} \leq 1 \qquad \forall k; \quad \forall u \in \{1, \ldots, W_{max}\} \tag{15}$$

$$y_{(i+1)(u+p_{ik})k} \geq y_{iuk} - \mathrm{E}\big(1 - z_{i(i+1)}\big) \quad \forall i \in \{1, \ldots, T-1\} \;\; \forall k, \forall \mathrm{u} \tag{16}$$

$$C_i = \left[\sum_{k=1}^{M} \sum_{u \in W_{ik}} y_{iuk} \cdot (u + p_{ik}) \right] - 1 \;\; \forall i \tag{17}$$

$$y_{ijk} \in \{0, 1\} \quad \forall i, j, k \tag{18}$$

$$C_i \geq 0 \quad \forall i \tag{19}$$

$$Cmax \geq 0 \tag{20}$$

The objective function to minimize is stated in Constraint (12) and the Makespan is obtained in Constraints (13). Constraints (14) require each task to be started exactly once and Constraints (15) ensure that at a given time period u, only one task can be executed on each machine. Constraints (16) are enforced to guarantee that the mandatory sequences between certain pairs of tasks are fulfilled. Constraints (17) define the completion time of all tasks and constraints (18), (19) and (20) are the basic restrictions on the decision variables.

3 Results and Conclusions

Time estimations based on previous records on the manufacturing process have been used to solve the problem with different configurations. Both models have been implemented in Python and solved on an Intel® Core™ i7-4790 CPU at 3.60 GHz with 12 GB of RAM using Gurobi Optimizer v9.1.1. Table 1 shows the makespan and runtime obtained from the 12 resulting configurations with $M = \{2,4,6\}$ and $T = \{20,40,80,160\}$.

The results show that the makespan obtained by the continuous model is better than the discrete model for all configurations. Moreover, the continuous model has shorter runtimes in most cases. It is worth mentioning that, in the largest of the configurations, M = 6 and T = 160, the discrete model manages to obtain an optimal solution in a runtime of less than 2 h compared to the continuous model, which does not. However, the continuous model still gives a better result for the objective function. This is due to the loss of information resulting from the discretisation of time, which could be minimised by using smaller intervals u, with a consequent increase in runtime. In conclusion, for problems of this volume, the continuous model reaches better results.

Table 1. Makespan (hours) and runtime (seconds) obtained for the 12 configurations in the continuous and discrete models. *LR*: limit reached (2 h/7200 s).

		Continuous model		Discrete model	
M	T	Makespan (h)	Runtime (s)	Makespan (h)	Runtime (s)
2	20	47.3897	0.1359	49.5	3.8118
	40	98.6939	0.6057	104.5	69.3254
	80	190.5366	26.2331	204	LR
	160	375.4440	LR	443	LR
4	20	40.6574	0.1659	42	2.6155
	40	48.0537	0.6876	51.5	52.6859
	80	87.5284	4.4235	91	1686.0407
	160	173.8521	LR	202	LR
6	20	31.7948	0.2019	34.5	3.8138
	40	40.6575	0.8925	42	54.7838
	80	62.2815	9.0968	69	1070.8293
	160	99.4577	LR	106	5148.3380

Acknowledgements. This research was co-funded by the European Regional Development Fund ERDF by means of the Interreg V-A Spain-Portugal Programme (POCTEP) 2014-2020, through the CIU3A project, and by the Agency for Innovation and Development of Andalusia (IDEA), by means of 'Open, Singular and Strategic Innovation Leadership' Programme, through the joint innovation unit project OFFSHOREWIND. The research was also supported by the Ministry of Universities of Spain through a grant for the Training of University Researchers (Ayuda para la Formación del Profesorado Universitario, reference FPU20/05584).

References

1. Floudas, C.A., Lin, X.: Mixed integer linear programming in process scheduling: modeling, algorithms, and applications. Ann. Oper. Res. **139**(1), 131–162 (2005)
2. Marchetti, P.A., Cerdá, J.: An approximate mathematical framework for resource-constrained multistage batch scheduling. Chem. Eng. Sci. **64**(11), 2733–2748 (2009)
3. Elekidis, A.P., Corominas, F., Georgiadis, M.C.: Production scheduling of consumer goods industries. Ind. Eng. Chem. Res. **58**(51), 23261–23275 (2019)
4. Graham, R.L., Lawler, E.L., Lenstra, J.K., Rinnooy Kan, A.H.G.G.: Optimization and approximation in deterministic sequencing and scheduling: a survey. Ann. Dis. Math. **5**, 287–326 (1979)
5. Muñoz-Díaz, M.-L., Escudero-Santana, A., Lorenzo-Espejo, A., Robles-Velasco, A.: Modelos lineales mixtos para la programación de la producción con una sola etapa: estado del arte. Dir y Organ. **77**, 63–73 (2022)

Systematic Literature Review Protocol: Multiple-Criteria Decision-Making (MCDM) in Urban Freight Distribution

Sandra Alvarez Gallo[1](✉) and Julien Maheut[2]

[1] Dpto. de Producción, Institución Universitaria Pascual Bravo, Medellín, Colombia
sandra.alvarezga@pascualbravo.edu.co
[2] Dpto. de Organización de Empresas, ROGLE, Universitat Politècnica de València, Camino de Vera S/N, 46022 Valencia, España
juma2@upv.es

Abstract. This paper presents a method for conducting a systematic literature review that can be reproduced in further research. This method focuses on identifying publications that make use of multicriteria analysis methodologies to select alternative solutions in city freight distribution that seek to minimize the ensuing social, environmental, and economic effects. The proposed protocol for literature review includes the definition of inclusion and exclusion criteria, search terms and search expression, and selection process for papers. It comprehends papers from 2012 to 2021 in the WoS and Scopus databases. The results provide details on the publications with the higher number of citations.

Keywords: Urban freight distribution · Protocol · Literature review · Multicriteria analysis · MCDM

1 Introduction

Efficient performance in urban freight distribution has become a fundamental component for business competitiveness, on the grounds of population growth and centralization in urban areas, increase in the products distribution and supply, new physical and virtual distribution channels, high expectations of service from increasingly demanding customers and the negative effects this type of distribution has both on the environment (in the form of environmental pollution), and in traffic congestion. All of this has caused companies and public authorities to be concerned about assessing and choosing the best policies for increasingly complex city logistics.

In order to meet the needs and interests of the parts involved in this decision-making, some researchers have implemented the *multiple-criteria decision-making* (MCDM) method. MCDM is part of the operations research domain, and it is considered a tool to face decision-making problems when many solutions are available, by contemplating multiple criteria, both quantitative and qualitative [1] and allowing to consider the interested parties' diverse objectives [2].

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 369–373, 2023.
https://doi.org/10.1007/978-3-031-27915-7_65

Few previous literature reviews related to strategy evaluation for urban freight distribution that implement MCDM methodologies have been identified. Macharis and Bernardini's [3] paper is one of these and it focuses on the *multi-actor multi-criteria analysis* (MAMCA) methodology. Moreover, there is the literature review published by Jamshidi et al. [4], which describes MCDM techniques and criteria considered.

Stojčić et al. [5], on the other hand, focus on implementing multi-criteria analysis methods in the sustainable engineering domain but the focal point of the search is not urban freight logistics.

Kahraman et al.'s review [6] classifies the use of fuzzy MCDM methods according to application areas; however, it does not consider logistics as a research scope among said areas.

Unlike the few literature reviews found, this paper identifies publications that allow to determine the MCDM frameworks or methodologies for the evaluation of urban freight logistics strategies and that can support research in this area.

This publication is structured as follows: first, the inclusion and exclusion criteria are proposed; second, the search terms are determined; third, the articles filtering is explained; then, the results obtained are described based on the most cited articles, and finally the conclusions are stated.

2 Methodology

The main aim of this article is to define the protocol used to conduct a systematic literature review in order to identify publications made on the subject of urban freight logistics strategies that implement multi-criteria analysis for decision-making. The protocol is based on the proposal developed by Marin [7]. The search is conducted in the Scopus and WoS database in publications from 2012 to 2021 in accordance with the following inclusion and exclusion criteria for choosing the papers:

2.1 Inclusion Criteria

- Works written in English or Spanish.
- Scientific papers or conference papers.
- Publications focused on decision-making strategies for the urban freight logistics that make use of multi-criteria analysis methodologies.

2.2 Exclusion Criteria

- Literature reviews and book chapters.
- References about urban passenger logistics.
- Publications that do not use MCDM for decision-making in urban logistics.
- Articles that do not specify which MCDM method was used.
- Publications focused on urban disasters, humanitarian logistics, spatial decision-making, waste management, energy sources or energy efficiency.
- *Multiple-objective decision-making* (MODM) methods that consider infinite and unknown alternatives are not included.

2.3 Search Terms

Multiple-criteria decision-making (MCDM) is designated with different names in the literature, such as *multi-criteria analysis* (MCA). Within the subclassification of the MCDM for discrete and predetermined alternative choices, it has been given the name of *multi-attribute decision-analysis* (MADA) or *multiple-attribute decision-making* (MADM) [8] and [9]. The term *multi-actor multi-criteria analysis* (MAMCA) is also used as it involves the multi-criteria evaluation from different part's standpoints, which are included in the title, abstract or keyword in the search expression of this review and must also contain some of the following terms: *((city OR urban) AND logistic) o "Low Emission Zone" o "Urban freight" o "urban distribution"*.

Likewise, the search expression specifies the type of source publication to be included, the type of document, language, and date of publication.

2.4 Selection of Publications

As shown in Fig. 1, the results of the literature search yielded a total of 232 results after eliminating 112 duplicates. Out of these publications, 171 that did not meet the specified criteria and 8 documents with access restrictions were excluded and finally 53 publications were selected.

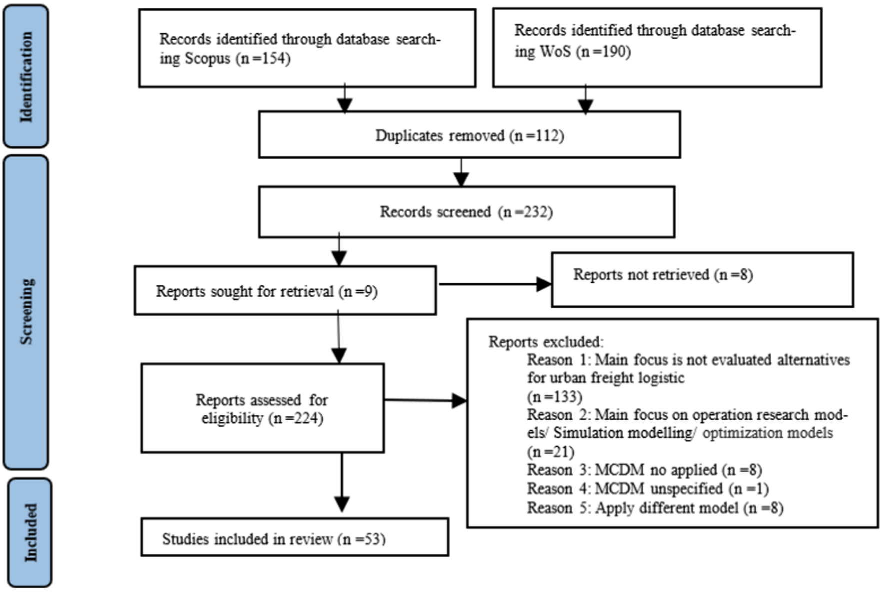


Fig. 1. Selection of references (Source: prepared by author using PRISMA flow diagram [13])

3 Results

A total of 53 publications from 2012 to 2021 were selected, with an average number of citations of 24.4 per document. These publications include a total of 93 authors, which indicates that most were developed in co-authorship, the average being 2.4 authors per paper. As for the type of publication, out of the selected articles, 42 are published in journals and 11 in conference proceedings.

The publications with the highest average number of citations per year include, in the first place, Tadić et al. [10], which proposes fuzzy DEMATEL, ANP and VIKOR models. Second, Rao et al. [11] propose a *multi-attribute group decision-making* method based on the THOWA operator under a fuzzy environment. Third, Awasthi and Chauhan [12] which include the affinity diagram, AHP and fuzzy TOPSIS.

4 Discussion and Conclusions

Defining a protocol for literature review provides a guide and a frame of reference to develop a bibliographic search process, which can be then reproduced, contributing to reduce researcher bias.

The results of this work appear to show that the subject of implementing multi-criteria analysis in the choice of strategies for urban freight logistics has been addressed in few research publications. Namely, the search done for this work identified only 53 publications from the last 10 years. However, the number of articles has been increasing slighly year by year. This shows a growing interest in the implementation of this methodology which is a tool that provides support to authorities and companies when making decisions on city logistics policies.

Significantly, it is worth noting that a common point among publications with the higher number of citations is that they have hybrid fuzzy models, which highlights the importance and interest that researchers give to this type of method.

In future work the systematic literature review will be developed using the publications of Jamshidi et al. [4] and Kitchenham et al. [14] that will allow quantifying the results and identifying gaps in the research, which could be considered as weak areas or topics for future studies.

References

1. Yannis, G., Kopsacheili, A., Dragomanovits, A., Petraki, V.: State-of-the-art review on multi-criteria decision-making in the transport sector. J. Traffic Transp. Eng. (English Ed.), **7**(4), 413–431 (2020). https://doi.org/10.1016/j.jtte.2020.05.005
2. Wątróbski, J., Jankowski, J., Ziemba, P., Karczmarczyk, A., Zioło, M.: Generalised framework for multi-criteria method selection. Omega (United Kingdom) **86**, 107–124 (2019). https://doi.org/10.1016/j.omega.2018.07.004
3. Macharis, C., Bernardini, A.: Reviewing the use of multi-criteria decision analysis for the evaluation of transport projects: time for a multi-actor approach. Transp. Policy **37**, 177–186 (2015). https://doi.org/10.1016/j.tranpol.2014.11.002

4. Jamshidi, A., Jamshidi, F., Ait-Kadi, D., Ramudhin, A.: A review of priority criteria and decision-making methods applied in selection of sustainable city logistics initiatives and collaboration partners. Int. J. Prod. Res. **57**(15–16), 5175–5193 (2019). https://doi.org/10.1080/00207543.2018.1540892
5. Stojčić, M., Zavadskas, E.K., Pamučar, D., Stević, Z., Mardani, A.: Application of MCDM methods in sustainability engineering: a literature review 2008–2018. Symmetry (Basel) **11(**3) (2019). https://doi.org/10.3390/sym11030350
6. Kahraman, C., Onar, S.C., Oztaysi, B.: Fuzzy multicriteria decision-making: a literature review *. Int. J. Comput. Intell. Syst. **8**(4), 637–666 (2015)
7. Marin-Garcia, J.A., Vidal-Carreras, P.I., Garcia Sabater, J.J., Escribano-Martinez, J.: Protocol: value stream maping in healthcare. a systematic literature review. WPOM-Working Pap. Oper. Manag. **10(**2), 36 (2019). https://doi.org/10.4995/wpom.v10i2.12297
8. Dean, M.: Multi-criteria Analysis, 1st edn., vol. 6. Elsevier Inc. (2020)
9. Vinogradova, I.: Multi-attribute decision-making methods as a part of mathematical optimization. Mathematics **7(**10) (2019). https://doi.org/10.3390/MATH7100915
10. Tadić, S., Zečević, S., Krstić, M.: A novel hybrid MCDM model based on fuzzy DEMATEL, fuzzy ANP and fuzzy VIKOR for city logistics concept selection. Expert Syst. Appl. **41**(18), 8112–8128 (2014). https://doi.org/10.1016/j.eswa.2014.07.021
11. Rao, C., Goh, M., Zhao, Y., Zheng, J.: Location selection of city logistics centers under sustainability. Transp. Res. Part D Transp. Environ. **36**, 29–44 (2015). https://doi.org/10.1016/j.trd.2015.02.008
12. Awasthi, A., Chauhan, S.S.: A hybrid approach integrating Affinity Diagram, AHP and fuzzy TOPSIS for sustainable city logistics planning. Appl. Math. Model. **36**(2), 573–584 (2012). https://doi.org/10.1016/j.apm.2011.07.033
13. “PRISMA (2020). http://www.prisma-statement.org/PRISMAStatement/FlowDiagram. Accessed 18 Nov 2021
14. Kitchenham, B., Pearl Brereton, O., Budgen, D., Turner, M., Bailey, J., Linkman, S.: Systematic literature reviews in software engineering - a systematic literature review. Inf. Softw. Technol. **51(**1), 7–15 (2009). https://doi.org/10.1016/j.infsof.2008.09.009

Planning Annualized Hours with Flexible Contracts

Andrés Felipe Porto[1,2](✉), Amaia Lusa[2], César Augusto Henao[3], and Roberto Porto[4]

[1] Corporación Universitaria Americana, Barranquilla, Colombia
aporto@coruniamericana.edu.co
[2] Universitat Politècnica de Catalunya, Barcelona, Spain
[3] Universidad del Norte, Barranquilla, Colombia
[4] Corporación Politécnico Costa Atlántica, Barranquilla, Colombia

Abstract. This study proposes and evaluates in a novel way a strategy for personnel planning, which combines the particular flexibility strategies i) Annualized hours and ii) flexible contracts. The problem is to plan a flexible workforce that minimizes the problems of overstaffing and understaffing in a retail store, during a time horizon of one year. The problem solution, involved resolving strategic and tactical decisions, its mean an a Tour Scheduling Problem, thus allowing to see the potential benefits of the proposed flexibility strategy. The results obtained show the important benefits, as well as their close link with workforce planning, in relation to operating costs, and robustness facing demand variability scenarios.

Keywords: Labor flexibility · Annualized hours · Flexible contracts · Retail

1 Introduction

Human resources (HR) planning, within its many decisions, determines types of contractual agreements, number and type of employees, weekly shift schedule, and even assignment of tasks to employees, that an organization will require in a planning horizon. The correct HR planning helps to satisfy personnel needs in an industry, avoiding periods of over- and under-staffing (i.e., number of personnel higher or lower than required, respectively), affecting the budget and service level offered [1, 2].

The economic sectors, especially the retail industry, are usually very sensitive in their personnel planning, due to operation long hours in which uninterrupted customer service is required; in addition, that the demand usually varies a lot over time, not only over the months and weeks, even over the different periods of operating day, the different functions and types of work, generating difficulty in defining optimal staff [3–5]. The HR planning problem prompts the economic sectors and industries to define new and better labor flexibility strategies. Organizations typically use traditional strategies to address these overstaffing and understaffing periods, such as using overtime and temporary staff, which are usually expensive and ineffective due to situations related to overexertion and incompetence, also affecting their service level. One way to reduce the negative effects of overstaffing and understaffing is to add flexibility in staff planning. In fact, the literature shows the advantages of more modern strategies (e.g., annualized hours, multiskilling, flexible contracts) over costs and effectiveness, in relation to demand [6–9].

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 374–378, 2023.
https://doi.org/10.1007/978-3-031-27915-7_66

2 The Problem

Focused on service sector, and particularly on retail industry, the problem addressed by this paper is to plan a flexible workforce at a strategic and tactical level, which allows a cost-effective operation and adequate mitigation of negative effects produced for under- and overstaffing, with a general case study applied in Chilean retail store. The solution for this problem incorporates the combination of two flexibility strategies: i) Flexible contracts (Full-time or Par-time), which allow relaxing the duration of shifts and the number of working weekly hours that employees must fulfill [5, 10] and ii) Annualized working hours, which implies the hiring of employees to work a fixed number hours per year (for example, 2000 h per year for Full-time contract), but the distribution of their working hours can be irregular or different between the weeks and months of annual planning horizon [6, 11–14].

In a more detailed way, it is intended to decide the number of employees to hire to satisfy the demand requirements, what type of annualized contract they will have (i.e., number of annual working hours), and taking into account the type of contract, determine the working day (i.e., shifts length), and establish the tentative weekly shift assignment (i.e., number of days and hours per day to work in a week) including rest days for each employee during a planning horizon of a year.

3 Methodology

The proposed methodology seeks to structure the planning of an optimized workforce with the implementation of annualized hours and flexible contracts, applied in a Chilean retail store case study. To evaluate the benefits of the proposed strategy, it is necessary to simultaneously solve the strategic problem of staffing (i.e., how many people need to be hired, and what type of contract should they have) and the tactical problem of weekly shift scheduling. (i.e., assign, according to the type of contract of each employee, the number of weekly working hours, the days of work/rest per week, and finally the respective work shifts, during a planning horizon one year). Therefore, we propose the formulation of a mixed integer linear programming model, which allows us to represent and solve this personnel planning problem with flexible contracts and annualized hours in a Chilean retail store (e.g., [6, 13]). This model includes parameters as contracts and workday's types, hours demand per department in store, times periods of operating day in the store, shifts; and variables associated with staffing, over-understaffing costs, and tour scheduling. The objective function (1) minimizes the following three annual costs: (i) total cost of understaffing; (ii) total cost of overstaffing; and (iii) total cost of salary per contract types.

Objective function

$$Min \sum_{s \in S} \sum_{d \in D} \sum_{p \in P} Understaffing\_cost * K_{sdp} + \sum_{s \in S} \sum_{d \in D} \sum_{p \in P} Overstaffing\_cost * L_{sdp} + \sum_{c \in C} Annual\_Salary_c * Z_c \tag{1}$$

The main constraints of the model, ensure that (i) The hours demand for department, week and day, are covered, or otherwise, penalized by cost (ii) That the number of hired by employees will allocated in totality according to contract type (iii) That the shift scheduling be feasible according to the workday's hours by contract types of each employee.

4 Experiments and Results

4.1 Experiments for Personnel Planning

In order to evaluate the potential benefits of flexible contracts and annualized hours, in addition to the impact that these generate in HR management, four test experiments are defined, which will each be compared through from a case study. These experiments consider flexibility strategies individually and jointly, which are presented in a summarized way:

1. Experiment 1: Employees are hired under the traditional or fixed configuration of Full-Time (FT) annual hours and weekly shifts (most inflexible scenario). In this case FT - $\{5 \text{ days} \times 9 \text{ h}\}$.
2. Experiment 2: Employees with different types of annualized contracts (i.e., different amounts of working hours per year per employee) are considered. In this case, could be full-time or part-time annualized hours contract, with a fixed workday's hours per week for each one FT - $\{5 \times 9\}$ y PT - $\{5 \times 6\}$.
3. Experiment 3: Employees hired under the traditional configuration of annualized hours are considered, but different configurations of workday's hours per week are allowed (e.g., FT- $\{6 \times 7.5, 5 \times 9\}$)
4. Experiment 4: Employees with different types of annualized contracts are considered (i.e., FT or PT), with their different configurations of workday's and shifts per week (e.g., FT- $\{6 \times 7.5, 5 \times 9\}$; PT- $\{5 \times 6, 6 \times 5\}$). This is the most flexible strategy.

For more details related with de flexible contracts, the authors recommend the review of (Porto et al., 2019)).

4.2 Preliminary Results

Below, staffing, costs and savings associated for each experiment is presented in Table 1, in order to analysis a comparison between the different flexibility levels represented on each one.

The savings percentages in experiment 2, 3 and 4 are calculated with respect to experiment 1, which is assumed to be the most basic and inflexible strategy. Regarding the costs for each experiment, the number 4, which represents the highest degree of flexibility studied (Annualized hours with flexible contracts, simultaneously), obtains greatest savings in total annual costs. It is interesting to note that, despite considering a higher staffing level than others (12 employees), the costs associated with over- and understaffing are always lower than in the other experiments, and only higher when it comes to salary. The foregoing means that, the flexibility obtained by the different contracts (i.e., FT and PT), and therefore, a greater number of workday's, allows a

Table 1. Staffing level, costs and savings associated to the experiments proposed

Experiment	# Hired employees per contract		Costs ($)			Annual cost ($)	% Savings
	FT	PT	Understaffing	Overstaffing	Salary		
1	9	0	109.678	170.220	48.600	328.498	-
2	2	9	75.518	91.620	46.800	213.938	35
3	9	0	47.824	84.810	48.600	181.234	45
4	2	10	20.740	31.350	50.800	102.890	69

better adjustment between the contracted and required working hours. The assignment is made in a more efficient way, avoiding periods of over- and understaffing throughout the planned days and weeks.

5 Conclusions

The main objective of this research was to design, through a mathematical programming model, a flexibility strategy that will incorporate annualized working hours and flexible contracts, which will allow the planning of a workforce that meets the demand, reducing operating costs and the negative effects of overstaffing and understaffing, with a case study applied in a Chilean retail store. The analysis of results obtained in this research show important benefits of the strategy proposed, as well as their close link with workforce planning. The potential savings in annual operating costs generated by the proposed strategy was evidenced in relation to experiments 1, 2 and 3 where less flexibility is considered, even when considering one of the two flexible strategies individually.

The costs of the proposed strategy (experiment 4) were reducing in understaffing and overstaffing terms, despite to hire more personnel, and get more salaries cost. In the particular of experiment 4, savings achieve 69% respecting to de experiment 1 (most inflexible situation studied). This flexibility strategy represents a great opportunity to face uncertainties in demand per days and week, because will be possible solve in different ways the shifts scheduling problem. Finally, the results allowed us to indicate some guidelines for the definition of interesting and viable labor flexibility policies for any company in the service sector, especially in the retail industry; in relation to the types of annualized contracts, that is, responding the number of annual working hours to be contracted, and their different configurations of shift and workdays.

References

1. Henao, C.A., Muñoz, J.C., Ferrer, J.C.: The impact of multi-skilling on personnel scheduling in the service sector: a retail industry case. J. Oper. Res. Soc. **66**(12), 1949–1959 (2015)

2. Álvarez, E., Ferrer, J.C., Muñoz, J.C., Henao, C.A.: Efficient shift scheduling with multiple breaks for full-time employees: a retail industry case. Comput. Ind. Eng. **150**, 106884 (2020)
3. Porto, A.F., Henao, C.A., López-Ospina, H., González, E.R., González, V.I.: Dataset for solving a hybrid flexibility strategy on personnel scheduling problem in the retail industry. Data in Brief **32**, 106066 (2020)
4. Henao, C.A., Muñoz, J.C., Ferrer, J.C.: Multiskilled workforce management by utilizing closed chains under uncertain demand: a retail industry case. Comput. Ind. Eng. **127**, 74–88 (2019)
5. Porto, A.F., Henao, C.A., López-Ospina, H., González, E.R.: Hybrid flexibility strategy on personnel scheduling: retail case study. Comput. Indust. Eng. **133**, 220–230 (2019)
6. Porto, A.F., Henao, C.A., Lusa, A., Mejía, O.P., Porto, S.R.: Solving a staffing problem with annualized hours, multiskilling with 2-chaining, and overtime: a retail industry case. Comput. Ind. Eng. **67**, 107999 (2022)
7. Ernst, A.T., Jiang, H., Krishnamoorthy, M., Owens, B., Sier, D.: An annotated bibliography of personnel scheduling and rostering. Ann. Oper. Res. **127**(1–4), 21–144 (2004)
8. Qin, R., Nembhard, D.A., Barnes II., W.L.: Workforce flexibility in operations management. Surv. Oper. Res. Manag. Sci. **20**(1), 19–33 (2015)
9. Henao, C. A., Batista, A., Porto, A. F., & González, V. I. (2021). Multiskilled personnel assignment problem under uncertain demand: A benchmarking analysis. Ann. Oper. Res., Forthcoming
10. Brunner, J.O., Bard, J.F.: Flexible weekly tour scheduling for postal service workers using a branch and price. J. Sched. **16**(1), 129–149 (2013)
11. Lusa, A., Pastor, R.: Planning working time accounts under demand uncertainty. Comput. Oper. Res. **38**(2), 517–524 (2011)
12. Domínguez, M., Porto, A., Rueda, L.: Gestión Matemática de los Recursos Humanos. Consolidación de los Escenarios de Formación de Ingeniería: Avances y Prospectivas. Sello Editorial Coruniamericana, Barranquilla, pp. 278–288 (2018)
13. Porto, A.F., Lusa, A., Henao, C.A., Solano, R.P.: Annualized hours, multiskilling and overtime on annual staffing problem: an uncertainty approach. In: XXV Congreso de Ingeniería de Organización, p. 123
14. Lusa, A., Pastor, R., Corominas, A.: Determining the most appropriate set of weekly working hours for planning annualised working time. Int. J. Prod. Econ. **111**(2), 697–706 (2008)

Description of the Problem of Aggregated Workforce Management Planning in Sheltered Employment Centres

Sofía García Manglano[1](✉), Julien Maheut[2], Julio J. Garcia-Sabater[2], and José P. Garcia-Sabater[2]

[1] Dpto de Organización de Empresas, Universitat Politècnica de València, Camino de Vera S/N, 46023 Valencia, Spain
sogarman@upv.edu.es

[2] Dpto de Organización de Empresas, Universitat Politècnica de València, ROGLE, Camino de Vera S/N, 46023 Valencia, Spain
{juma2,jugarsa,jpgarcia}@upv.es

Abstract. In sheltered employment centres, planning and scheduling of employees is a critical task because the legal issues are diverse and different, but also because not all employees are suitable for every place and every time. This complexity increases when the activities carried out in various work environments involve people with different needs and skills. In this paper, after a brief review of the literature and explanation of the case study, the problem of aggregate workforce management planning in sheltered employment centres is described.

Keywords: Human resource management · Disabled workers · Human resource planning · Aggregate planning · Case study

1 Introduction

Global competition, uncertainty and the intense pace of change faced today by organisations, workers and society have called into question the traditional rules on which human resources (HR) management has been organised, as well as the relationship between the employee and the company [1]. HR management is evolving as well as knowledge, and new information technologies are immersed in the globalisation process of today's world economic institutions. It is, therefore, necessary for organisations to optimise all available resources, especially those that give them unique capabilities. Among others, human resources are significant [2]. Commonly, the goal is generally to minimise the costs associated with the use of human resources [3].

Nevertheless, this focus needs to be adapted when the main part of the human resources of an organization is composed of people with functional diversity. In this case, facilitating the insertion of people in a stable working environment and improving their relationship with their professional context contributes to the access of any person to the status of worker, providing the individual with economic and social well-being [4].

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 379–383, 2023.
https://doi.org/10.1007/978-3-031-27915-7_67

The problem we face is related to the development and comprehensive care for people with disabilities in a Valencian non-profit organisation called Espurna, which helps more than 350 people, mainly with intellectual disabilities [5].

This paper presents the case study description of an aggregate planning problem faced by a Valencian Sheltered Employment Centre (SEC) named Espurna. In the annual planning, the work to be done, the weekly breaks, holidays and days off must be assigned and planned for all workers considering the affinity of the workers and the requirements of the labour enclaves of several clients in a specific time horizon [6] is considered.

The rest of the paper is presented as follows: first, a brief review of the literature on the topic is developed. Then, the case study is presented, and techniques and tools used to resolve similar problems are briefly introduced to facilitate the understanding of the problem. Finally, the paper ends with some conclusions and future lines of research.

2 Literature Review

Production planning is a continuous process whose purpose is to make decisions in advance to optimise the use of production resources [7]. It must be based on demand forecasting, i.e., the customer's requirements must be well known to be able to anticipate and serve them on time and with quality.

Such planning is a process in which many variables and factors must be considered to achieve specific objectives. According to [7], aggregate planning is concerned with determining the quantity to be produced and when it will be made in the medium-term horizon, usually between 3 and 18 months. Typically, the objective of aggregate planning is to minimise the total cost over the planning horizon [8].

The methods for aggregate planning proposed in the literature are diverse. In [9], a technique of aggregate planning over a period of time is presented, using a graph where production quantity is related to time. In addition, there are methods with decision rules, such as the linear decision rule (LDR) are used [10], the model of the direction coefficients [11], the method of the search decision rule [12]. In [8], a linear programming model for aggregate planning that is equivalent to the LDR model in its general structure is proposed. Finally, we find some extensions of the LDR model, such as the one in [13]. Finally, we find lineal programming, integer linear programming and mixed-integer linear programming models [14].

Two other features must also be taken into account for resource management. First, there is the need for each unskilled (temporary) worker to work together with at least one skilled worker (who can help the temporary worker if necessary). In addition, usually, a task requires the standard time if it is assigned to a permanent skilled worker. The "standard" time must be multiplied by a factor greater than one if the task is assigned to an unskilled temporary worker, as he/she needs more time than a skilled worker to perform the same task [15].

The study of personnel planning has been extensively studied in the last decades as one of the major business challenges. Proper HR management gives many companies a distinctive capability [2]. The problem is a combinatorial optimisation problem that has been solved by the literature using different solving techniques.

After reviewing the scientific literature on the new opportunities offered by companies and the inclusion of people with disabilities in the labour market, it can be stated that there is a real need for research in this field [16] since it affects a significant minority in the world since according to the World Health Organisation 10% of the population are disabled.

3 Description and Present State of the Case Study

The Espurna Foundation is a non-profit organisation with more than 350 employees. It has its own SEC and operates in different workplaces.

The company's activity consists of inserting people with special needs in manufacturing companies that subcontract part of their production activity to Espurna. To guarantee a job well done, Espurna also offers training to its workers, which makes the problem more complex, as the learning process is longer and the time for forgetting is shorter than for regular workers. For this purpose, the staff comprises people with intellectual disabilities and coaches. Coaches and workers with special needs have different working hours, personal calendars and work restrictions (holidays, working hours, mandatory minimum weekly rest, etc.) as they have different types of work contracts and personal circumstances (sick leave, waiting days off).

The tasks to be performed vary from one contract to another, as do the skills required to complete the jobs. Therefore, considering that each individual has particular skills and abilities, building teams of workers that match the requirements of each contract as closely as possible is a challenge for SEC managers [17]. It is worth mentioning that, in this context, training is seen not only as a tool to qualify people for tasks, but as a way to improve and acquire skills.

The time horizon over which it operates is annual, with weekly periods, so that the system comprises 52 periods. In this context, the objective of the yearly plan [17] is to create a global plan for the recruitment of the work teams, as well as to define the skill and training levels per worker to ensure their capacity to fit on each labor enclave. As for the decisions to be taken, it is a matter of deciding the number of workers to be hired and those who will be on holiday (because holidays must last at least two consecutive weeks, the horizon is divided into two-week periods). Vacations represent more than 15% of annual working hours, have specific limits and may vary from one enclave to another.

Aggregate planning extends to a maximum of 13 months (until the end of the first month of the following year) to adapt to the requirements of the collective bargaining agreement. The annual plan focuses on integrated capacity building. To this end, the number of workers to be hired of each type (workers with special needs and coaches), the main decision variable, remains to be determined. The decision criteria will be the operational cost, the level of income and the level of multi-skill training, and the risk of inactivity.

Concerning employment contracts, they can be of two types: temporary and permanent workers. Temporary workers are those hired for a specific period length (minimum duration of 6 months) to meet the demand at a given time or to carry out some of the pending tasks while the company's workers are on holiday. This contract can only be renewed twice thereafter the centre must make an indefinite contract. Permanent employees are those who are part of the regular staff of the SEC. The working hours of these workers are variable.

It should also be noted that the tasks to be carried out are very different in nature. According to the client's requirements, some activities must be carried out in a specific work location, at a specific time agreed by the client and with minimum training requirements. In this particular case, the system must allocate enough workers and coaches to meet the needs of the demand. However, some activities can be carried out at any time, as the client requests them a long time in advance and manufactured goods are not perishable. These activities will be carried out at times that the general manager deems appropriate, depending on the availability of workers at any given time.

Annual demand planning requires as inputs the client's work schedule (holidays and other production downtime), the expected number of workers and the ratio of workers to coaches needed. Another key information to consider is an estimate of an organization's "effective" capacity, which takes into account certain constraints, such as the ability of employees to perform certain tasks (their ability to work in a particular labor enclave or at a lower productivity level). To better assess effective competencies, managers use two matrices: a skills matrix and an affinity matrix. The skills matrix measures a worker's ability to perform the tasks required by each client through 3 levels of assessment. In this way, managers meet periodically to assess how workers' skills improve with practice and, if so, the skills matrix is updated accordingly. Also, when a worker does not perform a job within a certain period of time, the worker's qualifications are re-evaluated. Coaches' skills are also evaluated in a similar skills matrix, based on experience with clients and tasks. In addition, the SEC will provide direct and indirect hiring costs, rate limits, number of workers to be hired and hiring dates, as well as expected vacation weeks. In terms of legal requirements, maximum working hours and overtime restrictions should be considered. Finally, consideration will also be given to the hiring of new workers and the vacations foreseen in the previous plans.

Finally, it will be necessary to coordinate holidays on an annual basis, so that each one of them can enjoy the days of holiday that correspond to them according to the hours worked. This presents considerable difficulty, as the demand from companies is not known in advance, making it difficult to plan and organise well.

In the decision-making process, allocating all workers to the different work enclaves of the sheltered employment centre while respecting the days off of each worker is the objective.

In summary, the case described is an annual planning problem, considering customer demand forecasts and their expected vacations, the limitations of hours that employees can work each year, typology of workers, and integrating the training and education of workers. To solve the problem, a MILP-type mathematical scheduling model has been designed, currently in the validation and calibration phase for integration into the foundation's planning platform. Due to space restrictions, the model cannot be presented.

4 Conclusions

This article describes the context of the aggregated workforce management planning problem in sheltered employment centres considering the workers' cognitive abilities for a Special Employment Centre operating in the Valencian Community. In this context, the survival of these socially-driven organisations in a price and flexibility oriented market is a challenge for resource management. There are many factors that managers must take into account, such as the diverse skills of each worker, diversity, long learning times and diversity of tasks and contracts. Due to the complexity of the problem, employee training planning has been reserved for future research. It is interesting to introduce the performance of people with disabilities into the resource allocation task as it is rarely addressed in the literature. Future work includes the development of specific algorithms for the planning of training periods.

References

1. FUNDIPE: Informe sobre empleabilidad (1999)
2. Romero, F.M., Santana, M.P.P.: Una perspectiva dual para la gestión de los Recursos Humanos: Optimizar recursos o reducir costes contractuales? Dir y Organ **25**, 923–931 (2001). https://doi.org/10.37610/dyo.v0i25.222
3. Rocha, M., Oliveira, J.F., Carravilla, M.A.: Cyclic staff scheduling: optimization models for some real-life problems. J. Sched. **16**, 231–242 (2013). https://doi.org/10.1007/s10951-012-0299-4
4. de los Santos, P.J., Costa, R.S.: Workers with disabilities in sheltered employment centres: a training needs analysis. Int. J. Incl. Educ. **20,** 756–769 (2016). https://doi.org/10.1080/13603116.2015.1111446
5. Fundación Espurna. https://www.espurna.org/
6. Manglano, S.G., Maheut, J., García-Sabater, J.J., García-Sabater, J.P.: A MILP model to solve a sheltered employment center rostering problem: a case study. In: Ordax, J.M.G. (ed. lit.), de la Fuente, S.D. (ed. lit.), de Armiño Pérez, C.A. (ed. lit.), Delgado, R.A. (ed. lit.), Villahoz, J.J.L. (ed. lit.), Cosío, Á.H. (ed. lit.), del Campo, M.Á.M. (ed. lit.), del Olmo Martínez, R. (ed. lit.) (eds.) Proceedings of the 15th International Conference on Industrial Management and XXV Congreso de Ingeniería de Organización, p. 24 (2021)
7. Boiteux, O.D., Corominas, A., Lusa, A.: Estado del arte sobre planificación agregada de la producción. Eng d'Organització i Logística Ind **4**, 1–39 (2007)
8. Hanssmann, F., Hess, S.W.: A linear programming approach to production and employment scheduling. Manage. Sci., 46–51 (1960)
9. Alford, L.P., Bangs, J.R.: Production Handbook. Ronald Press Company, New York (1944)
10. Holt, C.C., Modigliani, F., Muth, J.F.: Derivation of a linear decision rule for production and employment. Manag. Sci. **2**, 159–177 (1956). https://doi.org/10.1287/mnsc.2.2.159
11. Bowman, E.H.: Consistency and optimality in managerial decision making. Manag. Sci. **9**, 310–321 (1963). https://doi.org/10.1287/mnsc.9.2.310
12. Taubert, W.H.: A search decision rule for the aggregate scheduling problem. Manage Sci. **14,** B-343–B-359 (1968). https://doi.org/10.1287/mnsc.14.6.b343
13. Buffa, E.S., Taubert, W.H.: Production-inventory systems planning and control. J. Oper. Res. Soc. **20,** 282–283 (1969)
14. Tadei, R., Trubian, M., Avendaño, J.L., Della Croce, F., Menga, G.: Aggregate planning and scheduling in the food industry: a case study. Eur J Oper Res **87**, 564–573 (1995). https://doi.org/10.1016/0377-2217(95)00230-8
15. Corominas, A., Pastor, R., Plans, J.: Balancing assembly line with skilled and unskilled workers. Omega **36**, 1126–1132 (2008). https://doi.org/10.1016/j.omega.2006.03.003
16. Mark, B.G, Hofmayer, S., Rauch, E., Matt, D.T.: Inclusion of workers with disabilities in production 4.0: legal foundations in Europe and potentials through worker assistance systems. Sustain **11** (2019). https://doi.org/10.3390/su11215978
17. Garcia Sabater, J., Maheut, J., Ruiz, A., Garcia Sabater, J.: A framework for capacity and operations planning in services organizations employing workers with intellectual disabilities. Sustain **12**, 1–17 (2020). https://doi.org/10.3390/su12229713

Cornflow. A Platform for the Development, Testing and Operation of Mathematical Models

Guillermo González-Santander[1](✉), Franco Peschiera[1,2], Hugo Larzábal[1], David Ampuero[1], and Marion Cottard[1]

[1] baobab soluciones, Madrid, Spain
guillermo.gonzalez@baobabsoluciones.es
[2] UN World Food Program, Rome, Italy

Abstract. The development, study, validation and operation of mathematical models for the same problem can be a tedious and complicated task when the developer wants to try an evaluate a higher number of models. Cornflow is a open source platform that deals with these complications by establishing a framework for the structure of the problem, allowing the efforts to be focused on the development of solving methods so they can be evaluated, validated and compared with each other with as much possibility as possible, and allowing the deployment of corrections to models or the deployment of new models by pushing them into a repository. In this way, the models can be developed more efficiently and all models can be evaluated under the same conditions and against the same instances of testing and validation of results, allowing the researcher or developer to focus on the results and robustness of their solving methods, rather than on the process of deploying and running the models.

Keywords: Model development · Model testing · Model validation · Operations research · Platform · Open-source

1 Introduction

Cornflow is a collection of projects that allow for the rapid prototyping and deployment of optimization-based applications. Contrary to other existing deployment servers, Cornflow is centered around the applications and the problems, not in the techniques. It offers several other advantages such as being completely free (as in freedom) and very flexible.

Cornflow uses input and output schemas to define "optimization problems" and then accepts any (for now python) code that reads data in the input schema and returns a solution in the output schema. We use JSONSchema [1] to define these schemas. By working like this, Cornflow becomes technique-agnostic without losing data-validation and re-usability (e.g., we can have more than one "solution method" for the same problem).

Being technique-agnostic implies we sometimes use CP models built with OR-Tools [2], MIP models built with Pyomo [3] and some heuristics in pure python. But again,

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 384–389, 2023.
https://doi.org/10.1007/978-3-031-27915-7_68

we could also have a LocalSolver [4] model or any metaheuristic as long as it complies with the interface format for the particular optimization problem.

The main objective of Cornflow is to serve as an open-source alternative for commercial deployment servers and at the same time serve as a framework for the development of models for new problems or new methods to solve existing problems on the platform reusing as much of the code already developed.

2 Key Concepts

In computability theory and computational complexity theory, a decision problem is a problem that can be posed as a yes-no question of the input values [5]. An optimization problem could be given a similar definition, where the objective is to find a solution (or the optimal one) on a given feasible solution space.

In this work we refer to this decision problem as an abstract problem or just problem. Some problems are quite famous, such as the Travelling Salesman Problem (TSP) or the Knapsack Problem. Naming a problem makes it possible to design solution methods that are tailored for that particular problem.

In Cornflow, a problem is represented by three json schema files: the first schema describes the kind of input data format it accepts. This schema describes any Instance of the problem. The second schema file describes the configuration for the solver, with properties such as time limit, relative gap or metaheuristic parameters. The third schema file describes the output data format it returns. This schema describes any Solution of the problem, see Fig. 1.

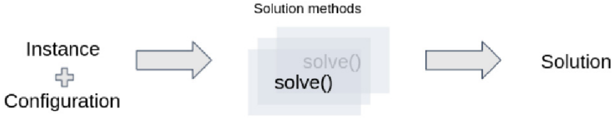


Fig. 1. Main concepts in a Cornflow deployment of an Optimization Problem

These three schemas get used by the solve method of a Solver go from the Instance (input data) and configuration, to the Solution.

2.1 Instance

An Instance represents all the data needed to completely formulate one case of a decision problem. In Cornflow, it is represented as a data json file. This file should be sufficient to represent the feasible solution space and provide enough information to determine if one Solution to the problem is better or worse than another. We sometimes call it “input data”. It needs to follow the input data schema.

2.2 Solution

A Solution represents all data needed to completely represent a feasible solution to an Instance. In Cornflow, it is represented as data json file. This file should be sufficient to, when used together with an Instance, determine if the solution is feasible and the objective function value of the Solution. We sometimes call it "output data". It needs to follow the output data schema.

2.3 Solution Method

A solution method (also called Algorithm) is a function that takes as input an Instance and returns a Solution. The Solution Method can be exact (i.e., it proves it can find the best solution) or inexact (i.e., there is no proof).

Each Solution Method has ways to configure certain characteristics. The Configuration stores that personalization, such as the time limit, the gap tolerance, among others.

2.4 Execution

Consists of: (1) an Instance with a (2) solve Configuration and a (3) Solution Method. Is the actual solving of the problem and it returns a Solution.

3 Implementation

In practice, Cornflow uses JSON Schmea to validate the schemas of Instance, Configuration and Solution. It uses python to define a solve method.

An example with TSP can be seen in the following Fig. 2:

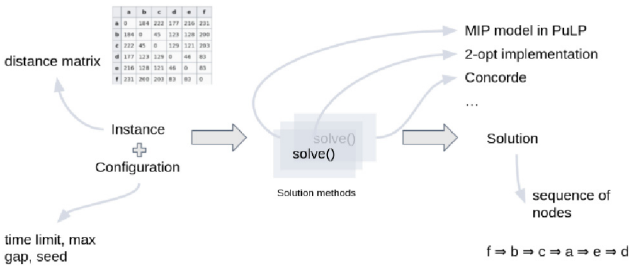


Fig. 2. Implementation of concepts for a TSP.

4 Cornflow Server Architecture

Cornflow gives the researcher or developer a full client-server architecture to deploy the models that comply with the framework exposed before, allowing them to test, validate and operate the models from a variety of clients, such a user interface or any client library developed on the desired language, see Fig. 3.

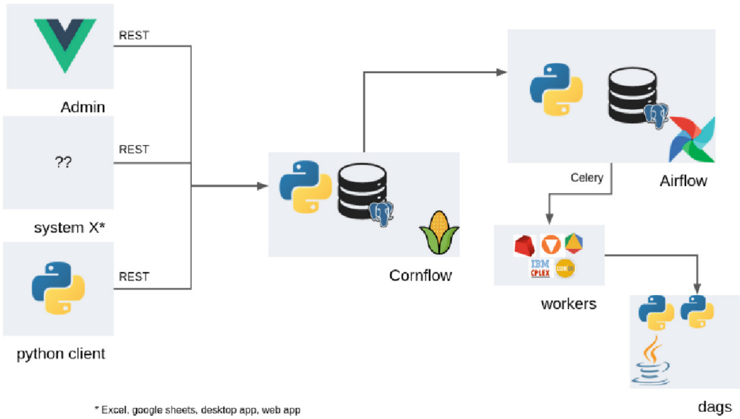


Fig. 3. Components with the connections between them.

Cornflow, the main component stores the user information, their instances, executions, etc. It is built in python and flask [6] and is served via a REST API.

Airflow [7] is a product of the Apache Foundation that is used to handle the executions. It manages a set of workers (machines or processors) that will execute the Solution Methods on the Instances. Airflow is also built on top of python and flask.

The clients can be varied, having Cornflow two clients right now: a user interface built on top of VueJS and a python library that handles all the connection with Cornflow via the REST API and a connection with PuLP [8] to build and create the Solution Methods.

The Cornflow REST API is built with Open API [9] standards so any new client should be fairly easy to develop.

The main data flow can be seen on Fig. 4. It all starts with the creation of a new instance, then Cornflow asks for the schema of the instance to validate that the instance data matches the schema, if it is a valid instance, then it gets saved and the user gets back the instance id.

To solve the client calls Cornflow and gives the instance code and execution configuration, Cornflow validates the configuration with the schema, sends the client the execution code and asks Airflow to star solving the problem. Then Airflow delegates the solve to a worker and the worker sends to Cornflow the results of the problem.

Then the client with the instance and execution code can ask Cornflow about the status of the problem (if it is solved or not, and if solved the status of the solution: optimal, feasible, unfeasible, unbounded, or another error) and get back the values for the Solution and the log of the Solution Method if it exists, see Fig. 4.

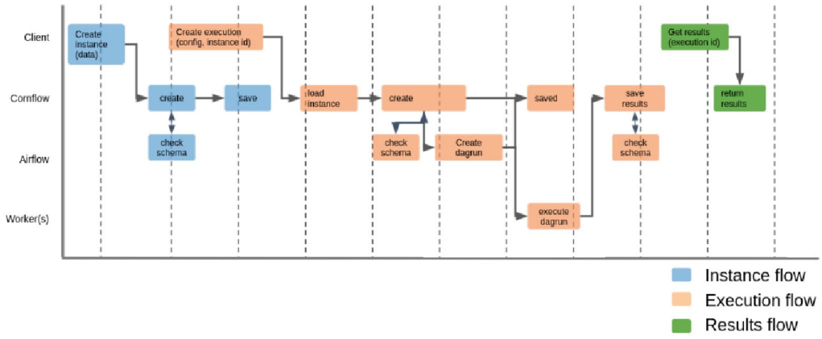


Fig. 4. Main data flows between components.

5 Results

Thanks to the framework developed for the structure of mathematical models and the development of the platform, modelling time has reduced about 30% in the development of models for new problems and 50% for the development of new solvers for existing problems, allowing to have an organized codebase of problems and solvers readily available on the cloud.

6 Conclusions

Cornflow allows with a framework of how to define models and its structure to test, deploy, validate and operate mathematical models, all built on top of open-source technologies to allow the developers to customize the environment to better adapt to its needs.

Once on operation Cornflow allows to easily obtain solutions of a problem with different Solution Methods in the same environment and under the same conditions and capabilities.

Additionally, Cornflow is an open-source alternative to commercial products such as Gurobi Cloud, IBM ILOG CPLEX Enterprise Server or AIMMS PRO as it allows full control over the platform, allowing both researchers and modelers to set it up to their needs and set it up with the resources needed, a future community of developers collaborating on the open-source project and the savings of highly costly commercial (or academic) licenses of the aforementioned products.

References

1. JSON Schema homepage. https://json-schema.org/. Accessed 14 Mar 2022
2. OR-Tools homepage. https://developers.google.com/optimization. Accessed 14 Mar 2022
3. Hart, W.E., Watson, J.-P., Woodruff, D.L.: Pyomo: modeling and solving mathematical programs in Python. Math. Program. Comput. **3**(3), 219–260 (2011)
4. LocalSolver homepage. https://www.localsolver.com/. Accessed 14 Mar 2022

5. CS254: Computational Compexity, Standford University. https://www.cs.stanford.edu/~trevisan/cs254-10/lecture02.pdf. Accessed 14 Mar 2022
6. Flask homepage. https://flask.palletsprojects.com/en/2.0.x/. Accessed 14 Mar 2022
7. Airflow homepage. https://airflow.apache.org/. Accessed 14 Mar 2022
8. PuLP homepage. https://coin-or.github.io/pulp/. Accessed 14 Mar 2022
9. Open API homepage. https://www.openapis.org/. Accessed 14 Mar 2022

Analysis of the Environmental Dimension in an Evaluation Model of Electricity Generation Technologies Through AHP and a Fuzzy Inference System in Spain

Jose M. Rivero-Iglesias, Jose M. Perez-Bernardo, Javier Puente(✉), and Alberto Gomez

Department of Business Administration, University of Oviedo, Oviedo, Spain
{UO28633,UO44094,jpuente,albertogomez}@uniovi.es

Abstract. The objective of the research has been to create a model to comprehensively analyse national electricity systems. To this end, specialized literature was selected and also the opinions of a set of experts were sought. This way, it was decided which generation technologies were to be assessed, the criteria and sub-criteria to be used and their relative importance. This work presents the case study of the Spanish electricity system, analysed exclusively from the environmental dimension.

The methodology used is based on assessing each technology in a two-phase process: in the first phase, weights were obtained for every criterion and sub-criterion by means of an AHP, which also allowed to establish a first comparative ranking of technologies. The second phase includes a fuzzy inference system, which uses the weights of the criteria obtained in the AHP to attain individual fuzzy assessments of each technology.

The results showed that the most important environmental criterion is the CO_2 emission, and that the best rated technology is Photovoltaic, while the worst rated is Coal.

Keywords: Multi-criteria decision making (MCDM) · Analytic hierarchic process (AHP) · Fuzzy Inference System (FIS) · Electricity generation technologies · Environmental criteria

1 Introduction and Background

The increase of the electricity demand and the growing worry about environmental issues makes national electricity systems evolve. There is a clear trend towards the widespread deployment of sustainable energy production technologies, including photovoltaic, wind, hydro or Combined Heat and Power (CHP), which are often installed in a decentralised manner as Distributed Energy Resources (DER) [1].

In this context, the assessment of different power generation technologies has become increasingly important for utilities, planners [2] and transmission system operators, as

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 390–394, 2023.
https://doi.org/10.1007/978-3-031-27915-7_69

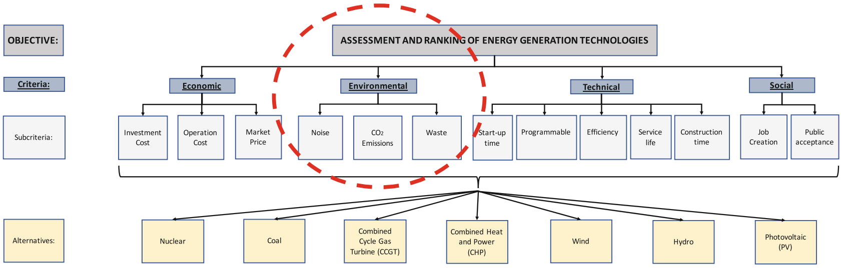
they need to take investment decisions. This assessment is the main objective of the research made.

These investment decisions depend on different criteria (economic, environmental, technical, social). Therefore, multicriteria decision-making [3] is a suitable approach for this assessment. It requires the collaboration of experts, whose opinions were asked about the criteria to be used and their comparative importance in this case study. However, uncertainty or subjectivity inherent to the experts' opinions needs to be considered. For that purpose, the model of the research work done also adds a fuzzy inference system, so as to incorporate the non-linear performance of some of the variables involved. These conditioning factors make up the gap which this research work fills. The group of experts was formed in this case by senior executives of electricity utilities.

Although the created model can be applied to any national electricity system and includes economic, environmental, technical and social criteria [4], this work is a case study of the Spanish electricity system, and focuses exclusively on environmental variables.

2 Conceptual Model and Methodology Phases

For the resolution of the objective, the criteria set out in Fig. 1 were selected in accordance with the specialized literature [5] and with the help of the group of experts. As said in the introduction, the case study presented in this article considers only the environmental dimension (Noise, CO_2, Waste) of the Spanish electricity system.



Source: Own elaboration

Fig. 1. Proposed hierarchical model for the evaluation of electricity generation technologies. *Source: Own elaboration*

In the first phase of the methodology, an AHP [6] is built in order to obtain the relative weights of the selected criteria and subcriteria. The objective can be seen at the top level of the AHP. At the second level, criteria can be found (economic, environmental, technical and social). The third level includes the considered subcriteria (investment cost, operation cost, market price, noise, CO_2 emissions, waste, start-up time, programmable, efficiency, service life, construction time, job creation and public acceptance). At the lowest level of the AHP, seven generation technologies are arranged as alternatives: Nuclear, Coal, Combined Cycle Gas Turbine (CCGT), Combined Heat and Power (CHP), Wind, Hydro and Photovoltaic (PV).

From the experts' opinions gathered, the paired comparison (PCM) is obtained, as well as the weights of the environmental subcriteria.

Then, the consistency of the PCM is validated, verifying that the consistency ratio of the PCM with the importance weights given by the experts is below the limits set for the dimension of the matrixes [7]. The AHP technique is also used to compare technologies under each environmental criterion. This makes it possible to establish a ranking of technologies according to the considered environmental variables.

In the second phase of the methodology, a Fuzzy Inference System is built in order to individually assess the technologies considered in the case study. Again, experts' opinions were gathered to establish both the partitions of the fuzzy variables [8] and the rule bases that make it possible to explain the potential valuations of all the subsystems created. The implementation was developed with the toolbox "Fuzzy" (v.2.0) MATLAB Software R2020b 2021 The MathWorks, Inc.

Partitions of three labels were made for the input variables (L-Low, M-Med, H-High) and of five labels for the output variables (VL, L, M, H, VH), both in the range [0–10], using the 2-Tuple method. A detailed explanation of this model can be found in [9]. With this method, the labels of all variables were parameterised using trapezoidal or triangular fuzzy numbers.

In this way, 27 rules were generated (as many as combinations of possible labels in the input variables). In each rule, the trapezoids corresponding to the labels of its antecedent were weighted according to the weights previoulsy obtained in AHP, in order to configure a weighted trapezoid for each rule. Subsequently, distances of this weighted trapezium to the five potential labels assignable to the output variable were calculated according to Eq. 1, where $[a_i, b_i, c_i, d_i]$ represents the weighted trapezium in the i-th rule, $[a^j, b^j, c^j, d^j]$ represents the j-th trapezium potentially assignable to the output variable, and (p_a, p_b, p_c, p_d) represents the importance given to the four vertices of any trapezium -in our case (0.15, 0.35, 0.35, 0.15)-.

$$\text{mind}\left[(ai, bi, ci, di) - (aj, bj, cj, dj)\right] = \sqrt{pa \cdot (ai - aj)2 + pb \cdot (bi - bj)2 + pc \cdot (ci - cj)2 + pd \cdot (di - dj)2} \quad (1)$$

Equation 1 Minimum distance formula used to obtain the output label.

The label of the output variable to which this distance is minimum will be the one assigned to the output variable. For our environmental subsystem, the base of rules obtained by this method is shown in Table 1.

Table 1. Base of rules for Subsystem S 1_2.fis (environmental variables).

S1_2		CO2 EMISSIONS								
		LOW	MED	HIGH	LOW	MED	HIGH	LOW	MED	HIGH
WASTE	LOW	VH	H	L	VH	H	VL	VH	H	VL
	MED	H	H	VL	H	H	VL	H	H	VL
	HIGH	H	VL	VL	H	VL	VL	H	VL	VL
		LOW			MED			HIGH		
		NOISE								

Source: Own elaboration

3 Results and Discussion

The results obtained in the first phase using AHP to calculate the weights of the environmental variables and the local assessment of alternatives were the following:

CO_2 emissions (0,615 of normalized weight) resulted to be the most important environmental variable, followed by waste generated (0,319). Noise (0,066) was ranked last. The best technologies according to AHP for the environmental criteria were Photovoltaic and Wind (0,251), and the worst was Coal (0,032).

In the second phase, the fuzzy inference system (FIS) was applied to the crisp valuations made by experts of the environmental variables of each technology.

The results obtained from the FIS for the environmental dimension of the assessed technologies showed that renewable technologies (Photovoltaic, Wind, Hydro) are the ones which attain the best score (9.248, 9.209 and 9.167 respectively), while coal attains the worst (0.791).

These results were presented to the panel of experts who collaborated in the assignment of weights of criteria and subcriteria. According to their expert opinion, the results obtained are consistent with the underlying rationale and are aligned with the weights they had given to the variables of the environmental criterion.

4 Conclusions

The model created to evaluate electricity generation technologies takes into account the set of criteria and sub-criteria selected with the collaboration of a group of experts. This allows the assessment to be balanced and objective.

The two-phase methodology used in the assessment process overcomes the common drawbacks in the evaluation process, such as the possibility of rank reversal when using only AHP. On the other hand, the use of linguistic variables in the proposed fuzzy inference system makes it possible to standardise the terminology used in the evaluation of electricity generation technologies and allows to incorporate the non-linear nature of environmental variables, being therefore more reliable for representing real assessments.

The results obtained are consistent and support the experts' opinions for the chosen criteria and technologies, as well as for the weights given to the environmental subcriteria.

The methodology can be applied to any national electricity system, and can be extended to all the subsystems dependent on the rest of criteria not analysed in this article.

Acknowledgements. This work was financially supported by the State Research Agency of the Spanish Ministry of Science and Innovation (MCIN/AEI/10.13039/501100011033), via the project 'Speeding Up the transition towards Resilient circular economy networks: forecasting, inventory and production control, reverse logistics and supply chain dynamics" (SPUR, grant ref. PID2020-117021GB-I00).

References

1. Strasser, T., et al.: A Review of Architectures and Concepts for Intelligence in Future Electric Energy Systems. IEEE Trans. Industr. Electron. **62**, 2424–2438 (2015). https://doi.org/10.1109/TIE.2014.2361486
2. Lorna A. Greening, Steve Bernowb: Design of coordinated energy and environmental policies: use of multi-criteria decision-making. https://doi.org/10.1016/j.enpol.2003.08.017
3. Mardani, A., Jusoh, A., MD Nor, K., Khalifah, Z., Zakwan, N., Valipour, A.: Multiple criteria decision-making techniques and their applications – a review of the literature from 2000 to 2014. Economic Research-Ekonomska Istraživanja. 28, 516–571 (2015). https://doi.org/10.1080/1331677X.2015.1075139
4. Strantzali, E., Aravossis, K., Livanos, G.A.: Evaluation of future sustainable electricity generation alternatives_ the case of a Greek Island. Renew. Sustain. Energy Rev. **76**, 775–787 (2017). https://doi.org/10.1016/j.rser.2017.03.085
5. Bhattacharyya, S.C.: Review of alternative methodologies for analysing off-grid electricity supply. Renew. Sustain. Energy Rev. **16**, 677–694 (2012). https://doi.org/10.1016/j.rser.2011.08.033
6. Lee, S.K., Yoon, Y.J., Kim, J.W.: A study on making a long-term improvement in the national energy efficiency and GHG control plans by the AHP approach. Energy Policy **35**, 2862–2868 (2007). https://doi.org/10.1016/j.enpol.2006.09.019
7. Saaty, T., Vargas, L.: The analytic network process. Presented at the September 10 (2006). https://doi.org/10.1007/0-387-33987-6_1
8. Doukas, H.: Linguistic multicriteria decision making for energy systems: building the 'RE2S' framework. WIREs Energy Environ. **2**, 571–585 (2013). https://doi.org/10.1002/wene.65
9. Herrera, F., Martinez, L.: A 2-tuple fuzzy linguistic representation model for computing with words. IEEE Trans. Fuzzy Syst. **8**, 746–752 (2000). https://doi.org/10.1109/91.890332

Heijunka in Mixed-Model Sequences with Minimum Work Overload: Economic Impact

Rocío Alfaro-Pozo(✉) and Joaquín Bautista-Valhondo

Institute of Industrial and Control Engineering - IOC, ETSEIB, Universitat Politècnica de Catalunya, Av. Diagonal 647, 08028 Barcelona, Spain
{rocio.alfaro,joaquin.bautista}@upc.edu

Abstract. This work seeks to evaluate the convenience of adapting mixed-model assembly lines to the Just in Time ideology adopted by Lean Manufacturing by means of application of *Heijunka* concept into production sequences. To do this two mixed integer linear programming models have been solved by the IBM-CPLEX solver on the set of 23 Nissan-9Eng.I instances. Results show that, provided the production system have assistance of an information system based on Internet of Things Technology within the framework of Industry 4.0, profits outweigh losses. Specifically, given the data set and the results obtained, the loss generated by the incorporation of regularity (€133 per day in the worst case) is compensated by the leveling of intermediate stocks and workload balancing.

Keywords: Production assembly lines · Mixed-model sequencıng problem · Heijunka · Mıxed integer linear programming · IBM-CPLEX solver

1 Introduction

Mixed-model assembly lines must be able to assemble several product types. Even though these products are similar because they can be from the same product family, they differ in use of resources and components consumption. In fact, in this assembly lines, it is normal that some products require greater workload than others at certain workstations, or vice versa.

This issue may lead to concentrate workloads at specific moments of the workday. Furthermore, the difference between workloads can cause some products require greater worktime than the cycle time at one workstation and, consequently, the required work cannot be completed.

The above problem is reduced by application of Internet of Things (IoT) Technology and the implementation of an information system that communicates a production control computer and a set of tablets that offer information on the progress of production to each operator in their specific workstation [1].

In this way, it can be introduced the concept of time window, which is the maximum time that one workstation can work on a product unit [2]. In this way, if a product unit

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 395–401, 2023.
https://doi.org/10.1007/978-3-031-27915-7_70

requires a processing time greater than the cycle time at one workstation, the cycle can be exceeded until reaching the maximum time established by the time window. Obviously, the consumption of this additional time by a product unit at one workstation reduces the time available to work on that product at the next workstation and on the next product at that workstation.

As result, sequencing consecutively products with processing times greater than cycle time, at any workstation, may give rise to work overload and, therefore, to a production loss.

Here the Mixed-Model Sequencing Problem with work overload minimization (MMSP-W) is relevant [3, 4]. This problem focuses on obtaining product sequences that minimize the work overload, or maximize the total work performed [2].

It is clear that reducing the amount of lost work is a desirable aspect of any product sequence. However, taking into account the general optimization criteria proposed by [5], other desirable aspect is the workload balance throughout workday or the stock leveling at the line.

That is why application of *Heijunka*, a specific Japanese concept of Just-In-Time (JIT) manufacturing systems [6], is another key aspect in production sequences.

This work aims at analyzing the economic impact of applying *Heijunka* at mixed-model assembly line production systems. In particular, it seeks to assess whether it is appropriate to incorporate regularity constraints into the MMSP-W in order to preserve the mix production in production sequences. This evaluation gauges, in economic terms, the impact of regularity on the production loss arising from work overload in regard with the production mix. Furthermore, it compares this production lost with the leveling of stocks in line.

2 Reference Models

Two reference models are used in order to evaluate the impact of applying *Heijunka* on mixed-model sequences [7].

M_4U3 is the first one. This model focuses on minimizing the work overload of the assembly line, allowing free interruption of operations at workstations at any moment comprised between the cycle time and the time window. In this way, the model aims to find sequences that both fulfill restrictions relating to the linkage between workstations and allow completing the greatest amount of required work.

The second model is the M_4U3_pmr. This model is also focused on obtaining sequences that minimize the work overload or the uncompleted work. However, M_4U3_pmr model, in addition to consider the restrictions from the link between serial workstations, also incorporates regularity restrictions. These restrictions force satisfaction of "*quota*" property [8] for all product types at all manufacturing cycles and, therefore, the mix preservation in the production sequences.

3 Computational Experience

The computational experience corresponding to the engines' plant study case from [3] has been repeated in order to compare both models in same conditions.

In practice, the 23 of the Nissan-9Eng.I set [7, 9–11] have been ran for each model demand plans the 23. These instances correspond to demand plans of one workday (270 engines) with different mix of engine types. Specifically, there are nine types of engines grouped into three families: SUVs -Sport Utility Vehicle- (p_1, p_2, p_3), vans (p_4, p_5) and trucks (p_6, p_7, p_8, p_9). Thus, it is intended to evaluate the effect of the composition of the production mix on the increase in work overload that regularizing the sequences entails.

On this occasion, the solver used has been the CPLEX 12.7.1.0 on an Apple Macintosh iMac computer with an Intel Core i7 2.93 GHz processor and 16 GB of RAM, and allowing a maximum CPU time of 3600 s.

3.1 Results

Introduction of "quota" restrictions generally increases the work overload of best production sequences found. The average increase is 10.2%. However, as it can be saw in Fig. 1, the given results by M_4U3_pmr for some instances are slightly better than those given by M_4U3 (instances #1, #3, #4, #18 and #20). This fact disappears if the best bounds found are taken into account (see Fig. 2). In fact, if we analyze the best bounds for each instance and each model, introduction of "quota" restrictions equals or gets slightly worse the work overload values (in 11 of 23 instances, best bounds are the same and in the others the average increase is 2.7%). Furthermore, for the three optimal solutions found by both models (#10, #19 and #22) the work overload values are the same.

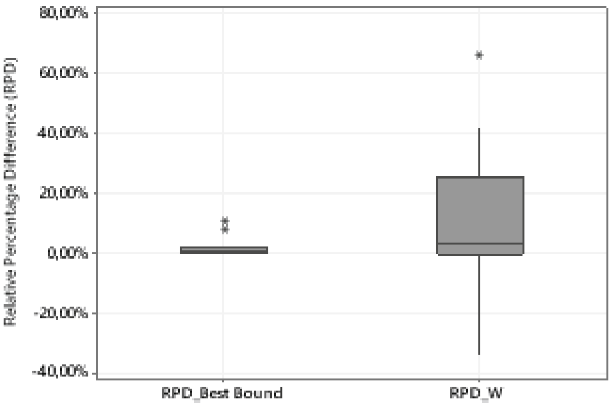


Fig. 1. Relative Percentage Difference between results given by both models (M_4U3 and M_4U3_pmr) for the 23 demand plans. $RPD\_X = \left(X_{M4U3\_pmr} - X_{M4U3}\right)/X_{M4U3}$, where X_i is the best bound or the best value of work overload found by model i.

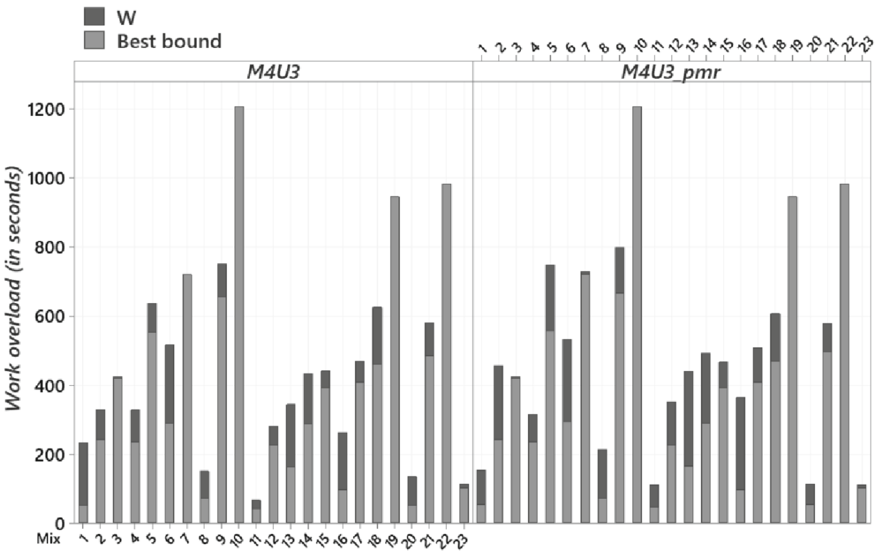


Fig. 2. Work overload values (in seconds) and best bounds found by both models for the 23 demand plans.

4 *Heijunka* Impact

In order to assess the economic impact of applying *Heijunka* in mixed-model assembly line sequencing problem, nine scenarios have been considered. These scenarios represent different situations in terms of frequency of appearance, in a year of work, of each one of the 23 demand plans studied[1].

Thus, considering 240 workdays, a Consolidated Operating Profit (COP) of the line of 10% of the profit of one engine (i.e., the 10% of 4000€) and the cycle time of 175 s, we can state the following (see Fig. 3):

- On average, applying *Heijunka* supposes an increase of 6,8% of cost due to the non-completed work on the line.

[1] E0: 23 demand plans occur with the same frequency; E1: most homogeneous plans by engine types (#1,#16,#13,#8, #12, #2, #4) appear 75% of days; E2: least homogeneous plans by types of engines (#9,#19,#22,#10) appear with a frequency of 75%; E3: opposite situation to E1, more homogeneous plans by type of engine appear 25% of the time and the rest of the plans 75%; E4: opposite situation to E2; E5: most homogeneous plans by engine families (#2, #16, #13, #12, #14, #15, #17) appear with a frequency of 75% of the time; E6: least homogeneous plans by engine families (#11, #9, #10) appear with a frequency of 75% of the time; E7: opposite to E5; E8: opposite to E6.

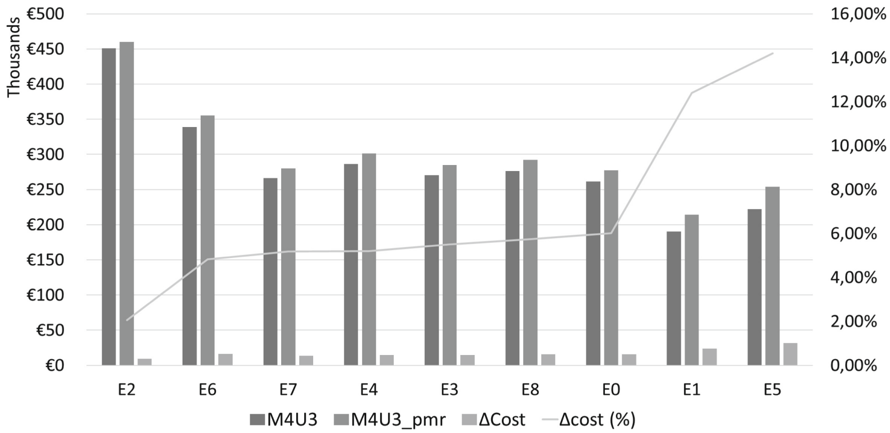


Fig. 3. Annual cost (€) of loss of engines due to work overload in regard with the homogeneity of demand plans.

- The greatest economic impact occurs when the daily demand plans are predominantly homogeneous (E5: cost increase of 14,21% and E1: increase of 12,40% of work overload costs).
- Preserving production mix throughout the workdays supposes lower extra costs when the demand plans are mainly imbalance within product types (E2: cost increase of 2,05%).

However, increase cost because of uncompleted engines is offset in part by (a) the leveling of stocks in line and (b) the balance between the workloads of workstations.

These improvements, that have been achieved for all sequences by introducing the "quota" property, may compensate the incurred extra costs by means of reducing the required space in workstations for components, minimizing the opportunity costs and reducing the physical and mental stress to operators. Illustrative are quantities of each product type that should be manufacture in accordance with the sequences given by M_4U3_pmr and M_4U3 for the instance with the greatest cost increase (#11), which corresponds with the higher demand of engines for trucks and lower demands of engines for 4x4 and vans (Fig. 4).

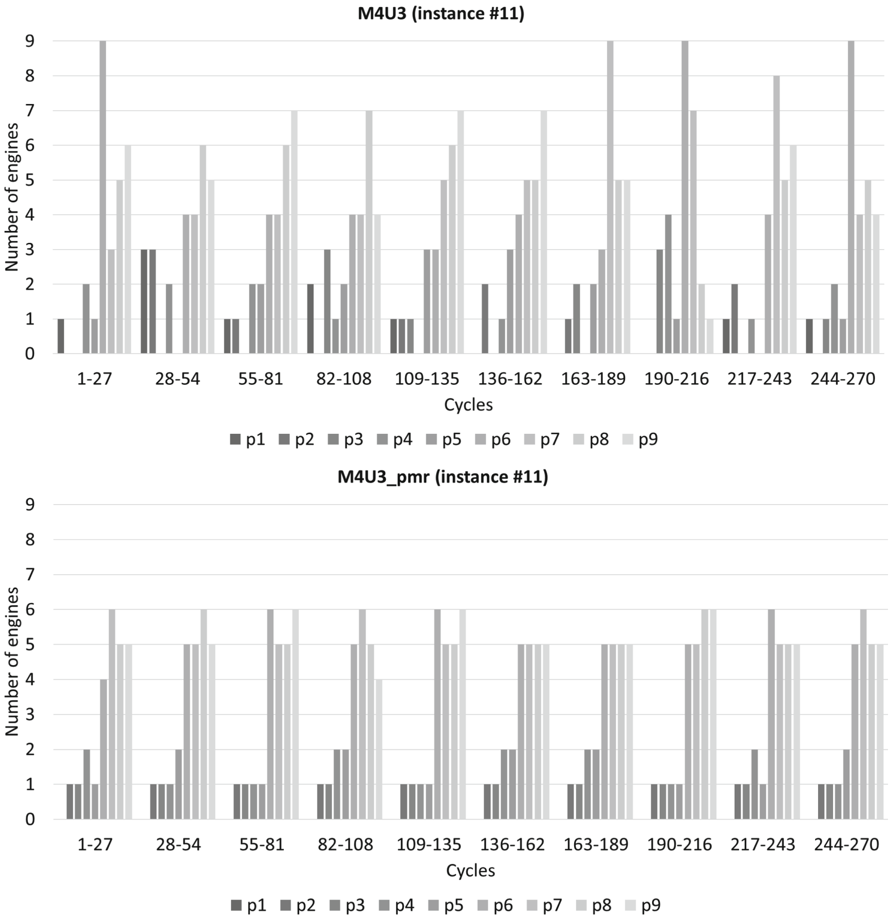


Fig. 4. Number of engines of each type that appears each 27 cycles from sequences given by both models for the demand plan #11.

5 Conclusions

Regularize production sequences in mixed-model assembly lines may increase work overload and, therefore, the amount of unfinished engines. Taking into account the worst scenario (E5: corresponding to a greater frequency of plans with a homogeneous demand for engines by families), the economic impact of regularizing sequences supposes an increase, in the cost derived from work overload, of 14.21%. This increase represents less than €32,000 per year, which results in one lost engine each three days (i.e. €133 per day). However, this preservation of production mix balances the workloads throughout the workday and both levels and reduces the stocks in line considerably.

Acknowledgements. This work has been funded by the Ministry of Economy and Competitiveness of the Government of Spain through project OPTHEUS (ref. PGC2018-095080-B-I00), including European Regional Development Funds (ERDF).

References

1. Bautista, J., Alfaro, R.: Transformación de una línea de montaje de modelos mixtos en un taller de flujo regular: Caso de estudio en la factoría Nissan de Barcelona. Dirección y organización **69**, 82–98 (2019)
2. Bautista, J., Cano, A.: Solving mixed model sequencing problem in assembly lines with serial workstations with work overload minimisation and interruption rules. Eur. J. Oper. Res. **210**(3), 495–513 (2011)
3. Yano, C.A., Rachamadugu, R.: Sequencing to minimize work overload in assembly lines with product options. Manage. Sci. **37**(5), 572–586 (1991). https://doi.org/10.1287/mnsc.37.5.572
4. Scholl, A., Klein, R., Domschke, W.: Pattern based vocabulary building for effectively sequencing mixed-model assembly lines. J. Heurist. **4**, 359–381 (1998)
5. Boysen, N., Fliedner, M., Scholl, A.: Sequencing mixed-model assembly lines: survey, classification and model critique. Eur. J. Oper. Res. **192**(2), 349–373 (2009)
6. Monden, Y.: Toyota Production System: An Integrated Approach to Just-In-Time, 4th edn. Productivity Press, New York (2011)
7. Bautista, J., Cano, A., Alfaro, R.: Modeling and solving a variant of the mixed-model sequencing problem with work overload minimisation and regularity constraints. An application in Nissan's Barcelona Plant. Expert Syst. Appl. **39**(12), 11001–11010 (2012). https://doi.org/10.1016/j.eswa.2012.03.024
8. Miltenburg, J.: Level schedules for mixed-model assembly lines in just-in-time production systems. Manage. Sci. **35**(2), 192–207 (1989). https://doi.org/10.1287/mnsc.35.2.192
9. Bautista, J., Alfaro-Pozo, R.: A GRASP algorithm for Quota sequences with minimum work overload and forced interruption of operations in a mixed-product assembly line. Prog. Artif. Intell. **7**(3), 197–211 (2018). https://doi.org/10.1007/s13748-018-0144-x
10. Bautista, J., Cano, A., Alfaro-Pozo, R.: A hybrid dynamic programming for solving a mixed-model sequencing problem with production mix restriction and free interruptions. Prog. Artif. Intell. **6**(1), 27–39 (2017). https://doi.org/10.1007/s13748-016-0101-5
11. Bautista, J., Alfaro-Pozo, R.: Free and regular mixed-model sequences by a linear program-assisted hybrid algorithm GRASP-LP. Prog. Artif. Intell. **6**(2), 159–169 (2017). https://doi.org/10.1007/s13748-017-0110-z

Industry 5.0 and Human-Centered Approach. Bibliometric Review

Aitor Ruiz-de-la-Torre[1](✉), Rosa M. Rio-Belver[1], Wilmer Guevara-Ramirez[1], and Christophe Merlo[2]

[1] Industrial Organization and Management Engineering Department, Faculty of Engineering Vitoria-Gasteiz, University of the Basque Country UPV/EHU, Nieves Cano 12, 01006 Vitoria-Gasteiz, Spain
aitor.ruizdelatorre@ehu.eus

[2] ESTIA en Ingeniería del Diseño y de los Sistemas Industriales, ESTIA - Institute of Technology-ESTIA RECHERCHE, Université de Bordeaux, Bordeaux, Bidart, France

Abstract. This research presents a bibliometric study of the Industry 5.0 scientific-technological field, identifying the beginning of its growth stage and dating it to the year 2019, visualizing the leading countries and the most cited authors and contributions, obtaining the general overview of the field of study. It is deepened by studying "Industry 5.0" authors' keywords, detecting the strong connection between Industry 4.0 and Industry 5.0, as well as the close relationship of both with the terms "Artificial Intelligence", "Internet of Things", "Blockchain", "Sustainability", "Triple Helix" and "Industrial Revolution". Industry 5.0 links are also observed with "Human factor", "Human robot collaboration", "Smart manufacturing", "Human-centric", "Human machine interaction", "Ergonomics" and "Self-organised-manufacturing". Finally, a new human-centred search and approach is performed, revealing that the author's term "human-machine" is used for the first time in 2020, demonstrating the novelty of this field of study.

Keywords: Industry 5.0 · Human-centered design · Bibliometric analysis · Network analysis

1 Introduction

While the main concern of Industry 4.0 is automation, Industry 5.0 will be a synergy between humans and automated machines. In other words, Industry 5.0, as the next industrial evolution, aims at exploiting the creativity of human experts in combination with efficient, intelligent and precise machines in order to obtain efficient manufacturing solutions. This efficient synergy between humans and technology will affect the economy, ecology and the social world, where adapting to it will benefit productivity improvement [1].

The world of technology, mass customisation and advanced manufacturing is undergoing a rapid transformation subject to changes and disturbances in the economic environment. The strong need to increase productivity without removing human workers

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 402–408, 2023.
https://doi.org/10.1007/978-3-031-27915-7_71

from the manufacturing industry is placing great challenges on the global economy, in addition to the need to lead change in environmentally friendly technological and the sustainability of human development [2].

In a challenging environment manufacturing systems need to adjust their operation and adapt quickly; it is becoming increasingly urgent to have resilient manufacturing systems operated by the so-called resilient operator 5.0 [3]. The future vision of work points to resilient workers who should be increasingly agile, more flexible and, therefore, ever more fragile due to their humanness.

Although Industry 4.0 has improved manufacturing costs, it has ignored the human cost through process optimization. Industry 5.0 will bring unprecedented challenges in the field of human-machine interaction as it will bring machines very close to the everyday life of any human. This inadvertently leads to a backward push in employment and will raise resistance from labour unions thereby affecting full adoption of Industry 4.0.

Industry 5.0 is seen as the answer to the question of this renewed human-centred industrial paradigm, based on the reorganisation (structural, organisational, managerial, knowledge-based, philosophical and cultural) of industry's production processes [4].

Without a correct definition of the nexus between technology and the role that people are obliged to adopt, it will be difficult to face the great digital transformation that we are experiencing or adapt to the new existing technologies. Therefore, this work aims to carry out the first stage of a bibliographic study of the methods for designing intelligent human-machine workplaces in order to create value for the people involved in the different production processes. Within these methods, we wish to study in depth those that use simulation for their design.

2 Bibliometric Study

For a first analysis of the existing literature, a structured method has been followed: starting with a general search to focus the query on the specific area of interest in a second stage. In this way, we first approach the field by retrieving records indexed in the Web of Science (WOS) and Scopus databases that contain the term "Industry 5.0". For a first approach to the field, the publication dates were not limited (retrieval date 8th March, 2022); the results of the search carried out in the fields Title (TI), Abstract (AB) and Keyword (KW) produced 101 results in WOS and 155 in Scopus respectively (Table 1).

Table 1. Industry 5.0 query

General query:	No Registers	Registers
Title:(industry 5.0) OR Abstract:(industry 5.0) OR Keyword:(industry 5.0)	103Web of Science	After merging, removal of duplicates and clean-up process
Limited by: Articles and Conference proceedings	155 Scopus	182

After retrieving the records, and the tasks of merging, cleaning, eliminating duplicates, etc. with the help of the text mining software Vantage Point [5], we proceed to the study of the main technological actors in the area. The first analysis shows that the term Industry 5.0 initially began to appear in 2005, with occasional publications until its growth from 2019 onwards, and now currently in full exponential growth. Its connections with Industry 4.0 are analysed, as well as the appearance of new terms, which are presented in the results section. Given the emergence of the field, "Authors' Keywords" this is considered to be the most representative as it contains more current terms than the traditional thesaurus, and its study is carried out by means of creating of a network of terms and the use of Gephi software [6].

In a second stage, once the relevant Industry 5.0 terms have been identified, the literature that addresses human-machine interactions from a human welfare approach is explored in depth. A method already applied by Alvarez-Meaza [7] based on the one developed by Gänzel [8] is followed in order to improve the precision and recall of a specific search. First, search #1 was performed obtaining an unconditional set of high precision but low recall results, second, in order to improve the recall, searches #2 and #3 were developed which, when crossed, make it possible to obtain set2, which also generates a final set with high precision and high recall results. The number of records retrieved is shown in Table 2 below.

Table 2. Specific bibliometric search strategy

	Specific query	No Registers	
		Scopus	WOS core collection
#1	Set1 = (TITLE-ABS-KEY ("Industry 5.0") AND TITLE-ABS-KEY (("Human-centred") OR ("Human machine") OR ("Human centric") OR ("human factor") OR ("human robot collaboration")))	69	34
#2	Download articles with Authors' keywords extended: (Ergonomics) OR (Simulation) OR ("Virtual reality") OR ("Human Engineering") OR ("Digital human model") Field: (AUTHKEY). Limited by (2019–2022) AND Articles or Conference proceedings	131824	104394
#3	Download set1 citing articles	358	152
#4	Set2: (#2 and #3)	16	5
#5	Final Set = (#1 or #4)	81	36

Table 3. Top 5 cited contribution details

Times cited	Title	Publication Year	Source	Author name	Affiliations	Country
127	Birth of Industry 5.0: Making Sense of Big Data with Artificial Intelligence, "the Internet of Things" and Next-Generation Technology Policy	2018	OMICS A Journal of Integrative Biology	Hekim, N	Department of Medical Biochemistry	Canada India
				Özdemir, V	Independent Researcher School of Biotechnology	Turkey
116	Industry 5.0-A Human-Centric Solution	2019	Sustainability	Nahavandi, S	Institute for Intelligent Systems Research and Innovation	Australia
61	Industry 5.0 and Human-Robot Co-working	2019	Procedia Computer Science	Döven, G	Department of Management	Turkey
				Demir, K.A	Graduate School of Social Sciences	
				Sezen, B		
52	A Novel Intelligent Medical Decision Support Model Based on Soft Computing and IoT	2020	IEEE Internet of Things Journal	Abdel-Basset, M	School of Computing	Chinat Egyp
				Gamal, A	Faculty of Computers and Informatics	United Kingdom United
				Chang, V	International Business School Suzhou and Research Institute of Big Data Analytics	States
				Manogaran, G	University of California at Davis	
39	Value-Oriented and Ethical Technology Engineering in Industry 5.0: A Human-Centric Perspective for the Design of the Factory of the Future	2020	Applied Sciences-Basel	Longo, F	Department of Mechanical	Italy
				Padovano, A	Department of Philosophy and Educational Sciences	
				Umbrello, S		

After merging and clean-up, 89 records are available for the human-centred approach. The final set is analysed by applying social network theory to generate a primary technological landscape, detecting the main universities, authors and their most cited works. Finally, in subsequent works, we will proceed to carry out the content analysis, choosing the method(s) to be applied in the project[1] that finances this contribution.

3 Results

In a first approach to the Industry 5.0 field, the analysis of the records retrieved with the first query allows us to identify the technological agents behind its growth as of 2019. The George Washington University and its School of Business, together with Samara State Technical University, have made the United States the leading country in world production. The contribution of the Italian "Universita de Roma" or "University of Parma", which will play an important role in the design of human-centred workplaces, is noteworthy. India, China and Russia complete the top five in world production according to the WOS and Scopus databases. Table 3 below summarises the most relevant information from the five most cited articles.

Due to the novelty of the area, the Authors' Keywords field of study was chosen because of its ability to reflect new terms in contrast to the stability of the thesaurus databases. Figure 1 shows the network structure of the terms used by the authors in their contributions, visualising eleven main communities that will be the subject of further study. In order to visualise the terms related to Industry 5.0, it was necessary to apply the Fruchterman Reingold algorithms and the attraction and repulsion algorithm called Force Atlas 2, subsequently a visualisation was generated based on the weighted

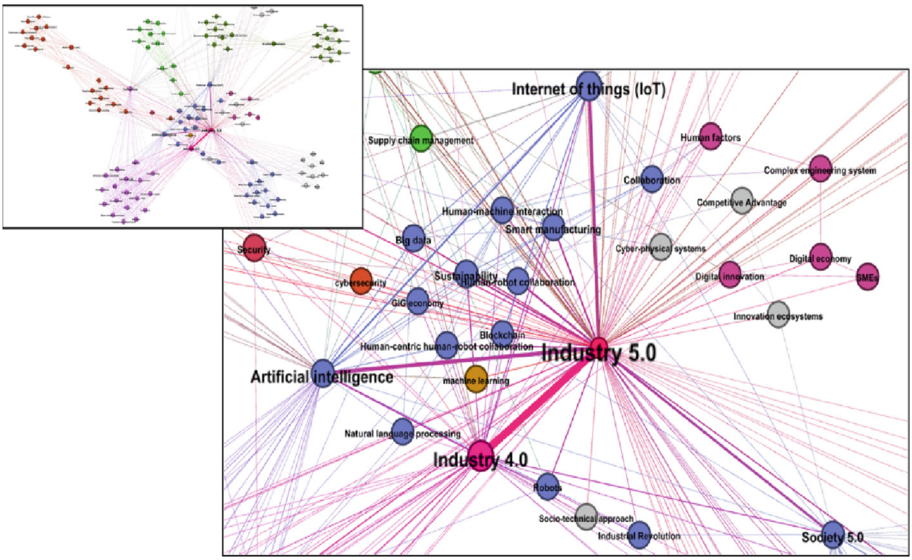


Fig. 1. Relationship between the terms Industry 5.0 and Industry 4.0 in a network elaborated with Authors' keywords. Scopus. 2005–2022. Source. Own elaboration

[1] Project entitled "Moving towards Industry 5.0. Learning to work with intelligent machines" financed by Fundación Caja Vital. (Ref: VITAL 21/13).

degree of the network allowing us to appreciate the nodes with the greatest number of collaborations by means of a weighted measure of the number of edges. In a first approximation we can visualise the strong link between Industry 4.0 and Industry 5.0, as well as the close relationship of both with the terms “Artificial Intelligence”, “Internet of Things (IoT)”, “Blockchain”, “Sustainability”, “Triple helix” and “Industrial revolution”. We can also observe the connections of Industry 5.0 with “Human factor”, “Society 5.0” or “Democracy 5.0”, however, in this article, we want to go deeper into the terms of the first class of the Industry 5.0 node related to Human robot collaboration, Smart manufacturing, Human-centric, Human machine interaction, Ergonomics, or Self-organised-manufacturing.

4 Conclusion and Future Steps

This paper focuses on the study of the scientific-technological field of Industry 5.0, detecting the beginning of its growth stage and dating it to 2019. However, it is a field strongly connected with Industry 4.0, as well as with the explosion of technologies such as IoT, Blockchain or Artificial Intelligence. The aim of Industry 5.0 is to change the focus to the human aspects of the workplace and the problem of human-technology interaction. There is a high level of interest in this new vision promoted by the European Commission through the support of research projects (11 articles in the downloaded database included EU funding).

The analysis of the specific search described in Table 2 shows that some human-machine terms are limited and are introduced in stages prior to Industry 5.0. For example, the term human-centred-design appears for the first time in an article in 2010, the term “Human-centred simulation” in 2011 and “Human-Centred Manufacturing” in 2018, nevertheless, “Human-machine interaction” does not appear until 2020. This prompts the need to align research in these fields with the European vision of Industry 5.0, representing an opportunity for industrial organisational engineering within the 5.0 Society.

References

1. Commission, E., Innovation, D.-G.. Breque, M., De Nul, L., Petridis, A.: Industry 5.0 : Towards a Sustainable, Human-Centric and Resilient European Industry. Publications Office (2021). https://doi.org/10.2777/308407
2. Nahavandi, S.: Industry 5.0—A Human-Centric Solution. Sustain 2019, vol. 11, p. 4371 (2019). https://doi.org/10.3390/SU11164371
3. Romero, D., Stahre, J.: Towards the Resilient Operator 5.0: the future of work in smart resilient manufacturing systems. In: Procedia CIRP. pp. 1089–1094. Elsevier (2021). https://doi.org/10.1016/j.procir.2021.11.183
4. Carayannis, E.G., Morawska-Jancelewicz, J.: The futures of Europe: Society 5.0 and Industry 5.0 as driving forces of future universities. J. Knowl. Econ. **13**, 1–27 (2022). https://doi.org/10.1007/S13132-021-00854-2/FIGURES/5
5. Search Technology, Home - the VantagePoint: www.thevantagepoint.com. Accessed 10 Mar 2022

6. Gephi: an open source software for exploring and manipulating networks. In: Proceedings of the International AAAI Conference on Web and Social Media, https://ojs.aaai.org/index.php/ICWSM/article/view/13937. Accessed 10 Mar 2022
7. Alvarez-Meaza, I., Zarrabeitia-Bilbao, E., Rio-Belver, R.M., Garechana-Anacabe, G.: Green scheduling to achieve green manufacturing: pursuing a research agenda by mapping science. Technol. Soc. **67**, 101758 (2021). https://doi.org/10.1016/j.techsoc.2021.101758
8. Glänzel, W.: How to use bibliometrics to enhance data retrieval. In: ESSS Conference (2019)

Deciding How Much to Self-consume Within the European Green Deal Framework

David González-Asenjo[1,2](✉), Luis R. Izquierdo[2], and Javier Sedano[1,2]

[1] Instituto Tecnológico de Castilla y León, Burgos, Spain
dga0024@alu.ubu.es
[2] Escuela Politécnica Superior, University of Burgos, Burgos, Spain

Abstract. Given the current situation of volatility in the European energy market, policies aimed at achieving a clean sustainable energy transition are beginning to be deployed. In these policies, the figure of the prosumer and the integration of renewable energy sources at the household level are essential. Thus, in this context, decisions made by individual citizens will have a large impact on the overall social welfare, so it is important to understand and model the factors involved in their decision making. By doing so, it will be possible to anticipate and assess the overall impact of different policies and incentives. In this paper, we have derived an expression that captures the main economic factors involved in the decision to become a prosumer at the household level, considering the recent updates of the Spanish electricity market regulation. This work will serve as a basis for the development of prosumer behaviour models.

Keywords: Profitability · Self-consumption · Decarbonization · Prosumers · Decision-making

1 Introduction

There is a strong consensus that the current European energy system is not environmentally sustainable due to its strong dependence on fossil fuels [1]. Furthermore, these fossil energy sources are mostly imported [2], causing an atmosphere of insecurity and energy dependence on the exporting countries. This situation leads to an energy system whose sustainability is permanently threatened, with high price volatility conditioned by changes in the geopolitical map of fossil fuel producers.

In this context, the European Commission has deployed political instruments in pursuit of energy independence and sustainable development [3, 4], which aims to achieve a clean energy transition and climate neutrality by 2050 [5]. Within these policies, there are also ambitious short-term targets for 2030. Among the numerous goals, three major lines of action in the energy and climate field can be highlighted: i) electrification of the economy (mainly heating, transport and industry), ii) decarbonization through the increased use of renewable energies and iii) active participation of consumers in the energy market [6].

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 409–413, 2023.
https://doi.org/10.1007/978-3-031-27915-7_72

These three lines of action are interrelated. The electrification of the economy can greatly facilitate the transition from our current situation –i.e. an economy highly dependent on fossil fuels– to an economy based on renewable energies, with lower CO_2 emissions. The electrification of the economy can also provide new opportunities for consumers to produce a significant part of the energy they require, and even to contribute their surplus electricity to the grid.

Nonetheless, these initiatives aimed at promoting electrification, advancing decarbonization and encouraging consumers' involvement will certainly increase the complexity of the energy system, which will count with a significantly greater number of actors. Therefore, new advanced tools and concepts for the design, characterization and analysis of the energy market will be required to ensure a robust and efficient operation of the power grid [7]. Many of these new tools and concepts are encompassed within the paradigm of smart grids, which are presented as a key part of the future energy systems.

In this paper we focus on one of the decarbonization actions with the greatest potential impact, due to its capacity to be easily replicated and the possibility of being implemented nowadays: the active involvement of citizens in the energy market through distributed renewable generation. To be precise, the goal of this paper is to analyse the economic savings that individual consumers could potentially attain if they became prosumers (i.e., small-scale producers as well as consumers) [8].

2 Methodology and Limitations

In this paper we deduce the expression that determines the maximum economic savings that can be achieved by producing energy at the household level. To do this, we take into account the latest updates of the Spanish energy market regulations regarding self-consumption. The derived expression will include the main factors that affect the potential savings, such as the size of the facility, its cost of installation and maintenance, the energy that is produced and consumed by the household, and the taxes involved in self-consumption.

Naturally, besides economic profit, many other motivations could drive the decision to become a prosumer. As a matter of fact, in general, surveys lead us to believe that European citizens are motivated to take actions to mitigate climate change [9]. However, these actions refer mainly to small changes in consumption habits. The implementation of larger-scale actions often requires supporting mechanisms from governments. Thus, here we focus on economic profit as one of the most relevant factors for most individuals at the time of choosing to become a prosumer.

Nonetheless, if our goal is to predict individual behaviour, we must not forget other factors that may affect this decision. Two prominent factors are the sustainability of the system and its performance. Therefore, from the citizen's perspective, the economic dimension of the problem is likely to be salient at the time of making the decision; but, in any case, the fact that we only consider monetary incentives is certainly a limitation of our study.

3 Derivation of the Formula

Our analysis considers a domestic prosumer with an individual self-consumption photovoltaic (PV) facility. We assume solar energy for concreteness, but the production of any other type of renewable energy would lead to the same analysis.

The profitability factors include the energy generated (E^t_{PV}) and the energy consumed (E^t_c), the price of the energy demanded from the grid (p^t_d) and the price of the energy injected in the grid (p^t_i), the installation and maintenance costs of the renewable energy facility (C^t_{PV}), taxes that may affect the energy bill (τ_1) and taxes or grants that may affect the energy installation costs (τ_2). All the terms are indexed in time slot 't', which captures the dynamic nature of this type of scenarios. In particular, C^t_{PV} refers to the fraction of the installation and maintenance costs that is assigned to time slot t.

The formalization of this decision problem requires a logical deduction process taking into consideration the latest updates of the Spanish Government regulations about electricity pricing [10] and the use of renewable energies for self-consumption [11,12] (which is similar to the European regulations [13]). These regulations establish the following conditions:

- Each time slot is one hour long, since the regulation establishes that the compensation between energy consumed (E^t_c) and energy produced (E^t_{PV}) must be conducted every hour. To be clear, for any hour during which the prosumer has consumed more energy than the energy she has produced ($E^t_c > E^t_{PV}$), the prosumer will have to pay for the energy demanded from the grid ($E^t_c - E^t_{PV}$) at price p^t_d. On the other hand, for those hours during which the prosumer has consumed less energy than the energy she has produced ($E^t_c \leq E^t_{PV}$), the prosumer will be compensated for the energy injected in the grid ($E^t_{PV} - E^t_c$) at price p^t_i, which is lower than p^t_d.
- Over each billing period, the total compensation that the prosumer may receive for injecting energy into the grid cannot exceed the total cost of the energy demanded from the grid.

With these considerations in mind, we have derived expression (1), which establishes the savings that an individual consumer would get over each billing period by becoming a prosumer. (Sums $\sum_t$ refer to all the time slots in the billing period).

$$Saving = \tau_1 \cdot \min\left\{ \begin{array}{c} \sum_t p^t_d \cdot E^t_c \\ \sum_t \left(p^t_d \cdot \min\left(E^t_c, E^t_{PV}\right) + p^t_i \cdot \max\left(0, E^t_{PV} - E^t_c\right)\right) \end{array} \right\} - \tau_2 \cdot \sum_t C^t_{PV} \tag{1}$$

In essence, the savings are expressed as the sum of two terms. On the one hand, there is a positive amount (1$^{\text{st}}$ term) that captures the savings achievable by producing energy –and self-consuming it (rather than buying it from the grid) or injecting it in the grid (when more energy is produced than consumed in the time slot). On the other hand, a negative amount (2$^{\text{nd}}$ term) that indicates the implementation cost necessary to achieve these savings.

The first term is bounded by the cost of the energy demanded from the grid in the absence of self-consumption ($\sum_t p^t_d \cdot E^t_c$), as prescribed by current regulations. The positive savings come both (i) from the time slots where $E^t_{PV} < E^t_c$, so all the produced energy is self-consumed (in which case, the savings are $p_d^t \cdot E_{PV}^t$), and (ii) from the time slots where $E_{PV}^t \geq E_c^t$, so there is some excess energy ($E_{PV}^t - E_c^t$) that is injected in the grid (in which case, the savings are $p_d^t \cdot E_c^t + p_i^t \cdot (E_{PV}^t - E_c^t)$.

Both terms in (1) will fluctuate dynamically according to the variation of the operating features of the renewable energy system (PV power, simultaneity of production and demand, system performance…) and market regulations (taxes, grants, wholesale market prices, etc…).

It is possible to add complexity to this balance by including the possibility of adding battery systems, by considering the market costs of CO_2 emissions (which do not currently apply to the domestic environment) and by studying the impact of possible disruptive events affecting the electricity system, such as power outages.

Equation (1) can be used to draw some simple inferences. Note that if the cost of the installation is greater than the cost of the household electricity consumption $\left(\tau_2 \cdot \sum_t C_{PV}^t > \tau_1 \cdot \sum_t p_d^t \cdot E_c^t\right)$, the implementation of the renewable energy facility will not be profitable, since even with the maximum profit, the overall savings (taking into account installation and maintenance costs) would be negative. If this is the case, we would expect citizens' reluctance to implement these measures.

In the case of a potentially cost-effective performance $\left(\tau_2 \cdot \sum_t C_{PV}^t < \tau_1 \cdot \sum_t p_d^t \cdot E_c^t\right)$, the different parameters of the model (e.g. how much energy to consume in each time slot) can be tuned to maximize savings. In any case, to assess the total savings over the whole life span of the facility, we would have to consider the time value of money, i.e. we would have to compute the Net Present Value of the savings.

4 Conclusions and Future Research

In summary, the objective of this extended abstract is to provide a formal mathematical expression that captures the factors that condition the economic profitability of a renewable energy project for self-consumption. The aim is to use the derived formula to facilitate modelling the decision-making process for the implementation of this type of action at citizen level. It can also be used as an individual cost-benefit function to be introduced in multi-agent environments to explore new global optimization techniques based on interdependent individual decision rules, for instance, regarding the concept of energy communities [13, Art.16] [14, Art. 22], with the aim of developing efficient algorithms that allow an optimal design and operation of the power grid in this type of dynamic environments.

As future research work, on the one hand we intend to apply Eq. (1) in other European markets to validate or adjust the expression where necessary. To do this, further data analysis will be required, taking as a reference different types of historical consumption datasets (individual, collective) and different price signals over time, in order to evaluate the importance of the different factors in each scenario and assess whether they can lead to different energy exchange strategies.

On the other hand, it will be of great interest to study how governments' incentive/tax mechanisms could affect profitability, assessing how acting on a specific part of the model can encourage or discourage citizens to become prosumers, or how the future demand-side management mechanisms to be introduced in the market (Demand response, storage management) can change the balance, both at individual and collective level.

This research has been founded by CDTI (Centro para el Desarrollo Tecnológico Industrial) under projects CER-20211003 and CER-20211022, and by the Spanish State Research Agency (PID2020-118906GB-I00/AEI/10.13039/501100011033).

References

1. Eurostat: Share of fossil fuels in gross available energy - Products Eurostat News – Eurostat (2022). https://ec.europa.eu/, https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20210204-1
2. Eurostat: Energy production and imports - Statistics Explained (2021). https://ec.europa.eu/, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_production_and_imports#More_than_half_of_EU_energy_needs_are_covered_by_imports
3. European Comission: Paris Agreement. (2016) https://ec.europa.eu/, 2016. https://ec.europa.eu/clima/eu-action/international-action-climate-change/climate-negotiations/paris-agreement_en
4. European Comission: A European Green Deal | European Commission (2020). https://ec.europa.eu/, https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/
5. European Comission: 2050 long-term strategy. https://ec.europa.eu/ . https://ec.europa.eu/clima/eu-action/climate-strategies-targets/2050-long-term-strategy_en
6. European Comission, "2030 climate & energy framework," https://ec.europa.eu/, 2020. https://ec.europa.eu/clima/eu-action/climate-strategies-targets/2030-climate-energy-framework_en
7. Saad, W., Han, Z., Poor, H.V., Başar, T.: Game-theoretic methods for the smart grid: An overview of microgrid systems, demand-side management, and smart grid communications. IEEE Signal Process. Mag. **29**(5), 86–105 (2012). https://doi.org/10.1109/MSP.2012.2186410
8. N. Šajn, "Electricity 'Prosumers,'" *EPRS | Eur. Parliam. Res. Serv.*, 2016
9. EIB, "2020–2021 EIB Climate Survey, part 1 of 3: post-COVID-19, Europeans want a green recovery. EIB Media Centre, 2021. https://www.eib.org/en/surveys/climate-survey/3rd-climate-survey/climate-change-and-covid-recovery.htm
10. Gobierno de España: Circular 3/2020: de 15 de enero, de la Comisión Nacional de los Mercados y la Competencia, por la que se establece la metodología para el cálculo de los peajes de transporte y distribución de electricidad.. BOE (2020). https://www.boe.es/eli/es/cir/2020/01/15/3
11. Gobierno de España: Real Decreto 244/2019, de 5 de abril, por el que se regulan las condiciones administrativas, técnicas y económicas del autoconsumo de energía eléctrica. BOE (2019). https://www.boe.es/eli/es/rd/2019/04/05/244
12. Gobierno de España: Orden TED/1247/2021, de 15 de noviembre, por la que se modifica, para la implementación de coeficientes de reparto variables en autoconsumo colectivo, el anexo I del Real Decreto 244/2019, de 5 de abril, por el que se regulan las BOE (2021). https://www.boe.es/eli/es/o/2021/11/15/ted1247
13. Parlamento Europeo, "Dırectıva (UE) 2019/ 944 DEL PARLAMENTO EUROPEO Y DEL CONSEJO - de 5 de junio de 2019 - sobre normas comunes para el mercado interior de la electricidad y por la que se modifica la Directiva 2012/ 27/ UE," BOE, 2019
14. Gobierno de España: DIRECTIVA (UE) 2018/ 2001 del Parlamento Europeo y del Consejo - de 11 de diciembre de 2018 - relativa al fomento del uso de energía procedente de fuentes renovables," BOE (2018)

Photovoltaic Solar Power Plant Maintenance Management Based on Statistical Analysis

Alba Muñoz del Río(✉), Isaac Segovia Ramirez, and Fausto Pedro García Márquez

Ingenium Research Group, Universidad Castilla-La Mancha, 13071 Ciudad Real, Spain
{alba.munoz,isaac.segovia,faustopedro.garcia}@uclm.es

Abstract. Photovoltaic solar energy is one of the most relevant renewable energies and it requires new monitoring control and data analysis systems to provide reliable information on the real state of photovoltaic systems. The approach presented in this paper combines energy generation data with solar irradiation data to detect abnormal drops that may be caused by failures and not for environmental conditions. The definition of possible failures is performed with statistical analysis to reduce the computational costs. A real case study is presented with Supervisory Control and Data Acquisition data from a solar photovoltaic plant located in Spain. The results show that this analysis is a suitable to determine periods of time where the solar plant presents faults that are not correlated to reduction of irradiation associated to environmental factors or meteorological changes.

Keywords: Photovoltaic solar power plant · Statistical analysis · Production · Irradiation

1 Introduction

Solar photovoltaic (PV) systems have a major role in global renewable energy production [1–3]. The competitiveness of PV energy has increased in recent years due to new technological advances in manufacturing and lower prices, although it is required the reduction of the operation and maintenance (O&M) costs to achieve the economic viability of PV energy [4, 5]. The hard environment conditions of the PV farms and the presence of different faults may reduce the crystalline-Si modules performance. Some of the most critical failures are hot spots, module open and short circuited, open-circuit bypass diode delaminated, cells with breaks or bubbles and presence of dust and dirt, among others [6]. These failures decrease the solar radiation received by the PV panels and reduces the generated power [7, 8], being necessary new techniques and methods for early fault detection [9]. Novel condition monitoring systems (CMS) and suitable maintenance management plans are widely applied to ensure proper levels of energy generation and monitor the reduction of PV performance [10, 11]. Supervisory Control and Data Acquisition (SCADA) system is widely applied in the industry to monitor the PV power production, providing reliable data on electrical performance, alarms and irradiation of each PV panel [12, 13]. Early fault detection and data processing methods are needed to identify faults before they become critical.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 414–418, 2023.
https://doi.org/10.1007/978-3-031-27915-7_73

This paper presents a novel approach based on the correlation between irradiation and energy production to detect faults that cause irregular performance of PV panels. This is a novelty in the current state of the art because the irradiation is usually applied for the estimation of the production, but not for fault detection. The application of basic statistics decrease the computational costs an easy interpretation of the results. As future work, it is proposed the application of machine learning algorithms to improve the reliability of the analysis.

This work is structured as follows: the approach is defined on Sect. 2; Sect. 3 provides a real case study with SCADA data from a real PV plant, showing the main results; The main conclusions are described in Sect. 4.

2 Approach

This paper aims to detect drops in energy production by the PV panels that cannot be explained by changes in irradiance. The detection of drops uncorrelated with the decrease in irradiation may indicate the presence of faults that cause the reduction in energy production. The developed approach is showed in Fig. 1.

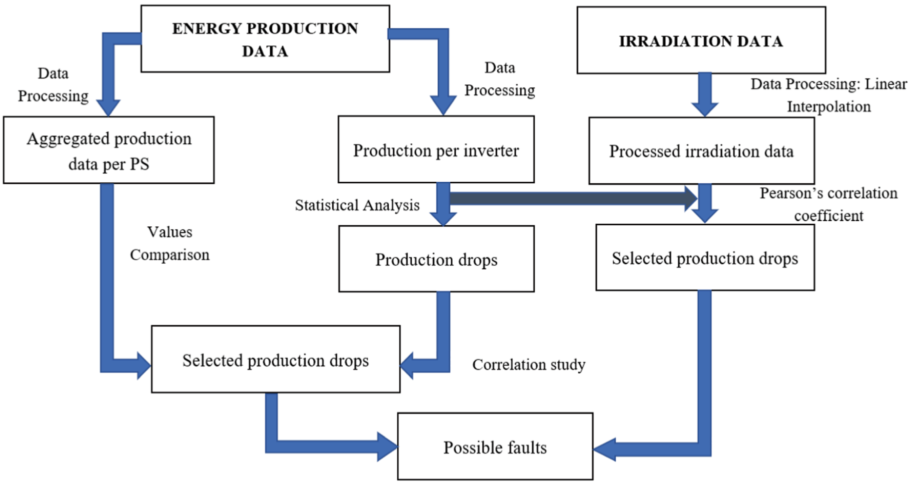


Fig. 1. Diagram of the approach.

The first step is the detection of drops through a statistical analysis of the production values. A non-gradual loss of production must be present to be considered a drop in production. The daily average production values are compared with those of the previous and following days to detect these drops. Once the dates with drops in production have been detected, the production values per inverter are compared with the values grouped by power station (PS) to determine whether the problem is a collection data or a production problem.

The correlation between production and irradiation data per month is analyzed, being the production data given in kW and the irradiation data in W/m^2 [14]. The relationship between both variables will be studied using Pearson's correlation coefficient, that measures the linear dependence between two quantitative variables X and Y, as it is shown in (1). The covariance of X and Y is denoted by $cov(X, Y)$ and defined in (2). The variance of X is $var(X)$ and computed as (3), where $E[X]$ is the expectation of X [15].

$$\rho(X, Y) = \frac{cov(X, Y)}{\sqrt{var(X)var(Y)}} \tag{1}$$

$$cov(X, Y) = E[(X - E[X])(Y - E[Y])] \tag{2}$$

$$var(X) = E\left[X^2\right] - E[X]^2 \tag{3}$$

The days extracted from the production analysis are re-analysed using correlation to find discrepancies between production and irradiation. This analysis aims to explain the discrepancies found in the production for these particular days.

3 Case Study and Results

The case study is formed by production data that has been collected by SCADA for 9 months every 10 min, forming a dataset with 39420 entries. This dataset contains production data per inverter and also production data grouped by PS. The real solar plant is formed by 2 inverters and each one presents different PS. The first analysis carried out is based on production values per month, aggregating the data per day and calculating their average production for better visualisation. Figure 2 shows certain periods of the production data by month.

The drops detected from the analysis of production per day are compared with the collected values aggregated by PS. This comparison yields 24 dates with a significant difference between the record per investor and the aggregate record per PS. It is possible to confirm that these dates represent a failure in data acquisition.

Further analysis compares the production data with the irradiance data. The correlations between production and irradiance data are strong for all months analysed, above 0.85 in all cases. These values indicate in general terms that the production data collected are correctly adjusted to the irradiance in each month. A wide correlation analysis of the days extracted from the previous production analysis has been carried out to find discrepancies between production and irradiance that could explain the differences in the production data. For most of the cases, the correlations found between irradiance and production are strong, above 0.8, indicating that the drops are due to changes in irradiance on those days. However, weaker correlations between irradiance and production are found for two of the selected dates. This decrease in the correlations would indicate a significant difference between the irradiance recorded on these days and the production recorded in the different PS, that could indicate a failure of the PV solar plant. Table 1 shows the results with lower correlation, and this period is considered as a strong candidate to present failures.

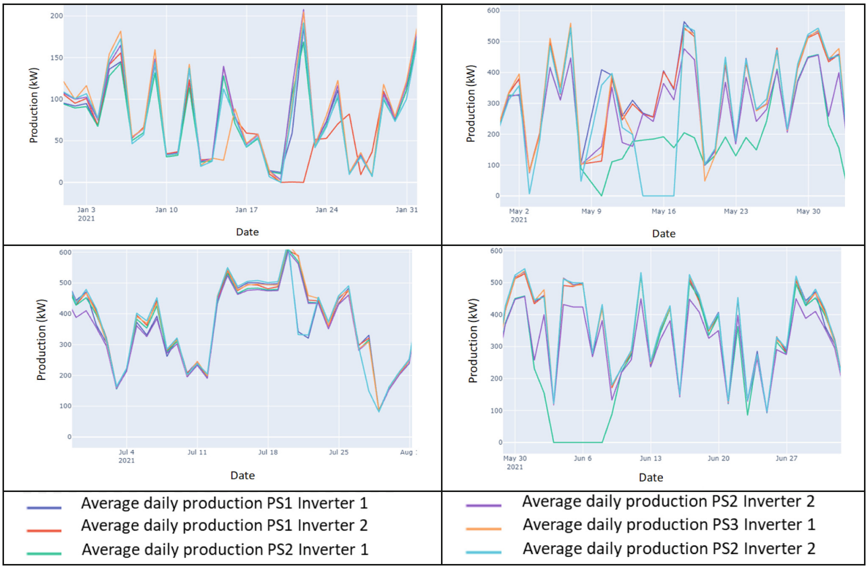


Fig. 2. Production data by month

Table 1. Correlation between production and irradiation

Variables	Radiation PS1	Radiation PS2
Total active power PS1	0.964	0.949
Total active power Ps2	0.611	0.617

4 Conclusions

The maintenance of solar power plants requires analysis of the data collected by Supervisory Control and Data Acquisition System of photovoltaic plants. This paper presents an analysis of the production of a solar plant compared with solar irradiation data in order to detect possible failures in the plant. This is done using advanced statistical analysis involving different tools such as Pearson's correlation coefficient. This analysis identifies different dates of production drops that cannot be explained by irradiance changes and could indicate a possible failure. The results indicate that it is possible to detect issues in data acquisition and identify specific periods where the reduction of production is not associated to lower irradiation.

Acknowledgments. The work reported herewith has been financially supported by the Spanish Ministerio de Economía y Competitividad, under the Research Grant (RTC2019-007364-3.).

References

1. Márquez, F.P.G., Karyotakis, A., Papaelias, M.: Renewable energies: Business Outlook 2050. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-45364-4
2. Dey, B., García Márquez, F.P., Basak, S.K.: Smart energy management of residential microgrid system by a novel hybrid mgwoscacsa algorithm. Energies **13**(13), 3500–3518 (2020)
3. Salam, R.A., et al.: An overview on energy and development of energy integration in major South Asian countries: The building sector. Energies **13**(21), 5776 (2020)
4. Branker, K., Pathak, M., Pearce, J.M.: A review of solar photovoltaic levelized cost of electricity. Renew. Sustain. Energy Rev. **15**(9), 4470–4482 (2011)
5. Rezazadeh, S., et al.: Photovoltaic array reconfiguration under partial shading conditions for maximum power extraction via knight's tour technique. J. Ambient Intell. Hum. Comput. 1–23 (2022)
6. Köntges, M., et al.: Review of failures of photovoltaic modules (2014)
7. Gómez Muñoz, C.Q., García Marquez, F.P., Liang, C., Maria, K., Abbas, M., Mayorkinos, P.: A new condition monitoring approach for maintenance management in concentrate solar plants. In: Xu, J., Nickel, S., Machado, V.C., Hajiyev, A. (eds.) Proceedings of the ninth international conference on management science and engineering management. AISC, vol. 362, pp. 999–1008. Springer, Heidelberg (2015). https://doi.org/10.1007/978-3-662-47241-5_84
8. Zorrilla-Casanova, J., et al. Analysis of dust losses in photovoltaic modules. In: World Renewable Energy Congress-Sweden; 8–13 May; 2011; LinkÃ¶ ping; Sweden. 2011. Linköping University Electronic Press
9. García Márquez, F.P., Peinado Gonzalo, A.: A comprehensive review of artificial ıntelligence and wind energy. Arch. Comput. Methods Eng. pp. 1–24 (2021)
10. Segovia Ramírez, I., Pliego Marugán, A., García Márquez, F.P.: A novel approach to optimize the positioning and measurement parameters in photovoltaic aerial inspections. Renew. Energy **187,** 371–389 (2022)
11. Segovia Ramirez, I., Das, B., Garcia Marquez, F.P.: Fault detection and diagnosis in photovoltaic panels by radiometric sensors embedded in unmanned aerial vehicles. Prog. Photovolt. Res. Appl. **30**(3), 240–256 (2022)
12. Márquez, F.P.G., Ramírez, I.S.: Condition monitoring system for solar power plants with radiometric and thermographic sensors embedded in unmanned aerial vehicles. Measurement **139**, 152–162 (2019)
13. Gonzalo, A.P., Marugán, A.P., Márquez, F.P.G.: Survey of maintenance management for photovoltaic power systems. Renew. Sustain. Energy Rev. **134**, 110347 (2020)
14. Nagadurga, T., et al.: Enhancing global maximum power point of solar photovoltaic strings under partial shading conditions using chimp optimization algorithm. Energies **14**(14), 4086 (2021)
15. Benesty, J., et al.: Pearson's correlation coefficient. In: Kirch, W. (ed.) Encyclopedia of Public Health, pp. 1–4. Springer, Dordrecht (2009). https://doi.org/10.1007/978-1-4020-5614-7_2569

IoT as an Enabler of Emergent Manufacturing-as-Service Business Model in the Precision Electronics Components Industry: The Exploratory Case Study of Two European Companies

Juan Antonio Torrecilla-García(✉), Ma Carmen del Pardo-Ferreira, Agnieszka Grazyna Skotnicka, Virginia Herrera-Pérez, and J. C. Rubio-Romero

School of Industrial Engineering, University of Malaga, 29071 Malaga, Spain
{juantorrecilla,carmenpf,askotnicka,juro}@uma.es,
virginia.herrera.p@gmail.com

Abstract. Manufacturing-as-a-Service (MaaS) is an increasingly propagated paradigm that aligns the internal processes optimization with the new business models opportunities when some features comprised. In present paper the Internet of Things (IoT) enabling role for new business opportunities on the MaaS basis is analyzed. The engineering literature exposes the field with significant possibilities for additional business lines with the MaaS as a core competence. However, the empirical evidence is still scares. Two exploratory case studies of high precision electronics manufacturing companies are described. IoT enables the specifics benefits from elastic manufacturing capacity creating gains for both MaaS -based organizations and their factories. Complementary services and assessment procedures can emerge from the potentialities of IoT when MaaS considered.

Keywords: IoT · Servitization · Business model innovation · MaaS · Case study

1 Introduction

The evolution of manufacturing systems towards the digitalization and automatization of manufacturing processes is closely aligned with the broad integration of IoT infrastructures and procedures across production systems. This phenomenon takes place in all types of manufacturing companies, across almost all industries and branches [1]. However, some of industries are more prone to rapid changes due to the changes in related technologies.

The high precision components manufacturing is one of the branches with certain dependance to technology trends and business model evolution to be able to gain competitive advantages. The high precision components, commonly electronics based, also takes the lead in the European markets in the relative growth of digitalization, and emergent business models implementation [2].

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 419–424, 2023.
https://doi.org/10.1007/978-3-031-27915-7_74

The Internet of Things (IoT) becomes a key approach at smart manufacturing, Industry 4.0 and manufacturing processes digitalization. The correct implementation of IoT on the level of processes shapes also new opportunities on the strategic level. Within the manufacturing company IoT can enhance optimization and improvement processes toward both inside and outside. Still, even if IoT is relatively new concept, it is more and more spread within the Industry 4.0 and Smart Manufacturing [3]. But the straight conduct that IoT provides for servitization development is a great opportunity for new business models related to the industrial processes. All within the constraints such as high efficiency requirement, industrial property protection, cybersecurity of digital processes and human-machine interactions.

Even though, servitization is nowadays already a widely known and applied trend adopted within the approach of changing the manufacturing and sale of the physical products to charging customers for the availability of a service or functionality that the product brings forth [4]. This focus applies both digitalization of manufacturing processes and the customization of products, and furthermore to customization of the manufacturing processes according to the clients' needs, making the Manufacturing as a Service (MaaS) paradigm arises.

MaaS surges as an evolutionary step where the traditional structures do not require centralized production facilities and distributed manufacturing enhance use of new manufacturing models and technologies [5, 6]. Subsequently, MaaS helps in the adoption of distributed manufacturing, thereby enabling production on demand and it can ignite servitization and customization processes within the new, more open and flexible business models [7, 8]. However, some authors [9] go beyond this conceptualization and they claim than MaaS to become the Service Manufacturing should comprise two necessary scopes: Process-as-a-Service (PaaS) + Manufacturing Operations-as-a-Service (MOaaS) (also known as a Production-as-a-Service) [3, 9].

Manufacturing-as-a-Service (MaaS) ≡ Service Manufacturing = Process-as-a-Service (PaaS) + Manufacturing Operations-as-a-service (MOaaS)

Within the MOaaS the service-oriented systems of production are opened to the establishment of the manufacturing procedures according to the individual (production) service requests [10]. Through the specific digitalized processes, the integrated concept of MaaS approach usually becomes the platform related business and operation model [11]. Due to this approach the importance of highly digitalized, based on Big Data and IoT systems, become of key importance. On the other hand, [12, 13] have analyzed the nexus between the sharing and circular economy with the MaaS platforms potential, sketching the even more emergent field of business model innovation with manufacturing at the basis. On the other end, MaaS reduces the production downtimes and if the IoT systems based, enables the new forms of clients' acquisition [14, 15]. In that sense, the similarity of IoT systems to integrated MaaS platforms can be observed.

2 Purpose

The purpose of the research is to explore the possibilities for emerging the new business models related to the MaaS platforms with special emphasis on the potential of IoT as a key part of the MaaS. The context of the study can be established as a confluent comparative study on different markets but within the same sector, high precision electronic components. The case studies companies have been chosen purposefully on the basis of first contacts within the European PSS seminars carried out in 2021. Furthermore, the expected outputs of the research are the analysis of IoT dependence when MaaS strategy implementation considered, the outline of business model opportunities for the MaaS scope and establishing the common context to enhance MaaS IoT based platforms for commercialization.

3 Methodology

The study is based on the two cases of manufacturing companies operating within the electronic components at the B2B environment (one Spanish, and one Polish firm). The exploratory case study has been selected as the research method since its characteristics are particularly suited to the purpose of the research included in this work. The multiple cases are analyzed in present research applying the rigor to the initial literature review, data collection through the in-depth semi-structured interviews with the managers responsible for conducting the new business lines within both organizations. The analysis of historical data and the background data collection concerning the sector evolution towards MaaS have been carried out as well.

The interviews with managers were conducted separately in each case company (in Spanish and in Polish, respectively). The selected firms had both strategies of successful implementation of the IoT-based servitization processes or/and deployed MaaS systems. The interviewees have engineering background with several years of experience in manufacturing environment as well as knowledge on IoT, Maas, cloud manufacturing. Open-ended questions were applied to prospective exploratory analysis, with an emphasis on patterns and business model opportunities. The data and text mining were processed manually and with NVivo software.

4 Results

The MaaS strategies implemented by the case companies can be included in preliminary classification of the progression of business model innovation for analyzed organizations. Both companies are related to the high precision electronics components destined for B2B markets.

Both have Industry 4.0 strategies implemented as well as, declare the interest in the new services line establishment alongside the manufactured production. The two companies have high specialization and more than 10 years’ experience on the market.

Company A. A Spanish high precision electronics manufacturing company dealing mainly with automotive and machine clients. Company A acts as a manufacturer of products and as a provider of personalized solutions (automatization processes design and platform installation) as well as operations and usability certification services. The company has implemented proprietary IoT-based system of components production, testing and validation, replacing the mostly human dependent activities. This solution has been based on the availability of resources and manufacturing line flexibility for adjustment and recalibration. It has become possible due to the development of the IoT specific modules, open (at restricted scope) to the costumers and more or less standardized material used within the manufacturing processes of products (components) aimed to other industries. Being recognized as a high-quality manufacturer, the actual and potential customers have embraced with interest the pilot services of MaaS (and in particular, the Manufacturing Operations-as-a-Service).

In the case of Company A, value creation and subsequently, the opportunity of new business model (through the strategy diversification within the same value chain) is provided by robust IoT system open through the B2B platform to deal with personalized scheduling and technical assessment to limited scale manufacturing process of components for determined clients. While this may increase the company's service and assessment business line to a certain extent of economic benefits, the main advantage for capitalizing the downtimes of production system, without complex recalibration due to flexibility of IoT programming and scheduling.

Company B. A Polish manufacturing company specialized in the prototypes manufacturing and additive manufacturing of electronic devices focused on the sensoring and controlling dispositive segment. This company has been the principal provider for highly specialized manufacturers of shielding coatings and for maintenance services firms centered on the reliability of the machinery. The company offers the performance-based contracting for pre-manufacturing phase of machinery or equipment manufacturing. Remote customer support and assessment for molds and prototypes de high precision is highly related to the IoT potential for detect and generate flexible and input-output devices that will provide validation-prediction knowledge for next generation coatings and sensors.

In the case of company B, value creation is based on the improvement of specific devices for clients from exigent and specialized sector in which the molds for final products manufacturing or functional prototypes must be elaborated to be able to certify or to be able to establish standardized production. The intensive use of IoT based analysis of manufacturing of prototypes comprises new opportunities for design and new molds implementation services within the final clients, as well as predictive maintenance of final dispositive based on previous testing and validation cycles (Table 1).

Table 1. Selected features of companies A and B on the BMI, IoT and MaaS scope.

	Company A	Company B
Familiarity with business model innovation within the manufacturing processes	Aware of BMI concept. Wanted to explore how MaaS can be implemented	Moderately familiar with BMI. Wanted to take advantage of processing capacity surplus
IoT operations and processes nexus	IoT implemented all along the production system	IoT implemented partially within the modelling, mold, and prototype validation
Business model Experiments carried out	Various BMI experiments related to different areas of the company	Sole IoT related BMI to undertake MaaS as a new business line
New business opportunity on the IoT basis	Capitalizing the downtimes of production system, without complex recalibration due to flexibility of IoT programming and scheduling	Design and new molds implementation services within the final clients, as well as predictive maintenance of final dispositive based on previous testing and validation cycles
MaaS implementation progress	Implemented for selected clients	Testing and early-stage launch
Project focus	Develop a business model that allows better optimization of materials and processes when spillovers detected	Look for a business model that can create additional revenue streams by using their existing design and prototyping capacity

5 Conclusions

The present paper presents integrative approach to the importance of IoT within the MaaS opportunities for new business models. It also compares two cases of manufacturing companies focused on developing new business models on the MaaS basis.

The IoT systems seems to be the essential feature for converting the MaaS from the additional, almost collateral services or implementation facilities offered to B2B industrial clients, to new business models of servitization of Production or Manufacturing Operations. The cyber platforms and IoT assessment enhance MaaS fulfillment by fostering the more precise and flexible modeling and decision analytics to exploit the implicit design and manufacturing knowledge required by some manufacturing clients. IoT manufacturing tasks libraries facilitate the parametric adjustment of procedures and create the fundaments of any new line of services on production/manufacturing basis. The IoT is also required as an anchoring step for Cloud Manufacturing-as-a-Service (CMaaS) and related new business models. Some manufacturing companies consider this approach as a next step within the digitalization strategy, leading digitalization toward new segments with new offers, on the basis of intensive IoT related internal processes.

The single, pure strategy of manufacturing as usual can no longer be sustained with an increased pressure on resources´ optimization, digitalization and complexity of final products. Companies are forced to change their way of doing business to be able to diversify the business model within the same, even if growing, resources constraints.

For the move from selling products to selling services as one of the popular examples of a ‘circular business model’, also within the manufacturing industry. The business model experimentation based on new uses and application of IoT systems can help companies make the first steps with reduced risk and investment to undertake the transformation towards Manufacturing-as-a-Service. The value creation within the MaaS strategy in case of consolidated industrial company seems to be easily reached. The change is perceived more as an improvement than a radical shift, what can be considered as an advantage within the business model innovation.

References

1. Xu, L.D., Xu, E.L., Li, L.: Industry 4.0: state of the art and future trends. Int. J. Prod. Res. **56**(8), 2941–2962 (2018)
2. Barrett, M., Davidson, E., Prabhu, J., Vargo, S.L.: Service innovation in the digital age. MIS Q. **39**(1), 135–154 (2015)
3. Kusiak, A.: Smart manufacturing. Int. J. Prod. Res. **56**(1–2), 508–517 (2018)
4. Sousa, R., da Silveira, G.J.C.: The relationship between servitization and product customization strategies. Int. J. Oper. Prod. Manag. **39**(3), 454–474 (2019)
5. Vargo, S.L., Maglio, P.P., Akaka, M.A.: On value and value co-creation: a service systems and service logic perspective. Eur. Manag. J. **26**(3), 145–152 (2008)
6. Srai, J.S., et al.: Distributed manufacturing: scope, challenges and opportunities. Int. J. Prod. Res. **54**(23), 6917–6935 (2016)
7. Sarasini, S., Sochor, J., Arby, H.: What characterises a sustainable MaaS business model. In: 1st İnternational Conference on Mobility as a Service (ICOMaaS), Tampere, pp. 28–29 (2017)
8. Cheng, Y., Tao, F., Zhao, D., Zhang, L.: Modeling of manufacturing service supply–demand matching hypernetwork in service-oriented manufacturing systems. Robot. Comput.-Integr. Manuf. **45**, 59–72 (2017)
9. Kusiak, A.: Service manufacturing: Basic concepts and technologies. J. Manuf. Syst. **52**(Part A), 198–204 (2019)
10. van Moergestel, L., Puik, E., Telgen D., Meyer, J.-J.C.: Implementing manufacturing as a service: A pull-driven agent-based manufacturing grid. In: Proceedings of 11th International Conference on ICT Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer, vol. 1356, pp. 172–187 (2015)
11. Helo, P., Hao, Y., Toshev, R., Boldosova, V.: Cloud manufacturing ecosystem analysis and design. Robot Comput Integr Manuf **67**, 102050 (2021)
12. Choi, T.M., Dolgui, A., Ivanov, D., Pesch, E.: OR and analytics for digital, resilient, and sustainable manufacturing 4.0. Ann. Oper. Res. **310**(1), 1–6 (2022)
13. Qian, C., Zhang, Y., Liu, Y., Wang, Z.: A cloud service platform integrating additive and subtractive manufacturing with high resource efficiency. J. Clean. Prod. **241**, 118379 (2019)
14. Bulut, S., Wende, M., Wagner, C., Anderl, R.: Impact of manufacturing-as-a-service: business model adaption for enterprises. Procedia CIRP **104**, 1286–1291 (2021)
15. Chaudhuri, A., Datta, P.P., Fernandes, K.J., Xiong, Y.: Optimal pricing strategies for manufacturing-as-a service platforms to ensure business sustainability. Int. J. Prod. Econ. **234**, 108065 (2021)

Fostering Innovative Industry 4.0 Value Networks

Francisco Javier Martínez-Borreguero(✉) and Isabel García-Gutiérrez

Escuela Politécnica Superior, Área de Ingeniería de Organización, Universidad Carlos III de Madrid, Avenida de La Universidad nº 30, 28911 Leganés, Madrid, Spain
{fjmborre,igarcia}@ing.uc3m.es

Abstract. The unprecedented transformation entailed by Industry 4.0 for the manufacturing, logistics and utilities sectors requires new value generation models among different actors in the technological and production value chains. Industry 4.0 technologies are highly disruptive (Cyber-Physical, Industrial IoT and 5G production systems, Artificial Intelligence, Digitization of operations, etc.) and being developed by organizations focused on technological innovation such as startups. Nevertheless, established organizations pursuing their transformation are anchored to traditional production processes, with high resistance to change and significant inertia. Exploiting the potential of technology in actual production environments requires creating innovative value networks that orchestrate and articulate the process. In this context, we have developed a methodology to assist in the creation of those value networks. The methodology is based on a series of collaboration and co-innovation steps that break and blur organizational barriers to accelerate this transformation.

Keywords: Industry 4.0 · Value networks · Smart manufacturing · Open innovation · Cyber physical production systems · Industrial IoT · Industrial 5G · Augmented reality · Computer vision · Artificial intelligence

1 Introduction

The term Industry 4.0, often associated with the fourth industrial revolution [1] involves the transformation of productive organizations through the adoption and implementation of cyber-physical production systems enabled by information and communication technologies, digitization, and operations. This transformation is even more radical than the cyber transformation based on information and communication technologies, since it also covers the transformation of the physical systems that articulate the extractive, manufacturing, transformation, logistics, etc. processes.

Every industrial revolution is associated with some key technologies that made it possible; the use of water and steam for mechanical propulsion in the First Industrial Revolution, electricity in the second and electronics in the third [2]. Likewise, this Fourth Revolution is supported by highly disruptive technologies that integrate the physical and cyber worlds such as Artificial Intelligence (AI), Industrial IoT, Industrial 5G, Collaborative and Autonomous Robots, Augmented Reality (AR), Computer vision, Digital

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 425–429, 2023.
https://doi.org/10.1007/978-3-031-27915-7_75

twin, Blockchain, etc. However, none of these technologies, nor especially their combinations are available Off the Shelve to be applied to productive processes and to obtain the potential they can offer [3]. These technologies still offer a high level of uncertainty in their uses, in their technical development and in their application to the market.

This "traditional" model of technological development is not meeting the transformational needs suggested by the institutional actors of Industry 4.0 (i.e., Platform Industrie 4.0 in Germany, European Commission across Europe, Industrial International Consortium in the US, Industrial Value Chain Initiative in Japan, etc.), neither in terms of its scope nor in terms of time [4]. Some reasons for this misalignment between vision and reality regarding the Fourth Industrial Revolution can be found in the fact that the Startup - Integrator - Adopter model is slow and more adapted to incremental innovations than to disruptive ones. The recipients of the transformation (i.e., the productive players) cannot assume risks so easily due to the physical nature of these changes, the high level of integration and the intensive SME structure [5]. The role of system integrators and communication service providers is traditionally more suitable for working in value chains with clear and predetermined roles (i.e., innovation agents vs. integration agents vs. exploitation agents). Startups do not easily find the way to collaborate with the rest of the actors to apply and validate the technology and the differences in priorities and vision in the short, medium, and long term hinder the development of joint work [6].

2 Objectives

The work we present seeks to reduce the gap between the value potential offered by the enabling technologies of Industry 4.0 and the actual generation of value in the production chains. Specifically, the research objectives are the following:

i) Facilitate the creation of value networks that can accelerate the transformation brought by Industry 4.0 in the production, manufacturing, and logistics sectors, through new models of collaboration between the different actors.
ii) Develop a methodology (a process that provides tangible elements to foster ideation and exploitation) to create new value networks and specific models of collaboration between the existing and new players in the Industry 4.0.
iii) Apply the methodology to specific technologies of Industry 4.0 in which we are working in our professional field in a company and in our academic field at the university (e.g. Augmented Reality, Computer Vision and AI, 5G and IIoT) and validate it through continuous work with stakeholders who promote, develop and exploit these technologies (e.g. Industry 4.0 startups, communications service providers, OT/IT systems integrators, ports authorities and freight carriers, automotive makers and parts providers.)

3 Methods

The methodology we use is based on Design Science Research (DSR) that aims to design artifacts that are useful for a given objective or problem [7]. The interest in this type of methodologies, well established in the field of Information Systems [8], is recently extending to other fields such as Service & Innovation Design [9] or Business Management [10]. To apply the methodology, we have worked on several iterative Build and Evaluate cycles of prescriptive artifacts [11] to propose a process or methodology that can be used for the creation of innovative value networks based on Industry 4.0 enabling technologies.

We have applied the methodology iteratively by developing an initial prototype, (based on our previous experience and evaluation cycles), evaluating this prototype in real instances of the problem we want to solve, and incorporating the scientific knowledge that allows the generalization and replicability of the prototype (artifact-process). The construction phases are articulated through cycles of bibliographic review around the problem to be solved.

We have developed the evaluation phases in the context of Industry 4.0 new business development of a Communications Service Provider with the ambition of occupying a relevant role in the industrial value chain, in which we have access to dozens of startups, customers, etc.

4 Results

As a result of the iterative cycles described above, we have built a new methodology that we have called "Industry 4.0 Value Networks: Discovery & Build Methodology". For the purpose of this abstract, we summarize this methodology in Fig. 1.

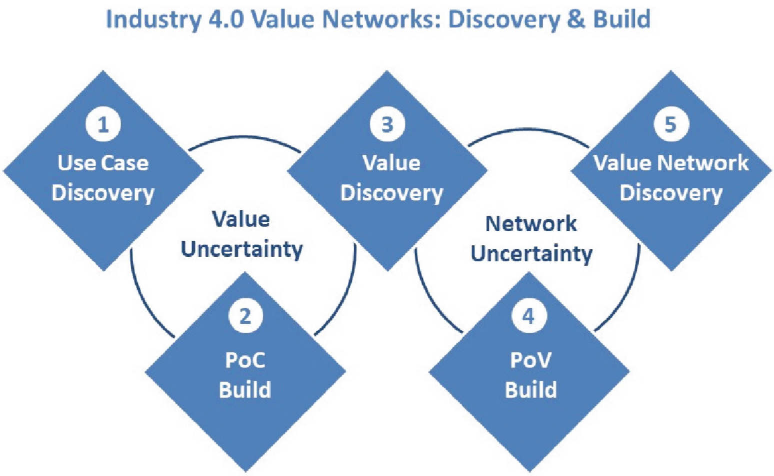


Fig. 1. Industry 4.0 Value Networks: Discovery & Build Methodology.

1) **Use Case Discovery:** The first step of the methodology consists of proposing ways to solve a specific problem through the potential offered by one or more of the core technologies of Industry 4.0 (i.e., Use Case). The result of this stage will be a list of use cases with generic potential (without considering possible implementation

or business limitations) to improve existing problems. For the implementation of Industry 4.0 applications through use cases, we have identified more than 30 use cases that combine 5G, AI, IIoT, OT, AR, etc. technologies.

2) **Proof of Concept Build:** This includes the selection and prioritization of use cases to develop pilots to validate their utility to solve specific problems in a real industrial environment. Each pilot is carried out by identifying one or several startups specialized in the technology and through a co-innovation model with the relevant organization in the production process. This process of building pilots is used to obtain specific insights on the technical uncertainties that will feed the next stage. As a concrete example of the work in the evaluation cycles, we highlight the pilots focused on the exploitation of Augmented Reality technologies combined with 5G for remote support applications in practice or expert guidance.
3) **Value Discovery:** In this phase, we work on identifying the sources of value, understood as those elements of the PoC that offer better performance compared to previous ways of solving the problem posed in the use case. To this end, we work with the different actors involved in the PoC built to evaluate the value delivered and received by each of them and to identify other actors with the potential to deliver or receive value from the actual experience during the Proof of Concept (PoC). A relevant example of the exploitation cycles involved the identification of stakeholders and the associated value of an advanced combination of Artificial Intelligence and precision positioning technologies to improve safety in logistics environments.
4) **Proof of Value Build:** Once the relevant actors and value elements have been identified, we need to implement specific and tentative articulations of the value ecosystem to work on ways to reduce its uncertainty for the industrialization of the most promising use cases. The result will be tangible ways to reduce ecosystem uncertainties by identifying value streams that work or need to be improved and proposing pathways for net value creation. In the case of the Augmented Reality use case, we work on the need to simplify devices to combine information from the environment and context to match the value generated and the technologies available.
5) **Value Network Discovery:** In this last stage of the cycle, we work on devising valid itineraries of value flows to provide solid networks of net value creation. The elements of technical and ecosystem uncertainty management obtained in the previous stages are used to refine and adjust the value network. As a result, we obtain configurations of stakeholders and value transfer derived from the application of Industry 4.0 technologies used as input to the process. In the evaluation cycles we came to propose value networks for the robotization of industrial environments by exploiting 5G and industrial IoT technologies.

The proposed methodology has proven to be an effective approach in the specific application cases used for testing and validation in the DSR validation cycles undertaken and therefore, we believe it can be applicable in a wide variety of intervention situations.

5 Conclusions

In order to unleash the potential of the technologies that must enable the Fourth Industrial Revolution, it is essential to establish value networks between the actors involved (technology specialists, production and logistics network specialists, industrialization specialists, institutional actors, etc.). We propose a methodology for the discovery and construction of such networks based on iterative cycles of ideation, instantiation, and generalization of the generation of value and the configuration of the networks.

The application and validation of our methodology has involved several interactions with Industry 4.0 technologies and stakeholders at the level of specific production processes. These interactions have revealed that a deliberated and systematic procedure of value assessment is a key element of the methodology, that enables the scalation and consolidation of the innovative developments as monetizable solutions.

Acknowledgement. This work has been supported by the Madrid Government (Comunidad de Madrid-Spain) under the Multiannual Agreement with UC3M in the line of Excellence of University Professors (EPUC3M20), and in the context of the V PRICIT (Regional Programme of Research and Technological Innovation).

References

1. Liao, Y., Deschamps, F., Loures, E.R., Ramos, L.F.P.: Past, present and future of Industry 4.0 - a systematic literature review and research agenda proposal. Int. J. Prod. Res. **55**, 3609–3629 (2017)
2. Xu, X., Lu, Y., Vogel-Heuser, B., Wang, L.: Industry 4.0 and Industry 5.0—Inception, conception and perception. J. Manuf. Syst. **61**, 530–535 (2021)
3. Ghobakhloo, M.: Industry 4.0, digitization, and opportunities for sustainability. J. Clean. Prod. **252** (2020)
4. Oztemel, E., Gursev, S.: Literature review of Industry 4.0 and related technologies. J. Intell. Manuf. **31**(1), 127–182 (2018). https://doi.org/10.1007/s10845-018-1433-8
5. Ghobakhloo, M., Ching, N.T.: Adoption of digital technologies of smart manufacturing in SMEs. J. Indust. Inf. Integr. **16** (2019)
6. Rocha, C.F., Mamédio, D.F., Quandt, C.O.: Startups and the innovation ecosystem in Industry 4.0. Technol. Anal. Strat. Manag. **31**, 1474–1487 (2019)
7. March, S.T., Smith, G.F.: Design and natural science research on information technology. Decis. Support Syst. **15**, 251–266 (1995)
8. Hevner, A.R., March, S.T., Park, J., Ram, S.: Design science in information systems research. MIS Q. **28**, 77–105 (2004)
9. Teixeira, J.G., Patrício, L., Tuunanen, T.: Advancing service design research with design science research. J. Serv. Manag. **30**, 577–592 (2019)
10. Dresch, A., Daniel, ·, Lacerda, P., Antônio, J., Antunes, V.: Design science research. In: A Method for Science and Technology Advancement, Springer Cham (2015). https://doi.org/10.1007/978-3-319-07374-3
11. Peffers, K., Tuunanen, T., Rothenberger, M.A., Chatterjee, S.: A design science research methodology for information systems research. J. Manag. Inf. Syst. **24**, 45–77 (2007)

Helping Students Without Professional Experience to Understand the Product-Process Matrix

Manuel Cardós Carboneras and Pascual Cortés-Pellicer(✉)

Department of Business Management, Universitat Politècnica de València, 46022 València, Spain
mcardos@doe.upv.es, pascorpe@omp.upv.es

Abstract. The different types of production are classified, according to the product-process matrix in a job shop, flow shop/batch and line flow. In this regard, it is essential that engineering degree students in industrial organization know and understand the characteristics of each of the different alternatives. However, given the lack of knowledge and, above all, previous professional experience in the field of operations management presented by degree students, it is necessary to develop learning activities that previously provide all students with adequate foundations of basic knowledge. In this work, a basic example to explain the different process types, according to the process flow and to understand its most important characteristics is provided.

Keywords: Product-process matrix · Operations management · Product life cycles · Learning activities

1 Introduction

Process selection is one of the main decisions that operations managers must consider about production processes [1]. This decision is focused on establishing the necessary resources to implement the organization's strategy around the product. In this sense, the classification of the processes according to the process flow is as follows [2]: Fixed position, intermittent workshop (job shop), batch workshop (flow shop) and line flow. For fixed position only, there is no flow of products, but a flow of resources around a fixed product. The other three options constitute the possible general configurations of the production systems. Likewise, these three configurations constitute the main stages of the process life cycle [3], serving as the basis for the process evolution matrix (product-process matrix). Knowing the different process types is very important in industrial organization engineering studies. For this reason, it is essential to be able to explain to students the characteristics and differences of each of the possible configurations or states of the processes. However, it is not always easy to understand neither the main characteristics of this type of production process, nor the relationship of the parameters of each of them, especially in students who have never had industrial experience, as is usually the case in most degrees. Therefore, teachers should take into account students' lack of

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 430–435, 2023.
https://doi.org/10.1007/978-3-031-27915-7_76

prior knowledge and experience as a starting point for the design of learning activities [4]. In this line, so that the students of the degree in industrial organization engineering (or similar) without any previous experience in production processes can successfully pass the learning activities, especially problem solving, teachers must provide learning activities on operations management concepts, so that the same level of knowledge is provided to all students [4]. To bridge this gap, this paper offers a basic learning activity with a triple objective: firstly, to show the evolution of the same process between different types of configurations, according to the diagonal of the product-process matrix. Secondly, study how the changes made in the production process become improvements in the performance of the system. Finally, analyze how the main system parameters evolve according to the throughput variation (jobs/h). The paper is organized as follows: Sect. 2 provides the background about production types according to the process flow and Sect. 3 presents an activity learning proposal. Finally, some conclusions are shown in Sect. 4.

2 Background

Just as a product goes through a number of important stages throughout its existence, so does the production process used in making that product. In this respect, Wheelwright and Hayes [3] introduced the concepts of process and product life cycle, thus facilitating the understanding of the strategic options available to a company, with respect to its manufacturing function. According to Wheelwright and Hayes [3], the evolution of the production process begins with a fluid and very flexible process, although not very profitable. Subsequently, further standardization, mechanization, and automation are advanced, ultimately culminating in a process that is much more efficient but much more capital intensive and, therefore, less flexible than the original process. In this sense, as the process evolves, flexibility is reduced to gain costs [5]. Through the product-process matrix of Wheelwright and Hayes [3], the interaction between the stages of the life cycle of the product and the process is represented (Fig. 1).

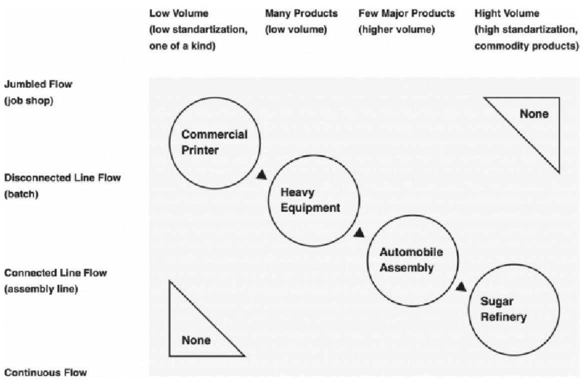


Fig. 1. The product-process matrix (Source: Wheelwright and Hayes [3])

The product-process matrix is used to illustrate the correspondence between capacity strategies and planning strategies, so that the producing companies are generally along the diagonal. This matrix has a great importance for the industrial strategy and the sense of selection of processes. In addition, in the usual manuals [6–8] there is only a description of the matrix, but not a clear justification when there is no industrial experience.

3 Activity Learning Proposal

This section proposes the evolution of the same example between the three possible states to study. It is analyzed the evolution of the Cycle Time (CT) and the Work In Process (WIP) depending on the variation in Throughput (TH). Firstly, the main stochastic production parameters used in this context are defined, according to [9]:

- **Cycle Time (CT):** The cycle time of a given routing is the average time from release of a job at the beginning of the routing until it reaches an inventory point at the end of the routing.
- **Work in Process (WIP):** The inventory between the start and end points of a product routing.
- **Throughput (TH):** The average output of a production process per unit time is defined as the system's throughput, or sometimes throughput rate.

Next, the case is presented as a job shop, later a series of changes are applied to transform it into flow shop/batch and finally a line flow is presented.

3.1 Job Shop

A certain commercial printer is prepared to carry out a large number of different processes related to printing on garments made according to the requirements of their customers. In particular, printing on T-shirts has been in growing demand in recent years. This process is prepared to ellaborate the jobs requested by the customers with a TH = 0.86 jobs/h, taking an average of 61.39 CT hours and having 52.79 WIP jobs in the manufacturing plant. This manufacturing time contrasts with the machine process time, which is just 2.51 h, which represents 4% of the time it remains in the plant, manufacturing time or cycle time. The lowest manufacturing capacity corresponds to machine 1, so it is the bottleneck. The bottleneck capacity is greater than the rate of arrival of new orders (or TH), therefore it is a stationary system and all the demand can be processed. As expected, CT and WIP grow indefinitely when the rate of new job arrivals approaches the capacity of the bottleneck. In our case, 80% of the maximum capacity is $0.8 \times 0.909 = 0.72$ jobs/h and it is observed that, although the CT begins to grow earlier, from this workload the CT grows significantly. Moreover, from $0.95 \times 0.909 = 0.86$ jobs/h, the growth of CT and WIP makes the management of this installation increasingly difficult. Consequently, the maximum capacity that can be achieved in practice is 0.86 jobs/h, or what is the same, 5% less than the capacity of the bottleneck.

3.2 Flow Shop/Batch

The commercial printer has come to the conclusion that this product is essential for its growth strategy, but it is necessary to ensure shorter terms of service to customers. To achieve this, the Sales Department has standardized the different types of printing and finishing of the t-shirts, reducing the variability of orders by half, 10% of the bottleneck process time and 20% of its variability. Under these new conditions, the CT has been reduced by 61.39–24.65 = 36.74 h, which means that it is now less than half that before. Analogously it happens with the WIP. These changes not only contribute to the company's service strategy but also improve costs and financing needs. The new manufacturing capacity is $0.95 \times 1.01 = 0.96$ jobs/h, which means CT = 57.25 h, similar to what we had before. However, now the manufacturing capacity has grown (0.96–0.86)/0.86 = 11.6%, which means a reduction in manufacturing costs and the possibility of growing 11% in manufacturing and sale of this product without the need for additional investment.

3.3 Line Flow

The manager of the commercial printer, encouraged by the improvements obtained previously and given the good reception of the market, wishes to analyze the possibilities of manufacturing growth. For this, the Director of Production proposes improvements to eliminate the need for internal transport between machines by relocating machine 2 to the output of machine 1. In addition, the variability of orders is reduced to 0.70, the processing time of the bottleneck is reduced in 10% and its variability by 20%, as well as the processing time of machine 2 is reduced by 10%. These new conditions offer a CT = 13.35 h, which represents a reduction in service time of 76% compared to the previous configuration. Moreover, thanks to the new changes proposed, the performance of the installation can be further improved, since the new manufacturing capacity is $0.95 \times 1.122 = 1.07$ jobs/h, which means CT = 31.17 h, similar to previous stage. However, now the manufacturing capacity has grown (1.07–0.96)/0.96 = 11.5%, which represents a reduction in manufacturing costs and the possibility of growing 11% in this product without the need for additional investment.

3.4 Results

As a summary of the consequences of modifying the throughput configuration in this company, the following table (Table 1) presents the CT value for the maximum capacities estimated in each case:

The following graph (Fig. 2) shows the variation of CT (Y-axis) as a function of the variation of TH (X-axis). As expected, CT grows indefinitely when TH approaches the bottleneck capacity. The CT representation obtained in the three previous configurations indicates that progressively each configuration is able to keep under control and reduced CT for increasing values of the TH.

Table 1. CT value for maximum capacities in each configuration

TH	CT (h)		
	Job shop	Flow shop/batch	Line flow
0.86 jobs/h	61.39	24.65	8.40
0.96 jobs/h	–	57.25	13.35
1.07 jobs/h	–	–	36.25

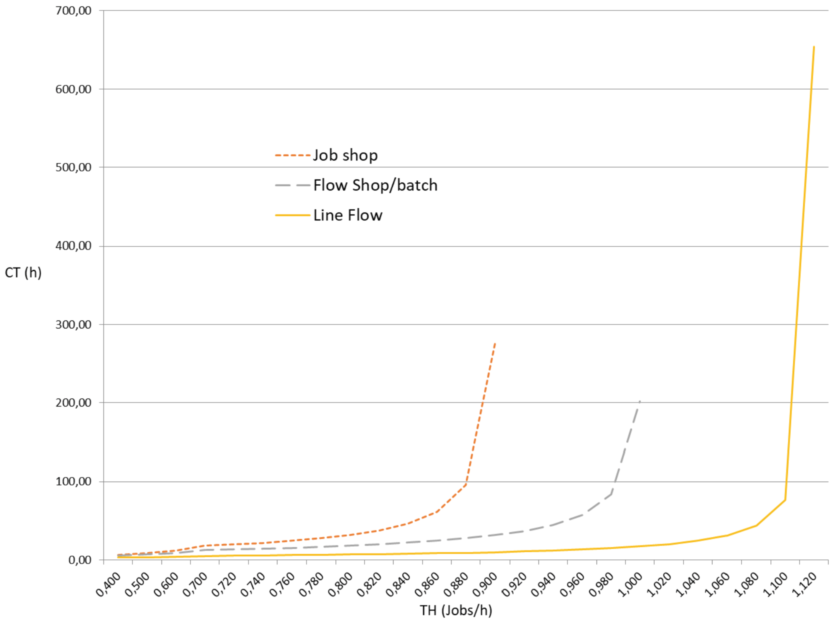


Fig. 2. Evolution of CT obtained in the three previous configurations

4 Conclusions

In this paper, a practical example of the same production process that has been evolving between the different types of process, according to the flow strategy, has been presented. In this respect, the evolution of the three principal types of processes have been shown. In addition, the changes proposed in each production model have been reflected in the main performance measurement parameters. The analysis of the evolution of these parameters, based on the evolution of the rate of Throughput also allows us to observe the laws of use, observing how the Work In Process and the Cycle Time grow non-linearly according to how the use of the system increases. This basic learning activity allows students who do not have previous knowledge of this field to provide a series of basic knowledge about operations management. In addition, this basic activity facilitates the understanding of basic parameters of stochastic production.

References

1. Carro Paz, R., Gómez, D.G.: Diseño y Selección de Procesos. Adm. las Operaciones **7,** Procesos, p. 23 (2013)
2. Hayes, S., Wheelwright, R.H.: The dynamics of product-process life cycles Harv. Bus. Rev. (1979)
3. Wheelwright, S.C. Hayes, R.H.: Link manufacturing process and product life cycles. Harv. Bus. Rev., January, 133–140 (1979)
4. Solaz-Portolés, J.J., López, V.S.: Conocimiento previo, modelos mentales y resolución de problemas. Un estudio con alumnos de bachillerato. Rev. Electron. Investig. Educ. **10**(1), 1–16 (2008)
5. Olhager, J., Rudberg, M., Wikner, J.: Long-term capacity management: linking the perspectives from manufacturing strategy and sales and operations planning. Int. J. Prod. Econ. **69**(2), 215–225 (2001)
6. Chase, F.R., Aquilano, R.B., Jacobs, N.J.: Production and Operations Management, 8th edn. Irwin McGraw-Hill (1998)
7. Nahmias, S., Olsen, T.: Production and Operations Analysis: Strategy, Quality, Analytics, Application, 7th edn. Waveland Press Inc., Long Grove (2015)
8. Fogarty, T. R., Blackstone, D.W., Hoffmann, J.H.: Production & İnventory Management, 2nd edn (1991)
9. Spearman, W.H.M.: Factory Physics, 3rd edn. Waveland Press, Inc., Long Grove (2008)

Exploring a New Oral Presentation Approach for Online Education Through Action Research

Karen Reina Sánchez(✉), Juan Pedro Arbáizar Gómez, Luis Isasi Sánchez, and Alfonso Durán-Heras

Dpto. de Ingeniería Mecánica, Escuela Politécnica Superior, Universidad Carlos III de Madrid, Avda. Universidad 30, 28911 Leganés, Madrid, Spain
{kreina,jarbaiza,lisasi,duran}@ing.uc3m.es

Abstract. In recent years, researchers have been writing about the importance of innovating in the classroom. They also referred that innovation becomes a necessity when we move from the face-to-face to the online environment. That is the case of the teamwork presentations, habitual and essential activities in the training of future professionals. In this article, we provide a comparative analysis of the results obtained in three iterations of action research about a new way to run team presentations in a Supply Chain Management online course. Findings suggest that this approach to online presentation can greatly improve learning and motivation, as students are required to get involved in the research of the topic and delivering an oral presentation. All of which enhances the development of a more integrative learning experience.

Keywords: Oral presentations · Teamwork presentation · Online education · Action research · Higher education · Soft skills

1 Introduction

Digital transformation in higher education is an inevitable process, which has been reinforced after the COVID-19 pandemic. This study is the result, on the one hand of the systematic search for methodologies to increase the effectiveness of synchronous online teaching, and on the other, of the transformation/adaptation of activities from face-to-face to online environment.

Presentations play a fundamental role in the acquisition of knowledge by students and for this reason, they are used as an assessment method in all disciplines. This research originates from the identification of bad practices in the realization of oral presentations in workgroups. Students show a lack of a comprehensive understanding of the work, hence the main objective of the activity is not achieved. In addition, due to time constraints and the number of students, interventions are often short, making individual assessments difficult for instructors.

In the first iteration of this research, two questions are raised: how to get students to carry out comprehensive learning of work? and how to maximize individual exposure time while taking advantage of the virtual environment?

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 436–441, 2023.
https://doi.org/10.1007/978-3-031-27915-7_77

Authors explore a new format for oral presentations of group work. It consists of presenting the work in small groups. Each team develops the assigned topic as in a traditional presentation, but instead of being presented in front of the entire class, the presentation is made in a subgroup. The class is divided, and one or two members of each team are assigned to a subgroup. In this way, all the members of the speaking teams must be prepared to present the complete work.

After this introduction and the Literature review, the action research methodology chosen will be presented and justified, highlighting the participants and context and the design details. The research findings are then described and discussed, leading to the conclusions section.

2 Literature Reviews

A systematic review of the literature on the use of oral presentations in higher education was conducted. Several studies have been focused on different aspects related to the presentation performance and assessing it [1]; other studies were more focused on the design of principles [2, 3], or self and peer assessment of oral presentation skills [4, 5]. Furthermore, other authors concentrated their research more on the role that feedback plays in improving those presentation skills [6, 7].

De Grez & Valcke, [8] define oral presentation competence as the combination of knowledge, skills, and attitudes needed to speak in public in order to inform, to persuade, and relate. McDougall & Holden, [9] however, include the preparation of the presentation as part of the oral presentation skills.

Presentation of teamwork has been used as a complement in the evaluation of various disciplines [10], including engineering [1] and management. To acquire this competence, students must go through a preparation phase, which ranges from the research and review of materials to the preparation of the means of the presentation [11].

3 Methodology

This research has been carried out in an online Supply Chain Management (SCM) course taught in an engineering degree. As in any action research (AR), applied in educational environments, the teachers involved played the double role of teacher-researcher, hence collecting all the information generated from the application of the new format while they carried out the activity.

The action research process is based on the principle of systematic research based on continuous reflection [12]. Figure 1 shows in a summarized and schematic way the series of steps followed by the researchers in which they reflect, plan, act and evaluate.

In the second and third iterations, the aspects that give rise to the research continue to be analyzed, trying to collect more information that allows reaching solid conclusions about the new format. During this process, new questions and possibilities for improvement arise.

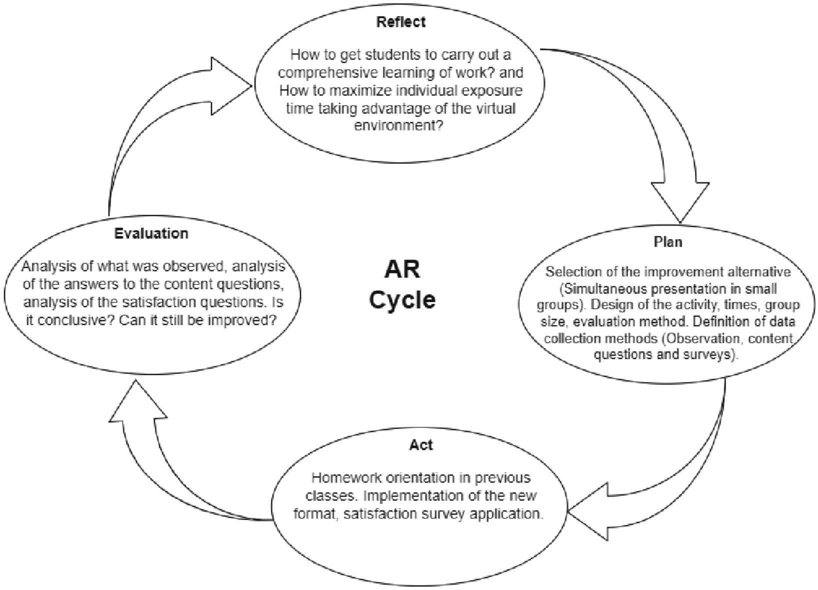


Fig. 1. Action Research cycle (Source: own elaboration based on [12, 13])

3.1 Design and Procedure

SCM is an elective subject offered to students in the third and fourth year of an Industrial Technologies engineering degree. The average enrollment in this subject is 25 students. The new format was implemented for two consecutive years in two types of activities: 15-min mini-presentations (MP) in classes and coursework presentations (FP). It is important to highlight the fact that the course in which this action research is carried out is not an oral presentation course. The oral presentations in the SCM subject are a complement in the training of soft skills of engineering degrees.

At the beginning of the course, students are asked to divide into teams to perform volunteer activities. These activities are not qualified for continuous evaluation but are qualified for extra evaluation. In previous sessions, teacher assigns research tasks to volunteer teams and explains how the activity will be carried out. Work teams are informed that on the day of the presentation they will be randomly divided into subgroups and will be informed in what order they will present. Similarly, it happens for coursework's.

Five content questions were elaborated by the teachers to check if the basic knowledge had been acquired in all the groups. They were based on main ideas about the topics to be developed and on student presentations of the subject in previous courses. Another six questions were set to assess the degree of satisfaction of the students with the new format, four of which were addressed only to the speakers. A Likert scale from 1 to 5 was used, where 1 corresponds to "totally disagree" and 5 to "totally agree". At the end of the presentations, the students were asked to answer the content questions first and then the satisfaction questions.

4 Findings and Discussion

In the answers to the content questions, no significant differences were observed neither between speakers and listeners, nor between the students of the subgroups. The main impact of the format change falls on the presenters, for this reason the study has focused more on their perception. The approach is based on the fact that for the speakers the new format implies greater dedication in the preparation of the activity, and longer presentation time.

To have an overview of the answers to the satisfaction questions, a summary table was made with the speakers of the three iterations (Table 1).

Table 1. Summary table of speakers' perception.

	Low (%)	Neutral (%)	High (%)	Mean	SD
Involvement of team members increases (S1)	2,8	17,1	80	4,2	0,8
Development of oral presentation skills increases (S2)	8,8	23,5	67,6	3,8	0,9
More time spent on preparation means improvement in learning (S3)	5,7	8,6	85,7	3,9	0,66
Longer presentation time improves experience (S4)	5,6	22,2	72,2	3,8	0,75
Preference for the new format (S5)	5,7	34,3	60	3,7	0,77
Always use the new format (S6)	14,3	28,8	57,1	3,5	0,85

A global analysis of the answers provided by the students of the three iterations was carried out. There seems to be a consensus among the participants that the new format favors the involvement of team members in the accomplishment of the task. Likewise, they seem to agree that having to spend more time preparing for the presentation improves the learning of the research topic. Less consensus is observed in the preference of the new format over the traditional format. Only 60% of the participants gave 4–5 score to the S5 question. In addition, the percentage of students who expressed indifference in this question is high (34%). A possible explanation for this result is that they have to devote more time to preparing the presentation. This could be the reason why they are conservative when it comes to selecting whether the new format should prevail over the tradditional format. Another possible reason is the novelty of this type of activity.

After a global analysis, speakers' data have been segmented per iteration in order to be compared (Fig. 2).

Answers to questions 1 to 4 are quite similar or have improved when compared recent data (2022) with last year's results. However, answers to questions 5 and 6 show a contradictory opinion in the reporters of the third iteration (P2022). While most people (80%) declared that they would change to the new format, only 10% prefer it.

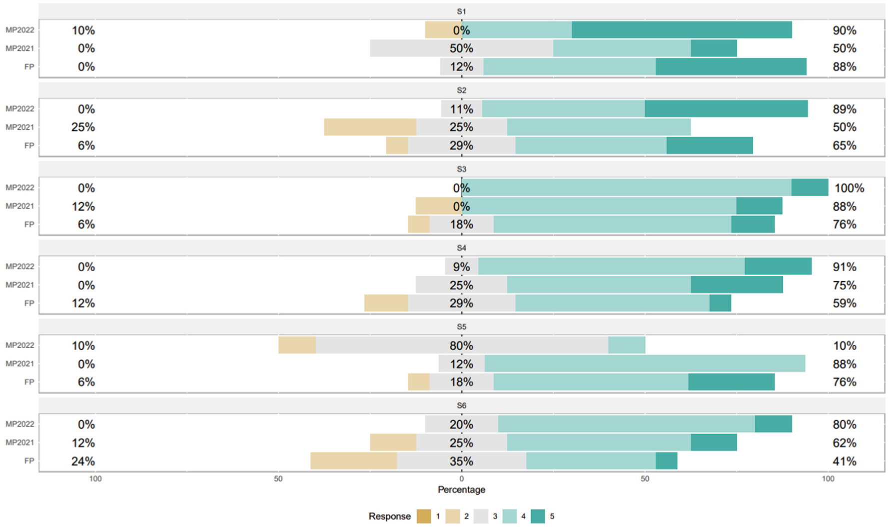


Fig. 2. Graph of presenters' perception of the three iterations (Source: own elaboration)

5 Conclusion

An alternative approach to develop and present team-works using digital platforms is being carried out through Action Research. In this current research phase, researchers are trying to confirm how students perceive changes focused on improving their learning about the topic they have been assigned. It is highly accepted that the new approach improves the involvement in all team members, presentation experience and a more comprehensive learning of the topic assigned. Oral presentation skills also improved even though it was not a key target of this research phase. However, it seems that students also noted that good research and extensive learning require effort on their part, but they do not seem to understand whether the effort is worth it. These results cannot be generalized yet due to the fact that the sample may still be short and biased by subject environment (such as last year´s course and optional subject, among others). Moreover, some aspects of the most appropriate way to evaluate this activity and the impact on the instructor's workload are still being studied. This new approach to oral presentations on digital platforms is clearly feasible and highly recommended by teachers to guarantee a better outcomes in students' learning experience, but there are still many doubts and adjustments that must be answered and solved in next action research iterations.

References

1. Galván-Sánchez, I., Verano-Tacoronte, D., González-Betancor, S.M., Fernández-Monroy, M., Bolívar-Cruz, A.: Assessing oral presentation skills in electrical engineering: developing a valid and reliable rubric. SAGE **54**(1), 17–34 (2016). https://doi.org/10.1177/0020720916659501
2. Lee, S.S.: Design principles of a responsive pedagogical model for multimodal skills of oral presentation. Malaysian J. ELT Res. **18**(1), 36–51 (2021). https://doi.org/10.52696/UQBF6793
3. van Ginkel, S., Gulikers, J., Biemans, H., Mulder, M.: Towards a set of design principles for developing oral presentation competence: a synthesis of research in higher education. Educ. Res. Rev. **14**, 62–80 (2015). https://doi.org/10.1016/J.EDUREV.2015.02.002
4. Bolívar-Cruz, A., Verano-Tacoronte, D.: Self-assessment of the oral presentation competence: effects of gender and student's performance. Stud. Educ. Eval. **59**, 94–101 (2018). https://doi.org/10.1016/J.STUEDUC.2018.04.001
5. Suñol, J.J., Arbat, G., Pujol, J., Feliu, L., Fraguell, R.M., Planas-Lladó, A.: Peer and self-assessment applied to oral presentations from a multidisciplinary perspective. Assess. Eval. High. Educ. **41**(4), 622–637 (2016). https://doi.org/10.1080/02602938.2015.1037720
6. Flores, M.A., Veiga Simão, A.M., Barros, A., Pereira, D.: Perceptions of effectiveness, fairness and feedback of assessment methods: a study in higher education," Stud. High. Educ. **40(**9), 1523–1534 (2015). https://doi.org/10.1080/03075079.2014.881348
7. Murillo-Zamorano, L.R., Montanero, M.: Oral presentations in higher education: a comparison of the impact of peer and teacher feedback. Assess. Eval. High. Educ. **43**(1), 138–150 (2018). https://doi.org/10.1080/02602938.2017.1303032
8. De Grez, L., Valcke, M.: Student response system and how to make engineering students learn oral presentation skills. Int. J. Eng. Educ. **29**(4), 940–947 (2013)
9. McDougall, J., Holden, H; The silence about oral presentation skills in distance and online education: new perspectives from an Australian university preparatory programme. Open Learn. J. Open, Dist. e-Learn. **32(**2), 163–176 (2017). https://doi.org/10.1080/02680513.2017.1316187
10. Tsang, A.: Enhancing learners' awareness of oral presentation (delivery) skills in the context of self-regulated learning. Act. Learn. High. Educ. **21**(1), 39–50 (2020). https://doi.org/10.1177/1469787417731214
11. Sugeng, B., Suryani, A.W.: Presentation-based learning and peer evaluation to enhance active learning and self-confidence in the financial management classroom. Malaysian J. Learn. Instr. **15**(1), 173–199 (2018). https://doi.org/10.32890/mjli2018.15.1.7
12. Hendricks, C.: Improving Schools Through Action Research: A Reflective Practice Approach. Pearson (2017)
13. Susman, G.I., Evered, R.D.: An assessment of the scientific merits of action research. Admin. Sci. Q. **23***,* 582–603 (1978)

A Methodology for Project Use Case Definition

Beatriz Andres[1(✉)], Faustino Alarcon[1], Daniel Cubero[2], and Raul Poler[1]

[1] Research Centre on Production Management and Engineering (CIGIP), Universitat Politècnica de València (UPV), Camino de Vera s/n, 46022 Valencia, Spain
{bandres,rpoler}@cigip.upv.es, faualva@omp.upv.es
[2] Factor Ingeniería y decoletaje, S.L., C/ Regadors 2 P.L., Campo Anibal, 46530 Puçol, Valencia, Spain
d.cubero@factorsl.es

Abstract. This paper proposes a methodology to support researchers, technology developers and industrial pilots, which are part of a European project consortium, on the use cases definition for the demonstration and validation of the project results. The proposed methodology analyses all the current business processes of each industrial pilot, to establish the starting point of the use cases project solutions. Thanks to this methodology, the detailed specification for the development of all composing elements of the use cases will be laid down, establishing the boundaries for the implementation and validation of the project results.

Keywords: Project use case · Industrial pilots · Business processes · Key performance indicators

1 Introduction

Horizon Europe is the EU's key funding programme for research and innovation with a budget of €95.5 billion [1]. It aims to (i) support Sustainable Development Goals (SDG) implementation; and (ii) boost the EU's industrial competitiveness and growth. Horizon Europe programme leads its activities on creating jobs, gathering talented personnel, stimulating economic growth and increasing industrial competitiveness; through the properly use of investment to strengthen the European research area. According to [1] a new approach to partnerships is boosted within the Horizon Europe Programme with the aim of achieving more ambitious partnerships with industry in support of EU policy objectives.

A use case is a sequence of transactions that yields a measurable result of value for an actor. In this way, when an actor uses the system, the system performs a use case. The collection of use cases defines the system's complete functionality [2, 3]. On the other hand, a scenario is a specific instance of a use case, in which a set of possible actions are carried out for that use case [4].

In order to help project managers and partners, including researchers, technology developers (RTDs) and industrial pilots, this paper has its objective on providing a Methodology to define Use Cases for the validation of the European research projects Results (MUCER). In this regard, a case study complements the proposed methodology,

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 442–447, 2023.
https://doi.org/10.1007/978-3-031-27915-7_78

by using a metal machining industry pilot, participating in the European Project "Industrial Data Services for Quality Control in Smart Manufacturing" i4Q [5] project. To do so, the paper is outlined as follows. MUCER methodology is depicted and contextualised in Sect. 2. In Sect. 3, MUCER is applied in the metal machining use case that is part of the i4Q project. Finally, Sect. 4 provides some conclusions and future lines.

2 Definition of Use Cases with MUCER

In this section a methodology to define use cases for the validation of European research projects Results (MUCER) is proposed (Fig. 1). The outputs of MUCER are related with the: (i) definition of the use cases *(UC^m)*; (ii) definition of the AS IS scenarios (*AsIs_Py_BP0x*) represented through business processes modelling notation (BPMN); (iii) definition of TO BE scenarios (*ToBe_Py_BP0x*) with BPMN: starting from the *AsIs_Py_BP0x* scenarios, the *ToBe_Py_BP0x* scenarios include the results of the project and where are going to be implemented (ERP_S^N); and (iv) mapping between the solutions that are going to be developed along the European research project (ERP_S^N) with the use cases; that is, amongst all the solutions ERP_S^N which of them are going to be implemented and validated in each of the use cases (UC^m).

The next step of MUCER would be led to define and formulate the KPIs to be measured for identifying the extent into which the solutions developed within the project ($\mathrm{ERP\_S^N}$) contribute to the industrial pilots' performance improvement. Nevertheless, the KPIs definition will be considered on extended works. Parallel to the project use cases definition, the requirements analysis and functional specifications must also be carried out. This is because, the complete definition of requirements and functional specifications is based on the use cases definition, from the TO-BE scenarios. Thus, the AS IS and TO BE scenarios defined within the use cases give further knowledge to analyse the requirements and functional specifications that the project solutions should have (see Fig. 1).

The purpose of MUCER is to describe and characterize European project use cases. The MUCER reflects the methodology to be carried out to help the industrial pilots become aware of the solutions developed in a project, as well as the technical capabilities and potentiality, and at the same time express the needs and future expectations from the project results. Hence, MUCER includes:

- The industrial pilots' characterization, modeling their current state (AS IS) and forecasting the future state (TO BE) when the results of a European project are implemented, as the foundation to reach a use case;
- The description of the use cases, based on the industrial pilots manufacturing processes;

The MUCER steps are:

Step 1. Characterize the industrial scenarios

1.1. Describe the current manufacturing domain
1.2. Identify and describe the technical advancement desired from the European research project.

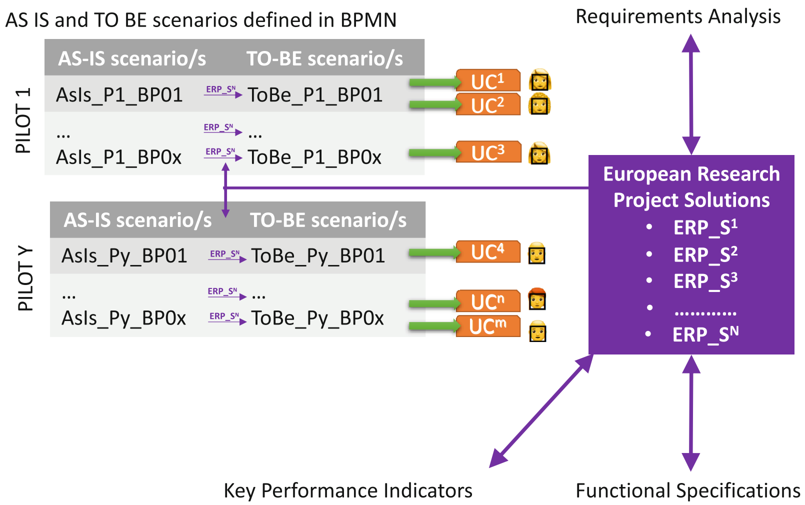


Fig. 1. MUCER contextualization

1.3. Map the technical advancements with the European research project solutions

Step 2. Describe and analyze the current situation of each use case (AS-IS scenario)

2.1. Introduce the industrial pilot involved
2.2. Define the current industrial pilot business processes
2.3. Describe the main facing problematics of the industrial pilot
2.4. Describe the desired improvements of the industrial pilot

Step 3. Describe and analyze the future situation of each use case (TO-BE scenario) by considering the implementation of the european project solutions:

3.1. Define the industrial pilot business processes expected after the implementation of European project solutions
3.2. Map the TO-BE business processes of the use case with the European project solutions

The main results from MUCER are grouped in three categories:

- The definition of business processes identified in each use case (AS-IS scenarios);
- The definition of TO-BE business processes in each use case, in which the AS-IS scenarios evolve to the TO-BE scenarios, which include the European project solutions;
- The mapping between the TO-BE business processes and the potential European project solutions applicable to achieve such TO-BE scenarios.

3 Metalworking Enterprise Use Case Definition in i4Q Project

In i4Q European project [5] participate six industrial pilots, each one takes part of different use cases that will serve to validate i4Q project solutions. This paper focuses on the industrial pilot of aeronautics and aerospace metal parts quality. FACTOR [6] is an engineering and metal machining company located in Valencia, Spain. FACTOR is labelled as pilot 4 within the i4Q European project, and includes two business processes, which has been modelled both in the AS-IS analysis of the current situation and in the TO-BE analysis of the expected use cases that will implement and apply i4Q solutions:

- *AsIs_P4_BP01: Product quality control*
- *AsIs_P4_BP02: Machine adjustments in the machining process*
- *ToBe_P4_BP01: In-line product quality control*
- *ToBe_P4_BP02: Automatic online correction of the CNC machining process*

MUCER application in the ToBe_P4_BP01: In-line product quality control is shown in Table 1. In the meanwhile, the BPMN for the ToBe_P4_BP01: In-line product quality control, is represented in Fig. 2.

Table 1. MUCER application in the ToBe_P4_BP01: In-line product quality control

Process name	"In-line product quality control"
Process description	The in-line control process begins once the machine has started production and the quality department checks the part and confirms that it is OK. The i4Q RIDS will be connected to the machine controller, tool and other sensor systems available for measuring the pieces as they leave the machine. i4Q solutions will be trained to correlate a range of processing parameters with the quality of the manufactured parts. During the process, i4Q systems will predict the final quality of the future production and will propose to the machine controller the parameters that can improve the quality of the manufactured parts or stop the machine in case there is not any alternative
Actors and roles	Innovation department, Engineering department, machine operator, machine assembler, quality manager
Information systems	CNC machine tool, Data Acquisition Systems, Inspection guideline and part drawing, i4Q solutions
Problems and needs	It is necessary to have a system for inspection/control of the manufacturing process that allows the permanent reading and storage of the data of the manufactured parts for subsequent analysis

(*continued*)

Table 1. (*continued*)

Process name	"In-line product quality control"
Internal and external barriers	The barriers are on the one hand internal as the appropriate information systems infrastructure and training of manufacturing staff is not in place, and on the other hand external as there are no qualified staff to operate/analyse these information systems
i4Q solutions involved [7]	i4Q Services for Data Analytics; i4Q Big Data Analytics Suite; i4Q Analytics Dashboard; i4Q Infrastructure Monitoring; i4Q Rapid Quality Diagnosis; i4Q Continuous Process Qualification; i4Q Line Reconfiguration Toolkit

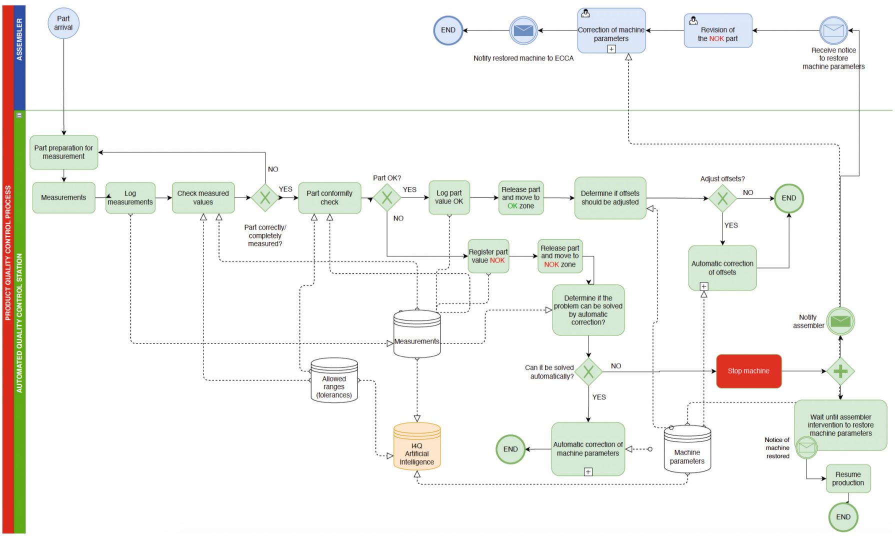


Fig. 2. BPMN example for the ToBe_P4_BP01: In-line product quality control

4 Conclusions and Future Research Lines

The purpose of MUCER is to propose a methodology to define the use cases that will validate the solutions of a European project. MUCER leads to model use cases in BPMN, both in the AS IS and the TO BE scenarios, which are prompt to be improved by the implementation of the project results. Future research lines of MUCER are led include a methodology that will enable to collect the use cases requirements and functional specifications. Additional effort in MUCER will be devoted to the definition of precise validation methods and procedures to univocally determine the real values of KPIs, that will enable to compare AS IS and TO BE scenarios in each use case. These KPIs will be used for an initial assessment of the use cases in order to allow results comparison and improvements analysis at the end of the project, when solutions are implemented in the use cases.

Acknowledgements. The research leading to these results is part of the i4Q project that has received funding from the European Union's Horizon 2020 Research and Innovation Programme, under Grant Agreement No. 958205.

References

1. Horizon Europe: Research and innovation funding programme until 2027. How to get funding, programme structure, missions. European Partnerships, News and Events (2022)
2. Jacobson, I., Christerson, M., Jonsson, P., Overgaard, G.: Object-Oriented Software Engineering – A Use Case Driven Approach. Addison Wesley, Wokingham (1992)
3. Oberg, R., Probasco, L., Ericsson, M.: Applying requirements management with use cases. White Paper Rational. Software Corporation, versión 5 (2000)
4. Roldán, M.L., Vegetti, M., Marciszack, M., Gonnet, S., Leone, H.: Un Modelo Conceptual para la Especificación y Trazabilidad de Requerimientos Funcionales basados en Casos de Uso y Casos de Prueba. In: 5to Congreso Nacional de Ingeniería Informática / Sistemas de Información Ing. de Sistemas, Ing. de Software y Gestión de Proyectos, pp. 503–514 (2017)
5. i4Q: Industrial Data Services for Quality Control in Smart Manufacturing. Euroepan union's Horiz. H2020 rese-arch Innov. Progr. under grant agreement. vol. n°958205 (2022). https://www.i4q-project.eu
6. FACTOR: Factor ingeniería y decoletaje, 2022. [Online]. https://factorsl.es/. (Accessed 14 Mar 1 BC)
7. Karakostas, A., Poler, R., Fraile, F., Vrochidis, S.: Industrial data services for quality control in smart manufacturing - The i4Q Framework. In: 2021 IEEE International Workshop on Metrology for Industry 4.0 IoT, 2021 - Proceedings, vol. 60, pp. 454–457 (2021)

Determining the Order Picking Time in Food Retailing

Sara Riveiro-Sanromán(✉), Mar Vazquez-Noguerol, José A. Comesaña-Benavides, and J. Carlos Prado-Prado

Business Organization and Marketing Department, School of Industrial Engineering, Campus Lagoas-Marcosende c/Maxwell, University of Vigo, 36310 Vigo, Spain
sara.riveiro@uvigo.es

Abstract. Online sales service is becoming increasingly important for food retailers. Many supermarket chains adopt store-based model in which online orders are picked in traditional stores. Companies must carry out proper resource planning to achieve success in the implementation of this omnichannel strategy. The purpose of this paper is to determine which aspects influence the order picking process and to provide a tool for estimating the workload involved in omnichannel retailing. By carrying out an empirical analysis in a Spanish e-grocer, a Multiple Linear Regression (MLR) model is proposed to estimate the order picking time. The results obtained determine the degree to which some of the store and order characteristics affect the picking process. Therefore, this work provides a valuable tool for both researchers and e-grocers to effectively manage resources in the current omnichannel context.

Keywords: Picking process · Online grocery · Supply chain management · Omnichannel · MLR · Empirical analysis

1 Introduction

The order picking process represents one of the most important costs to meet online demand in supermarket chains [1]. This is due to the fact that, while in the traditional sales channel this activity is carried out by the customers, in the online sales channel it must be assumed by the companies. In order to be more efficient, and therefore more competitive, many supermarket chains have opted to prepare online orders from traditional stores. This strategic model, known as store-based, allows grocers to take advantage of the availability of their store staff avoiding specific online costs [2]. Due to online demand is continuously increasing, companies need to pay more attention to the overlap between channels. In this regard, e-grocers must be able to maintain a great traditional shopping experience while trying to be efficient and competitive in the online sales channel.

All the potential factors that influence the picking process must be bearing in mind to ensure proper resource planning. With regard to these factors, on the one hand, it is noteworthy the aspects related to the products that make up an order, since items are very heterogeneous. There are large differences between these products in terms of weight,

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 448–453, 2023.
https://doi.org/10.1007/978-3-031-27915-7_79

size and temperature [3, 4]. Another aspect to take into account is that grocery purchases are usually made up of a great number of products. On the other hand, not all stores are identical; traditional stores have different characteristics that can facilitate or hinder the picking process [5]. The main differences are related to store design, size and the level of service. There are also operational aspects specific to each store, such as the experience or the work method used by the picker. Despite these particularities, there are no studies in the current literature focused on determining to what degree each of the characteristics of stores and orders affect the picking process. However, knowing the time required for this task is valuable information to calculate the workload. This would allow e-grocers to plan fulfillment operations, to organize resources appropriately and also to know when capacity needs to be increased. To fill this gap in the literature, the following research question is proposed:

RQ: How do store and order characteristics affect the order picking process?

To answer the research question, this study is based on a statistical analysis of order and store factors that affect order picking time. The aim is to provide e-grocers with a model to predict the time required for the preparation of orders demanded by the online sales channel.

2 Methodology

To achieve the objective proposed in the previous section, it is necessary to identify which aspects influence the order picking time. In this study, two categories were considered: one related to the characteristics of the order, and the other related to the characteristics of the stores. The following three-step methodology is used to determine the degree to which each of characteristic affects the picking time. Firstly, potential order and store characteristics that influence order picking time were identified through a literature review process. Secondly, a field study was conducted in some of the main omnichannel stores of a Spanish e-grocer. The order measurements of the picking time were carried out on a sample of orders from each stores. Thirdly, a Multiple Linear Regression (MLR) is used to predict the value of a response variable (order picking time) based on the value of two or more explanatory variables (store and order features). By applying this statistical technique, it was analyzed which of the characteristics have a significant influence on order preparation time. Moreover, the degree to which each variable is affected was determined. Applying this methodology, the study can be applied to any supermarket chain that seeks to determine the preparation time of its online orders to optimize the use of resources. All this information will promote the availability of pickers to facilitate the scheduling of online orders to each traditional picking store.

3 Model Formulation

Multiple regression analysis is used to estimate how the response variable (picking time) changes as the explanatory variables (store and order features) change. Thus, the equation of the MLR model is given by:

$$t_i = \beta_0 + \sum_{j \in J} \beta_j \cdot x_{ij} + \varepsilon_i$$

A set of orders $i \in I = \{1, \ldots, I\}$ and a set of characteristics $j \in J = \{1, \ldots, J\}$ that may be different for each order and preparation store were considered. The term *ti* represents the picking time of order *i*, and *xij* is the input data for the *j* significant characteristics. MLR is used to determine the values of β_0 and βj. Whereas β_0 is a fixed value. Each β_j is the regression coefficient of the explanatory variables x_{ij}. Finally, εi is the error term representing unobserved heterogeneities.

In this study, numerous explanatory variables are considered. As [6] point out in their study, both size and product range can condition the travel distance of pickers. On the other hand, a store traffic variable is used to measure the interaction between pickers and store customers. This attribute is defined by an indicator of daily offline customers per square metre of store [7]. The experience variable, which is understood as the skill of the pickers, has been categorized according to the monthly volume of online orders. That is, the more online orders a store prepares, the more experience the pickers will have. Finally, regarding the work method, three practices applicable to this study are identified: (i) order bagging is performed during the picking or at the end of the process, (ii) heavy products are prepared during or at the end of the process and (iii) fresh products are picked by the picker or by specific staff [8].

With regard to the order, in addition to the number of units that make up an online order, an item variable was also defined. It should be noted that the units indicate the number of products in an order, while the items correspond to the total number of different products that constitute the order. In other words, there may be several units of the same item. Moreover, the number of fresh and bulky products in each order were considered because those products usually require a different treatment [9]. A summary of the characteristics that can affect the order picking process is shown in Table 1.

Table 1. Summary variables

Variable	Type
Size (m^2)	Store
Assortment (items)	Store
Store traffic (orders/m^2)	Store
Experience (orders/month)	Store (Method)
Bagging process during the picking (yes/no)	Store (Method)
Picking of bulky products during the picking (yes/no)	Store (Method)
Fresh products are prepared by the picker (yes/no)	Store (Method)
Units	Order
Items	Order
Number of fresh products	Order
Number of bulky products	Order

Once the variables were identified, the picking time needed to prepare a sample of online orders has been measured in the eight most representative omnichannel stores of the firm. The measurements were made on the daily demand of each of the stores.

4 Results

The empirical results of the Multiple Linear Regression indicate that not all the variables identified in the literature affect the picking time. With regard to the order, only the number of items turns out to be significant at the 0.01 level. Furthermore, four of the characteristics are significant in the picking time at the 0.01 level in terms of the store. Those are the store size, the assortment, the store traffic and the bagging method carried out by the pickers. The results obtained for the response and explanatory variables are listed in Table 2.

Table 2. Descriptive statistical values for variables

Variable	Coefficient	S.E	p-value
Intercept (β_0)	32.22	14.77	0.035
Size	2.74	0.63	<0.001***
Assortment	−2.15	0.56	<0.001***
Store traffic	0.71	0.23	<0.01**
Experience	−0.12	0.05	0.018
Bagging during picking	−8.67	2.98	<0.01**
Bulky products during picking	8.66	4.93	0.087
Fresh products prepared by picker	6.38	5.47	0.250
Units	0.16	0.07	0.036
Items	0.38	0.14	<0.01**
Number of fresh products	0.46	0.21	0.037
Number of bulky products	-0.07	0.11	0.565

The results show that two of the significant variables have a negative coefficient, which implies a reduction in order picking time. The variable that most affects is the method of bagging during picking. The study demonstrate that this method can reduce the total time by more than 8 min for a picking time of 40 min per order (average of the sample data). The other variable that speeds up preparation is related to the assortment of the store, since lower time values are found in stores with a greater variety of products. In contrast, a positive coefficient is obtained for the three remaining significant variables so it can be stated that these variables increase the preparation time. Therefore, the study shows that for high values of items per order, store size and customer traffic, the picking process will be slower.

5 Discussion and Future Research

The research question proposed in the study was answered by identifying the factors that affect the online order picking process in supermarket stores. As a result, the study has a double contribution. On the one hand, the results offer a model for predicting the picking time of each online order. On the other hand, authors identify five store and order characteristics which have a significant influence on the order picking time.

Among the five significant variables, two of them reduce the preparation time. These variables that improve picking time are surprising. The results show that the bagging process is more agile when it is performed during picking, reaching a decrease of up to 20% of the total picking time. Conversely, the existing literature considers more efficient to perform bagging at the end of the process [9]. In addition, the results determined that the preparation time is lower in stores with a wide range of products, despite the fact that this characteristic might seem to penalize the preparation time.

The other three significant variables represent an increase in the preparation time by taking positive coefficients. With regard to the variables of store size and number of items per order, both have been widely used in the literature to categorize orders [10]. As the present study shows, these two variables are relevant but they are not the only ones affecting the picking process. Store traffic should also be considered because with high values of congestion processes become less efficient. This result is consistent with the contribution presented by [11], where the authors idientify that small stores with a high volume of customers have a worse performance.

Thus, the firm under consideration is able to plan the picking resources. This information is of great value for strategic decisions such as modifying capacity or defining a new e-fulfillment strategy. Future lines of research could focus on applying the methodology described in an e-grocer with a warehouse-based strategic model. Completing the vision of picking orders from stores and from warehouses, researchers will be able to carry out a comparison between the two models. Lastly, it is important to bear in mind that although this study is oriented to supermarket chains, this methodology can easily be applied to other sectors. For that, the variables that can influence the online order picking process must be identified in each case. As a result, this information will improve the availability of pickers and the scheduling of activities to meet demand in a more efficient way.

References

1. Fikar, C.: A decision support system to investigate food losses in e-grocery deliveries. Comput. Ind. Eng. **117**, 282–290 (2018)
2. Hübner, A.H., Kuhn, H., Wollenburg, J.: Last mile fulfilment and distribution in omni-channel grocery retailing: a strategic planning framework. Int. J. Retail Distrib. Manag. **44**(3) (2016)
3. Ishfaq, R., Defee, C.C., Gibson, B.J., Raja, U.: Realignment of the physical distribution process in omni-channel fulfillment. Int. J. Phys. Distrib. Logist. Manag. **46**(6/7), 543–561 (2016)
4. Valle, C.A., Beasley, J.E., Da Cunha, A.S.: Optimally solving the joint order batching and picker routing problem. Eur. J. Oper. Res. **262**(3), 817–834 (2017)

5. Mkansi, M., Eresia-Eke, C., Emmanuel-Ebikake, O.: E-grocery challenges and remedies: Global market leaders perspective. Cogent. Bus. Manag. **5**(1) (2018)
6. Pires, M., Silva, E., Amorim, P.: Solving the grocery backroom layout problem. Int. J. Prod. Res. **59**(3), 772–797 (2021)
7. Salgado, T.M.F.D.N.: In-store order picking routing: a biased random-key genetic algorithm approach. University of Porto, Portugal (2015)
8. Gorczynski, T., Kooijman, D.: The real estate effects of e-commerce for supermarkets in the Netherlands. Int. Rev. Retail Distrib. Consum. Res. **25**(4), 379–406 (2015)
9. Vazquez-Noguerol, M., González-Boubeta, I., Portela-Caramés, I., Prado-Prado, J.C.: Rethinking picking processes in e-grocery: a study in the multichannel context. Bus. Process. Manag. J. **27**(2), 565–589 (2021)
10. Eriksson, E., Norrman, A., Kembro, J.: Contextual adaptation of omni-channel grocery retailers' online fulfilment centres. Int. J. Retail Distrib. Manag. **47**(12), 1232–1250 (2019)
11. Volpe, R., Cho, C.: Market structure determinants of performance for independent supermarkets. Manag. Decis. Econ. **40**(8), 871–881 (2019)

Entrepreneurship Ecosystems: Not Just Stakeholders, A Study Case

Camilo Muñoz Arenas[1(✉)], Carmen Avilés-Palacios[1], Juan José Morillas Guerrero[2], and Joaquín García Alfonso[1]

[1] Unidad Docente de Organización de Empresas, ETSI Montes, Forestal y del Medio Natural, Universidad Politécnica de Madrid, C/ José Antonio Nováis, 10, 28040 Madrid, Spain
{camilo.munoz.arenas,carmen.aviles}@upm.es

[2] Departamento de Ingeniería de Organización, Administración de Empresas y Estadística, ETS Ingeniería Aeronáutica y del Espacio, Universidad Politécnica de Madrid, Plaza Cardenal Cisneros, 3. Despacho B.220, 28040 Madrid, Spain
juanjose.morillas@upm.es

Abstract. Entrepreneurship and innovation development is key for a new and sustainable nature based economy. Particularly, industry and management in forestry present great opportunities in order to achieve this kind of new bioeconomy. The present communication has the aim of analyzing a cluster focused in forestry products development, through the macro-meso-micro perspective and to take it as a reference point for the study of other forest bioeconomy entrepreneurship systems.

Keywords: Entrepreneurship ecosystems · Entrepreneurship · Innovation · Forestry · Bioeconomy

1 Introduction

The continuity of human societies depends to a large extent on changes in their modes of consumption and production. Knowing that these have severely affected global ecosystems to the point of climate disruption, changes must be aimed at minimizing our impact. The Sustainable Development Goals (SDGs) established by the United Nations (UN) have established a framework that serves as a guide to minimize impact. Responsible production and consumption is SDG 12 and argues exactly what has just been stated: "The economic and social progress achieved over the last century has been accompanied by environmental degradation that is endangering the very systems on which our future development (and indeed, our survival) depends." (United Nations 2022). A change in the economic model can be brought about through innovation, as explained in SDG 9 (Industry, Innovation and Infrastructure): "Innovation and technological progress are key to discovering lasting solutions to economic and environmental challenges, such as increasing energy and resource efficiency".

Forest resources are very varied. From wood to essential oils, through paper, biomass, mushrooms, honey, or extensive livestock (among others). They come to be what is

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 454–461, 2023.
https://doi.org/10.1007/978-3-031-27915-7_80

distinguished in timber and non-timber products. Very traditional products coexist with others resulting from research and development. However, without a greater exchange of knowledge, without diversity and information flows, the capacity to generate innovative products, services or processes is very limited. That is why fostering new entrepreneurship ecosystems that favor relationships between agents and the approach to new technologies and the development of new ideas is essential for a sector as traditional and territorially anchored as forestry. Moreover, it can be crucial not only for the forestry industry but for society as a whole. This paper aims to analyze already established ecosystems, in particular the one generated by the French cluster Xylofutur with 15 years of experience, in order to encourage the development of new entrepreneurship ecosystems, especially considering the diversity of forest ecosystems in the Iberian Peninsula, with the many opportunities they present.

2 Methodology

The methodology used has been the analysis of a case. In particular, the case of the entrepreneurship ecosystem generated by the French competitiveness center Xylofutur. The analysis is carried out on the basis of the macro-meso-micro levels proposed by Kuckertz et al. (2020).

Case-study methodology has been chosen in order to obtain qualitative information that could help to generate hypotheses about clusters related with forestry industry. For this reason, main information about competitiveness cluster Xylofutur has been obtained from its website, whereas information of French regional innovation politicies has been obtained from different official Ministeries documentation.

In addition, information obtained has been structured into three levels, as said before, macro-meso-micro. The macro level studies the role of administrations and governments in support and leadership tasks. The meso level tries to understand the role of entrepreneurship ecosystems and the networks that shape them. The micro level focuses on entrepreneurial activity and the process towards entrepreneurship (and its impact on the transformation towards a sustainable bioeconomy).

3 Results

Xylofutur is a French competitiveness cluster that is managed with many activities aimed at fostering cluster efficiency. This management is carried out by a team financed by state funds, thus having a constant relationship with the different administrations and ministries. The national innovation strategies, as well as the regional ones, establish the framework and the lines of work of the cluster. In this way, it is possible to establish communication channels and common work bases with the administrations, research centers, universities and local companies, generating collaborative projects and favoring the competitiveness of the companies associated to the cluster.

3.1 Macro Level: State Vision of Innovation and Entrepreneurship Dynamics and Its Relationship with Xylofutur

Since 2004, France has had a policy of competitiveness clusters to mobilize the key factors of competitiveness, including innovation. These clusters are developed on a territory identified as a priority in which a number of companies of all sizes, research laboratories and training centers are located (Direction générale des Entreprises. Ministère de l'Économie 2022). As will be discussed in detail below, the objective of generating these structures is to support innovation as a driver of economic growth. Facing the challenge of a transition to a decarbonized economy by 2050, France needs to develop its markets, as well as mobilizing and adding value to national forestry resources. (Conseil national de l'industrie, 2018). To this end, two main axes are established: 1) The development of particularly innovative collaborative research and development projects and 2) To accompany the development and growth of companies associated with the cluster (Direction générale des Entreprises. Ministère de l'Économie 2022).

It is therefore a national initiative with regional implementation. The French government plays a supporting role at the economic level by providing aid to the best projects. In addition, it also partly finances the structures that manage the clusters (in the form of associations), which is financed in partnership with other administrations (regional or local) and companies. Finally, being a national strategy, the State works in the ecosystem with a global perspective, involving actors that act throughout the territory and that are of interest for the development of entrepreneurship and innovation. The two main ones are: the National Research Agency (Agence Nationale de la Recherche) and the French Public Investments Bank (Banque Publique d'Investissements de France, BPI France) (Direction générale des Entreprises. Ministère de l'Économie 2022).

Currently, the competitiveness clusters are in phase 4 of development. After 14 years of implementation, this fourth phase covers the period 2019–2022, focused on taking further what has been achieved so far. While the previous objectives were the industrialization of Research and Development (R&D), thus becoming a "project factory", as well as support for the marketing of products resulting from R&D, the steps to be taken are aimed at consolidating what has been achieved. On the one hand, expanding borders, through collaborative projects in Europe thanks to Horizon Europe projects. On the other hand, by strengthening the clusters with better defined and more demanding criteria for their inclusion under the "pôles de compétitivité" label and with greater coherence with the innovation ecosystem (Direction générale des Entreprises. Ministère de l'Économie, 2022).

56 clusters have obtained the "Pôle de Compétitivité" label, thus benefiting from the various aids and collaboration schemes mentioned above. This labeling is not indefinite. For each period, it is renewed by a specific committee, with the possibility of renewal for 4 years or for one year (Gouvernement 2022). Among those that have renewed their label for the 2019–2022 period, there is one that is dedicated exclusively to the forestry industry sector: Xylofutur.

Since 2005, this cluster has been operating in the New Aquitaine region in southwestern France. Xylofutur has three strategic areas of activity:

– Management and exploitation of cultivated forests,

– Wood derivatives,
– Wood pulp products and biochemicals.

In addition to the aforementioned entities at the national level (Agence Nationale de la Recherche and BPI France), this cluster is supported by entities related to the forestry sector. On the one hand, at the national level, another entity supports funding: Comité professionnal de Développement des Industries Françaises de l'Ameublement et du Bois (Professional Committee for the Development of the French Furniture and Woodworking Industries, CODIFAB). It finances activities such as training, innovation and design, technical actions and research or economic, statistical and strategic studies, among others (COFIDAB 2022).

On the other hand, different Regional Directorates support the cluster. The territorial perspective, closer to Xylofutur's reality, allows to detect opportunities for new projects and new actions, as well as to discuss their successes and difficulties. Among these Directorates are: Regional Directorate of Food, Agriculture and Forestry, Regional Directorate of Economy, Employment, Labor and Solidarity and Regional Directorate of Environment and Housing.

At the last administrative level, there are the provincial and municipal entities, which allow the cluster to approach the specific needs of the territories and their stakeholders.

This whole network of actors is not limited to the New Aquitaine region. Although it was born in this region, the cluster has been extended to others with a similar projection in the forestry sector. Four other regions will have "antennae" which will enable the network to be extended. In this way, being an element of union, it allows to tackle one of the classic problems of the forestry sector in Europe: the atomization of private property. As there are many owners with small areas, joining allows them to achieve higher yields in their harvests. The new regions incorporated are: in the east of the country, Auvergne-Rhône-Alpes and Bourgogne-Franche-Comté, in the west, Pays de la Loire.

3.2 Meso Level: Forestry Bioeconomy Ecosystem

One of the differences between the classic clusters and the French "pôles de compétitivité" lies in the way in which the agents relate to each other. While both comprise companies, universities, research centers and other parties with common interests (as opposed to industrial districts and local production systems, which only group together companies), the big difference lies in who acts as a link between them, reinforcing their activities. Clusters manage their collaborations among the cluster actors themselves. In contrast, French clusters manage relations between actors through a public entity that will promote synergies and enhance their capacities (Froehlicher and Barès 2014).

Malecki precisely picks up on this factor as one of those ignored in the research, with the discussion focusing more on the ingredients than on the process of combining a sustainable environment for entrepreneurship (Malecki 2018). Stam (2015) puts it this way: "Systemic conditions are at the heart of the ecosystem: networks of entrepreneurs, leadership, funding, talent, knowledge, and support services. The presence of these elements and the interaction between them predominantly determines the success of the ecosystem."

Thus, the fact of setting up an entity to act as an intermediary between the agents can be fundamental. In the French case, Xylofutur operates in three areas identified as essential (Xylofutur 2021):

– Creation of structures adapted to the needs of the cluster,
– Detection and mobilization of sources of funding for R&D&I projects of clusters or companies,
– Carrying out actions to strengthen the Center's resources and avoid conflicts of interest between actions carried out within the Center itself and those carried out with other support structures.

This collaboration between the cluster and the entities prioritized can be grouped into five areas of action:

– Relationships (including visibility, information and communications),
– Strategy (needs analysis, territorial analysis),
– Accompaniment (different forms of follow-up of start-ups and companies, internationalization),
– Projects (project assembly, development of new projects),
– Events (conventions, national or international events, other actions).

Thus, in the relational aspect, there is an important task of information transmission between the different entities aimed at: Maintaining the visibility of the actions, informing about calls for projects or exchanging information about ongoing projects.

Global coherence is essential in innovation policies. This is why part of the cluster's management work is dedicated to contributing to strategies, whether at the national level, with the General Directorate of Enterprises or the National Research Agency, or at the regional level with local agencies. It also participates at the strategic level, for example with the Biocontrôle et Biosolutions Cluster, in which it has participated in the study of the levers and brakes of the cluster's products by the various target audiences (agricultural and forestry technicians, cooperatives or companies, as well as chambers of agriculture).

At the more tactical level, project monitoring and financial, technical and communication support is essential. On the one hand, Xylofutur is in charge of the project overview that will seek success in its market launch or collaboration between two entities in accordance with the objectives set. But, in addition, there are all those external projects that are a source of opportunities for companies. As far as the business project itself is concerned, it should be noted that it is carried out both nationally and internationally. Xylofutur acts nationally and at the international level main work is managed with Regional, Local (Bordeaux) and International Chambers of Commerce.

The support is designed to ensure that the projects are innovative and have real possibilities in their market launch. This is why we work with very different actors that can give rise to innovative projects. An example is the collaboration between the clusters Xylofutur and Atlanpack, which jointly built the action "Regional opportunities, packaging and transition from plastic", which provided information on the opportunities for replacing plastic with wood, paper and cardboard products, through the development of innovative solutions that meet the needs of plastic substitution. Throughout this process, the proposals are monitored and a diagnosis of the proposed solutions is carried out. This, which may be a proposal relatively close to the sector, although with potential for innovation, contrasts with the possible results obtained with Aquitaine Robotics, another cluster in the Aquitaine region with which contact is maintained for innovation projects. The forestry industry is very broad, so the technology can be applied in multiple sectors, improving yields and productivity, among other factors.

Finally, the Xylofutur association is responsible for projecting the image, projects and potential of the cluster both nationally and internationally. This is done through joint events with other clusters such as the Yes We Wood day with the Odeys cluster (Aquitaine region cluster dedicated to sustainable construction and equipment) to bring together professionals from both sectors. At the international level, it participates in events such as Woodrise, jointly organized by the FCBA Technological Institute (France), the private research center FPInnovations (Canada) and the Building Research Institute (Japan). Being the first partner of Xylofutur, the access of cluster partners to this type of international events allows them to be at the forefront of finding new partners, clients, markets, etc.

3.3 Micro Level: Entrepreneurship Activity

Xylofutur is a cluster born in the New Aquitaine region, the largest in terms of surface area and forest harvesting: 2.5 million hectares producing 25% of France's national timber production (Programme Régional de la Forêt Bois 2019). The first of the regional strategic objectives for the timber sector is to strengthen the competitiveness of the sector. To achieve this, it is proposed to: 1) Invest to better valorize regional forest resources, 2) Modernize companies and improve their positioning on the markets, 3) Improve competitiveness in the mobilization of forest resources, 4) Invest in R&D and technology transfer by relying on the Xylofutur cluster and 5) Involve sectoral stakeholders. In addition, in the program priorities, the first one is "Invest and strengthen partnerships to improve resource mobilization: infrastructure, supply clustering, procurement and logistics". Considering that most of the forest area is private (90% of the area) and that 80% of it is less than 10 ha in size, the effort to generate joint mobilization is essential.

In order to achieve competitiveness in the sector, Xylofutur is developing R&D projects in 3 strategic areas (Xylofutur. Produits et Matériaux des Forêts Cultivées 2022):

- Forestry management and exploitation (107 projects),
- Wood products (76 projects),
- Pulp and green chemical products (80 projects).

A total of 263 projects have been registered under the cluster brand as of March 1, 2022. These projects follow a selection process that allows them to be instructed and oriented towards the appropriate funding agencies, having an extra benefit thanks to being under the umbrella of the cluster brand (Xylofutur. Produits et Matériaux des Forêts Cultivées 2022). A process that is consistent with the development and innovation strategies established by the Internal Regulations of the Technical Commissions (Xylofutur. Produits el Matériaux des Forêts Cultivées 2019), which highlights the following aspects to be taken into account for accessing the services of the Xylofutur Association:

- Projects that respond to at least one of Xylofutur's strategic areas,
- The research or development project can be carried out by: a company, a group of technical partners, several companies and at least one technical or academic partner (research centers, higher education institutions, organizations competing for technology transfer), several technical partners (research centers),
- Its objective must be to develop the activity and the performances of the companies involved and/or to favor the emergence of new products/services on the market and/or new innovative companies and/or to create new competences for the territories in which the cluster operates (Auvergne-Rhône-Alpes, Bourgogne-Franche-Comté, Grand Est, Nouvelle-Aquitaine, Pays de la Loire),
- It must involve a maximum of skills obtained from private or public structures established in the territories in which the cluster operates,
- It must involve a maximum of Small and Medium-Sized Enterprises (SME), Micro-SMEs and Intermediate-Sized Enterprises (ETI, French classification designating enterprises between small and medium-sized enterprises and large enterprises, with 250 to 4999 employees and a turnover of less than 1500 million euros (Wikipédia, 2021)),
- Research projects (ANR type) must be disseminated and usable by industry.

In addition to these projects, Xylofutur collaborates in structuring projects for the region, modernizing research laboratories through INEF4 projects. INEF4 is the Institute for Energy Transition Factor 4 (aiming to divide greenhouse gas emissions by 4 by 2050), which plays a role of experimentation and support in the development of innovation in sustainable building. It allows the direct channeling of public funds in support of construction companies, while promoting collaborative projects supported by the Investissements d'Avenir (Future Investments) program.

Finally, Xylofutur is integrated into the higher education network with Bordeaux Sciences Agro, National Higher School of Agronomic Sciences. It hosts initial training courses at the engineer and Master's level, as well as conferences and seminars.

4 Conclusions

The development of an entrepreneurship ecosystem implies a strategic vision that allows for coherence in the actions of the ecosystem, as well as a binder that mediates between the actions and the vision. From the macro perspective, the national strategy triggers cascading reactions on the regions and local entities. It also establishes the financing conditions for the objectives to be attainable. At the meso level, the major interactions that will give rise to innovation arise because of the number of actors involved. The strategy is broken down into different areas that will allow the agents to interact in different ways, progressively achieving the objectives proposed in the different strategies at different levels. Finally, the micro level allows visualizing the conditions established for the inclusion of projects under the Xylofutur brand, which again responds to the needs imposed by the analysis of the local factors of the forestry sector and the strategic vision for its development.

This analysis gives the opportunity to look at the Spanish landscape and study in parallel the path, policies, vision and needs present in the industrial fabric of the forestry sector. The analysis of the strategy, financing, interactions between the different actors in the sector, at national, regional and local level, are key to promote an entrepreneurial ecosystem that allows a green transition based on the multiple opportunities of the forestry sector.

References

COFIDAB. cofidab.fr, 10 March 2022. https://www.codifab.fr/taxe-affectee/utilisation

Conseil National de l'Industrie. Contrat Stratégique de la Filière Bois 2018/2022 (2018). http://www.conseil-national-industrie.gouv.fr/files_cni/files/csf/bois/dossier-presse-signature-contrat-de-filiere-bois-16nov18.pdf. Accessed 27 Feb 2022

Direction générale des Entreprises. Ministère de l'Économie, d. F. Le portail de la Direction générale des Entreprises, 1 March 2022. https://www.entreprises.gouv.fr/fr/innovation/poles-de-competitivite/presentation-des-poles-de-competitivite

Direction Régionale de l'Alimentation, de l'Agriculture et de la Forêt. Plan Régionale de la Forêt et du Bois 2020/2030 (2020). https://fibois-na.fr/wp-content/uploads/2021/04/PRFB020-COR-Decembre_cle86c1f2.pdf

Froehlicher, T., Barès, F.: Pôles de compétitivité et clusters, vers de ecoystèmes de croissance? Entreprendre Innover. **23**(4), 45–58 (2014). https://doi.org/10.3917/entin.023.0045

Gouvernement. Gouvernement.fr, 19 February 2022. https://www.gouvernement.fr/partage/10873-labellisation-de-56-poles-de-competitivite-pour-la-phase-4-des-poles-de-competitivite-2019-2022#:~:text=48%20p%C3%B4les%20de%20comp%C3%A9titivit%C3%A9%20sont,Finance%20Innovation%2C%20Hippolia%2C%20IAR%2C

Kuckertz, A., Berger, E.S.C., Brändle, L.: Entrepreneurship and the sustainable bioeconomy transformation. Environ. Innov. Soc. Trans. **37**, 332–344 (2020). https://doi.org/10.1016/j.eist.2020.10.003

Malecki, E.J.: Entrepreneurship and entrepreneurial ecosystems. Geogr. Compass **12**(3), e12359 (2018). https://doi.org/10.1111/gec3.12359

Stam, E.: Entrepreneurial ecosystems and regional policy: a sympathetic critique. Eur. Plan. Stud. **23**, 1759–1769 (2015). https://doi.org/10.1080/09654313.2015.1061484

United Nations: Sustainable Development Goals, 21 February 2022. https://www.un.org/sustainabledevelopment/

Wikipédia: Entreprise de taille intermédiaire. Recovered (2 03 2022), 4 October 2021. http://fr.wikipedia.org/w/index.php?title=Entreprise_de_taille_interm%C3%A9diaire&action=history

Xylofutur, A.: Xylofutur. Générateur de croissance! Rapport d'activité. Année 2020 (2021). http://xylofutur.fr/wp-content/uploads/2021/08/Rapport_activite_Pole_Xylofutur_2020_VD.pdf

Xylofutur: Produits et Matériaux des Forêts Cultivées. Règlement Intérieir des Commissions Techniques. Gradignan (2019). http://xylofutur.fr/wp-content/uploads/2020/07/Reglement-interieur-des-commissions-techniques-2020-2023-VF.pdf

Xylofutur: Produits et Matériaux des Forêts Cultivées. Xylofutur, 2 March 2022. http://xylofutur.fr/

Social Life Cycle Analysis: An Overview of the Literature to Compare and Complement Current Methodologies

David Hidalgo-Carvajal[1], M. Cristina De Stefano[2(✉)], and Rodrigo Fernández Aguirre[1]

[1] Department of Organization Engineering, Business Administration and Statistics, Escuela Técnica Superior de Ingenieros Industriales (ETSII), Universidad Politécnica de Madrid (UPM), c/José Gutiérrez Abascal 2, 28006 Madrid, Spain

[2] Department of Business Organization, Facultad de Comercio y Turismo, Universidad Complutense de Madrid (UCM), Avenida de Filipinas 3, 28003 Madrid, Spain

maridest@ucm.es

Abstract. Even more studies on life cycle analysis highlight the environmental, economic, and social impact of supply chains, making evident to society realities that were unknown so far. Most academic and professional works are focused on developing indicators and standards to measure the environmental and economic impact of goods and services, whereas there are low contributions that improve tools to capture their social effects. The main difficulty in developing and applying social life cycle analysis (S-LCA) is due to the presence of high components of subjectivity and context specificity. The objective of this study is to offer a systematic literature review on S-LCA to understand in depth the existing applied methodologies. From the review, this paper identifies some aspects that the current methodologies are not considering and proposes as a result to complement such methodologies with other relevant perspectives.

Keywords: Social life cycle analysis · Sustainability · Literature review

1 Introduction

The Life Cycle Sustainable Assessment (LCSA) is a method developed to understand and identify the impact that products and production processes have over time [1]. Based on the results of this method, it is possible to improve and support decision-making that prioritize those resources and processes that have a positive impact or reduce the negative impact on the actors involved in the chain of a process, as well as the impact on other stakeholders [2]. The LCSA is based on three dimensions of sustainability: environmental, economic, and social. Its implementation allows to have a complete picture of the impact, positive or negative, of a product and its process at all levels, considering possible interactions among dimensions. Each dimension involves a type of analysis: the Environment Life Cycle Assessment (LCA or E-LCA); the Life-Cycle Costing Analysis (LCCA) and, the Social Life Cycle Assessment (S-LCA).

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 462–467, 2023.
https://doi.org/10.1007/978-3-031-27915-7_81

Focusing on the S-LCA, it "is a method that can be used to assess the social and sociological aspects of the products, their actual and potential impacts, both positive and negative throughout the life cycle. It deals with the extraction and processing of raw materials, manufacturing, distribution to use, reuse, maintenance, recycling, and final elimination. The S-LCA uses generic and site-specific data, which can be quantitative, semi-quantitative or qualitative, and complements the LCA and the LCCA. It can be applied on its own or in combination with other techniques" [3]. Although there known the benefits of the application of S-LCA, in terms for example of assessment of the social risks coming from value chain or from policies and investment choices, respect to E-LCA and LCC it is still underdeveloped. A previous literature review shows that the first study concerning S-LCA dates back to 1996, but only from 2013, it is evident an increasing trend of publications focused on this topic that offer application cases, and only from 2018 it can be appreciate an effort to standardize methodologies [4]. Hence, the objective of this work is to offer a literature review to uncover the methodologies used in those studies focused on S-LCA, in order to i) understand deeply the key aspects of applied methodologies; ii) propose a systematization of the main concepts and steps and iii) contribute to future improvements.

2 Theoretical Framework

First of all, it is important to notice that S-LCA is a field of study that is evolving and whose application is fundamentally based on specific contexts [5]. For this reason, a standardization that allows to establish a well-defined method to apply the S-LCA has not been developed yet. The first guideline dedicated to performing S-LCA are proposed by UNEP/SETAC in 2009 [6]. These guidelines identify five groups of stakeholders (workers, consumers, society, communities, and social actor in the value chain) and six impact categories (human rights, working conditions, health and safety, governance, socio-economic consequences, and cultural heritage), as well as other subcategories, which refer to the different social impacts that each stakeholder group may suffer. However, these guidelines recognize that does not exist a model of subcategories and impact categories generally accepted for actors who participate in the analysis. The UNEP/SETAC guidelines only make possible to establish some stages to perform S-LCA, which involve i) objective and scope definition, ii) inventory analysis, iii) impact assessment and iv) interpretation. The definition of objective and scope of the analysis can involve the assessment of the impact of a particular phase of the product life or of a greater number of phases within the process. The greater is the number of phases analyzed, the greater is the possibility to achieve a framework, which can be used in further analyses. In the stage of inventory analysis, it is collected the information which will allow to evaluate what the impact of social life cycle is. The type of information collected depends on the objective to be achieved and can range from general information (through internet) to specific information (through Non-Governmental Organizations (NGOs), company reports), and even the compilation of information through interviews or surveys. Subsequently, it is necessary to translate the information collected into impact assessment. The first step to do so is to select a pool of indicators that will be used for the analysis and the impact method assessment establishes the way of operating during the whole analysis. For example, it is possible to choose between type I and type II methods. S-LCA type I methods work with Performance Reference Points (PRP), i.e. the specific information collected is comparted with a series of targets to assess the social performance of a company or product. Whereas S-LCA type II methods use impact pathways to assess social impacts [7]. These two impact assessment tools allow to fit the selected information to the requirements of each way of proceeding and will be selected according to the advantages and disadvantages embedding. Finally, in the stage of interpretation, the results of the study can be displayed and analyzed, and conclusions can be extracted, showing the limitations of the study, and providing recommendations. In view of this frame, the objective of this study is to compare the methodologies used so far in the literature.

3 Methodology

In this work, a systematic literature review of existing studies on S-LCA was performed. Systematic reviews have traditionally been applied in fields and disciplines such as medical science and software engineering [8, 9]. However, its use has also been extended in other fields not necessarily technology-based and empirically founded like engineering. According to the guidelines by [10], a systematic literature review helps to present and evaluate research for a particular field of interest by using a trustworthy, rigorous, and auditable methodology including mainly three phases – planning, conducting, and reporting the review. Following the procedure by [4], we located studies on S-LCA by searching in *Web of Science* and *Scopus* databases. Available English-written, academic peer reviewed documents were collected using the following key words: "SLCA" OR "S-LCA" OR "social LCA". Once dropped duplicated documents because there were present in both databases, a total of 374 academic documents were considered and assessed. A first screening was performed by reading the title and the abstract of documents. Those papers whose title or abstract was not related at all to the S-LCA methodology were thrown out. From this first stage, 70 academic documents were obtained. These 70 papers were then analyzed in their content to select those strictly related with the topic. After this second screening, a total of 52 academic documents were considered as specifically focused on the issue.

4 Analysis and Results

Based on the content analysis, the selected papers were clustered into six main groups which aim to identify common elements and ideas shared across them. Through this process, it has been possible to collect relevant information about the S-LCA concept, trends and methodologies used by different authors. In order to have a representation of variability and lack of standardization currently present in S-LCA methodology, Table 1 was built by using a sample of papers that belong to the same industry (renewable energy) and were published between 2013 and 2021, the span of period in which according to the literature there is an increasing of methodology application. The first column of Table 1 identifies the application of LCSA and then specifically the stages of S-LCA, whereas the column 2 show the subsections that characterize each S-LCA stage. Through the comparison of methodologies employed in each of the papers, it is possible to observe that not all studies include all elements that characterize a detailed analysis. Additionally, the proposed methodology by the authors (currently under development), attempts to fill the gaps that the rest of methodologies leave unattended.

Table 1. Methodology comparison

Stage	Sections	[11]	[12]	[13]	[14]	[4]	[15]	[16]
LCSA	E-LCA y LCC	Yes	No	No	Yes	No	Yes	No
S-LCA PHASE I: Objectives and scope	UNEP/SETAC guidelines	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Functional unit	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Functional unit type	Num	Num	Num	Num	Num	Num	Num
	Functional unit identical to that used in other analyzes	Yes	No	No	Yes	No	Yes	No
	Phases of the life cycle studied	Partial	Partial	Total	Total	Total	Partial	Partial
	Stakeholders*	W, LC, S, VCA	W, LC, S, VCA	W	W, S	W,LC, S	W, LC, S	No exp
	Experts on S-LCA	No	Yes	No	No	No	No	No
	Inclusion of stakeholders	No	No	No	No	No	Yes	No
	Participatory systems	No	Yes	No	No	No	Yes	No
S-LCA PHASE II: Inventory	Choice of indicators used in other studies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Generation of specific indicators	Yes	No	No	No	Yes	Yes	No
	Justification for choosing indicators	No	No	No	Yes	No	No	No
	Use of PRP	Yes	Yes	Yes	Yes	Yes	Yes	No
	Use of specific information available for the study	Yes	Yes	Yes	Yes	Yes	Yes	No
	Generation of information for the study	No	Yes	Yes	No	Yes	Yes	No
	Use of generic databases**	SHDB, PSILCA	No	Yes	SHDB	Yes	Yes	SHDB
	Type of impact evaluation	Type I	Type I	Type I	Type I	Type I	Type I	Type I
S-LCA PHASE III: Impact evaluation	Weighting method	Average weight	Experts evaluation	Numerical	Numerical	Numerical	Numerical	Scaling
	Participation of experts in the weighting method	No	Yes	No	No	No	No	No
	Indicator evaluation criteria***	-2/+2	0/1	0/10	-2/+2	PRP	-5/5	Nº
	Quantitative indicators	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Qualitative indicators	Yes	Yes	Yes	Yes	Yes	Yes	No
	Semi-quantitative indicators	Yes	Yes	Yes	Yes	Yes	Yes	No
	Subjective indicators	No	No	No	No	Yes	Yes	Yes
	Positive and negative indicators	Yes	Yes	Yes	No	Yes	Yes	Yes
	Numerical result	Yes	Yes	Yes	No	Yes	Yes	Yes
S-LCA PHASE IV: Results	Iterative system (values updated more than once)	No	No	No	No	No	No	No

* (W) Worker, (C) Consumer, (LC) Local Community, (S) Society, (VCA) Value Chain Actors;
**(SHDB) Social Hotspots Database, (PSILCA) Product Social Impact Life Cycle Assessment Database;
***(PRP) Performance Reference Point

As it can be inferred in Table 1, there is lack of standardization among the different methodologies that makes challenging their comparison. These differences are due mainly to difficulties in collecting information, assessing different stakeholders and scope. In the proposed methodology, we suggest that the assessment of all stakeholders is key as it can complement the information that could not be obtained through other indicators. It is also possible to appreciate in Table 1 that most of studies apply S-LCA Type I method, which really provides a static image of reality. Through type I method, data are collected over a specific point in time, generating static results which don't allow to generate continuous evaluations. We suggest that the proposed methodology needs to modify indicators, aiming to enhance the assessment of positive impacts and mitigate or cancel the negative ones over time.

5 Conclusions

It is important to consider that S-LCA is a methodology currently under development and that it is becoming more and more relevant, due to the research interest around the subject, as well as its application in industry. For this reason, generating a standardized methodology allows the development and greater application of S-LCA. Through this research, a proposal for a standardized methodology is presented that combines qualitative and quantitative analysis, complementing the work previously carried out by other researchers. Despite the low quantity and quality of existing information to carry out an adequate life cycle analysis from its social component, in most cases it is not possible to apply the impact pathway evaluation method (type II) in deference to the type I methodology or reference scale, developed by UNEP. This prevents showing a relationship between the phenomena and their impact and evaluating the processes or products through reference values with a greater level of detail. In addition, the absence of experts and interest groups is notable in the analyzed bibliography. The fact that they do not participate makes it difficult to identify problems or benefits that arise from the production processes, which is negative for the results of social analysis.

Acknowledgement. The work on this communication has been generated in the framework of the WEDISTRICT project, which received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°857801.

References

1. UNEP: Social Life Cycle Assessment and Life Cycle Sustainability Assessment (2012)
2. Guinée, J.: Life cycle sustainability assessment: what is it and what are its challenges? In: Clift, R., Druckman, A. (eds.) Taking Stock of Industrial Ecology, pp. 45–68. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-20571-7_3
3. Siebert, A., Bezama, A., O'Keeffe, S., Thrän, D.: Social life cycle assessment: in pursuit of a framework or assessing wood-based products from bioeconomy regions in Germany. Int. J. Life Cycle Assess. **23**, 651–662 (2018)
4. Ramos Huarachin, D.A., Moro Piekarski, C., Neves Puglieri, F., de Francisco, A.C.: Past and future of social life cycle assessment: historical evolution and research trends. J. Cleaner Prod. **264**, 121506 (2020)

5. Macombe, C., Loeillet, D., Gillet, C.: Extended community of peers and robustness of social LCA. Int. J. Life Cycle Assess. **23**, 492–506 (2018)
6. UNEP/SETAC: Guidelines for Social Life Cycle Assessment of Product (2009)
7. Garrido, S.R., Parent, J., Beaulieu, L., Reveret, J.-P.: A literature review of type I SLCA - making the logic underlying methodological choices explicit. Int. J. Life Cycle Assess. **23**, 432–444 (2018)
8. Petti, L., Lie Ugaya, C.M., Di Cesare, S.: Systematic review of Social-life Cycle Assessment (S-LCA) case studies (2013)
9. Tranfield, D., Denyer, D., Smart, P.: Towards a methodology for developing evidence-informed management knowledge by means of systematic review. Br. J. Manag. **14**, 207–222 (2003)
10. Brereton, P., Kitchenham, B.A., Budgen, D., Turner, M., Khalil, M.: Lessons from applying the systematic literature review process within the software engineering domain. J. Syst. Softw. **80**(4), 571–583 (2007)
11. Corona, B., San Miguel, G.: Social performance of electricity generation in a solar power plant in Spain—a life cycle perspective. In: Muthu, S.S. (ed.) Social Life Cycle Assessment. EFEPP, pp. 1–57. Springer, Singapore (2019). https://doi.org/10.1007/978-981-13-3233-3_1
12. Aung, T.S., Fischer, T.B., Azmi, A.S.: Social impacts of large-scale hydropower project in Myanmar: a social life cycle assessment of Shweli hydropower dam 1. Int. J. Life Cycle Assess. **26**(2), 417–433 (2021). https://doi.org/10.1007/s11367-021-01868-3
13. Siebert, A., O'Keeffe, S., Bezama, A., Zeug, W., Thrän, D.: How not to compare apples and oranges: generate context-specific performance reference points for a social life cycle assessment model. J. Clean. Prod. **198**, 587–600 (2018)
14. Lobsiger-Kägi, E., López, L., Kuehn, T., Roth, R., Carabias, V., Zipper, C.: Social life cycle assessment: specific approach and case study for Switzerland. Sustainability **10**(12), 4382 (2018)
15. Hsu, C.W., Wang, S.W., Hu, A.H.: Development of a new methodology for impact assessment of SLCA. In: Nee, A., Song, B., Ong, S.K. (eds.) Re-engineering Manufacturing for Sustainability. Springer, Singapore (2013). https://doi.org/10.1007/978-981-4451-48-2_76
16. Holger, S., Jan, K., Petra, Z., Andrea, S., Jürgen-Friedrich, H.: The social footprint of hydrogen production - a social life cycle assessment (S-LCA) of alkaline water electrolysis. Energy Procedia **105**, 3038–3044 (2017)

Understanding the Ripple Effect Through Spreadsheet Simulation

Borja Ponte(✉), María de Arquer, Isabel Fernández, and Raúl Pino

Department of Business Administration, University of Oviedo, Oviedo, Spain
{ponteborja,uo225019,ifq,pino}@uniovi.es

Abstract. The *ripple effect* —i.e., the propagation of disruptions in supply chains— has become a crucial component of supply chain management courses, given its current importance in the industrial sphere. Understanding this dynamic phenomenon is essential to build resilient supply chains that are able to effectively accommodate disruptive events. This paper shows how, despite its complexity, this effect can be fruitfully explored through relatively simple simulation approaches, such as spreadsheets. We explain how to develop a multi-tab spreadsheet to study this effect. We also discuss how students and practitioners can use it to gain insight into the way several parameters and responses impact the magnitude of this phenomenon.

Keywords: Ripple effect · Supply chain management · Simulation · Spreadsheets · Business learning

1 Introduction

Several recent disruptive events with far-reaching consequences have unveiled the lack of resilience of real-world supply chains in most industries (Ivanov 2021). The COVID-19 pandemic is arguably the clearest example of a recent disruptive event, but it is not the only one. We may also refer to Brexit, the grounding of the Ever Given in the Suez Canal or, just now, the Russian invasion of Ukraine.

When one of these events affects a company, causing a disruption in its operations, the disruption tends to propagate along its supply chain. This decreases the performance of its supply chain partners and may leave the consumers or users of the product unsatisfied. This dynamic phenomenon is the so-called *ripple effect* (Dolgui et al. 2018), which is illustrated in Fig. 1 for a simple supply chain. Its simultaneous occurrence in many global supply chains has led to what has already been termed as the 'shortage economy', a problem that has aroused the concerns of modern societies (The Economist 2021).

Due to its current (and expected future) importance, supply chain management courses need to be updated to provide students with the relevant skills and knowledge to prevent the ripple effect from wrecking supply chains. From this perspective, this paper shows how spreadsheet simulation may be an effective tool to explore it. Although this effect is a complex phenomenon whose magnitude is determined by the interactions of various supply chain parameters (including lead times and safety stocks,

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 468–472, 2023.
https://doi.org/10.1007/978-3-031-27915-7_82

among others) and structures, a relatively simple simulation approach allows students to understand how it emerges as well as what countermeasures may be fruitful to build the much-needed supply chain resilience.

After this introduction, the rest of this article is structured as follows. Section 2 explains how we have designed and implemented a spreadsheet to study the ripple effect. Section 3 discusses how students and practitioners can use this simple simulation model to better understand the causes, consequences and solutions for the ripple effect. To this end, we provide a numerical example. Finally, Sect. 4 concludes and suggests interesting avenues for future development.

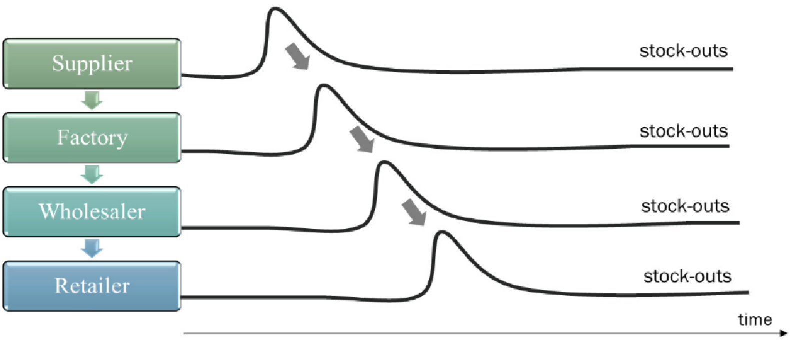


Fig. 1. Simple illustration of the ripple effect in a four-echelon, serial supply chain.

2 Development of the Spreadsheet Model

Spreadsheet simulation has been often used to study and teach students about the complex dynamics of the *bullwhip effect* in supply chains, i.e. the amplification of the variability of orders as they move upstream (see, e.g., Boute and Lambrecht 2009). Similarly, simulation can be very useful to understand and investigate the dynamics of the increasingly important ripple effect. For research purposes, authors have generally employed more complex approaches to address this phenomenon, such as discrete-event and agent-based simulation (Ivanov and Dolgui 2021). For teaching purposes, we claim that spreadsheet simulation is generally the most appropriate alternative, given that most students will feel more familiar with the rationale and functioning of spreadsheets.

We have designed the spreadsheet to model the dynamics of the flow of materials in a supply chain formed by a factory, a retailer, and the consumer, as well as its behaviour in response to a disruption in the factory. We have assumed that the factory and the retailer issue orders according to a periodic-review policy, as these policies are more common in practice. Specifically, we have implemented a proportional order-up-to (POUT) policy in both echelons, given that they are able to provide highly efficient supply chains (Gaalman 2006), and the review period has been defined as one week. Also, we assume that both supply chain nodes forecast according to a moving average, which is a common forecasting method in practice. In addition, the customer demand has been modelled through a random variable that follows a normal distribution. Last, we have modelled a disruption in the factory from week no. 20, where the level of production will be reduced, or even production will be stopped for a limited number of weeks.

In this sense, the following 12 supply chain parameters emerge: production lead time (of the factory), shipping lead time (from the factory to the retailer), mean and coefficient of variation of the consumer's demand, two proportional controllers of the POUT policy (one for each node), two moving average parameters (representing the number of periods considered to forecast by both echelons), two safety stocks (one for each node), duration of the disruption, and capacity of the factory during the disruption period (if it is 0, production will be completely stopped). The values of all these parameters are introduced by the user in the upper part of the first tab (Tab 1 – *Parameters & Metrics*).

The mathematics of the model are introduced in the following three tabs (Tab 2 – *Customer*; Tab 3 – *Retailer*; Tab 4 – *Factory*). In particular, the mathematical model of the supply chain can be formalised as a set of difference equations that include the relationship between the variables that jointly define the state of each supply chain node each week, as well as the dependence with the parameters whose values are introduced by the user in the first tab (see, e.g., Table 4 in Cannella and Ciancimino 2010). Specifically, these state variables are: receipts, initial inventory, demand, satisfied demand, final inventory, backlog, work-in-progress, demand forecast, and order). Each variable is represented in a different column, while the rows identify the different weeks in the simulation model. By way of illustration, Table 1 shows the table of the 'Factory' tab for one of the simulations from week no. 18 to week no. 22 (we note that some columns have been removed for the sake of simplicity).

The system performance is measured through a set of indicators that are also shown in the first tab (Tab 1 – *Parameters & Metrics*). These include metrics that directly quantify the ripple effect —in particular, lost performance and time-to-recovery— and others that evaluate the supply chain performance —fill rate, inventory cover, and bullwhip ratio. These common key performance indicators are useful to evaluate the impact of the ripple effect on the overall supply chain. Also, this tab includes several graphs that allow the user to see how the ripple effect cascades down in the supply chain. By way of example, Fig. 2 shows the shipments from the factory to the retailer and the fill rate in one of the simulation runs. Notice that the consequences of the disruption in the factory on the demand of the customer that is satisfied by the retailer occur a few weeks later.

Table 1. Example of the 'Factory' tab in the spreadsheet simulation model.

Week (t)	Receipt (r)	Demand (d)	Satisfied (s)	Inventory (i)	Order (o)
18	64	108	108	2	101
19	101	76	76	27	86
20	0	78	27	0	128
21	0	135	0	0	226

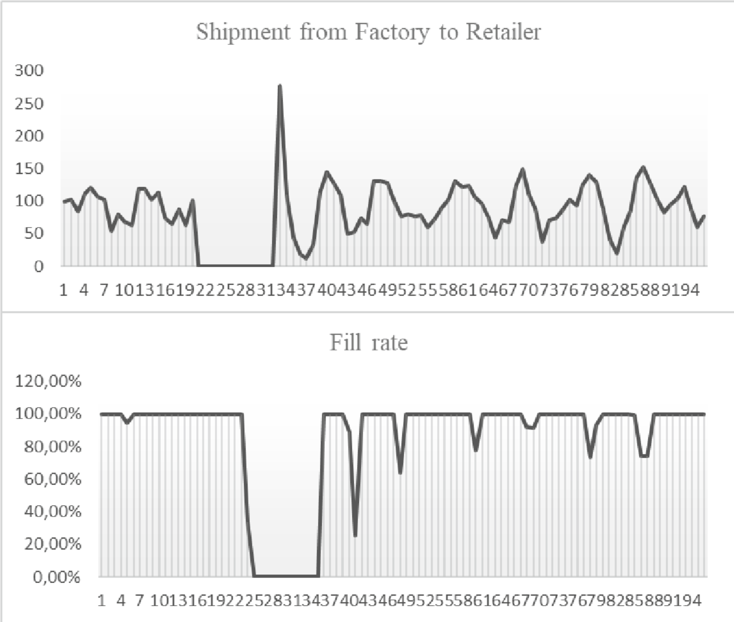


Fig. 2. Evolution of the shipments and the fill rate in a 100-week simulation run.

3 Usage of the Spreadsheet Model

Keeping the parameters and metrics in a different tab from the mathematics of the model facilitates the user's control of the simulation runs and the analysis of the results. In this sense, users can easily perceive the effect of changes in the value of the parameters on the key performance indicators that have been defined. To this end, the user may want to use new tabs to store the results of the simulation runs in sensitivity analyses or experimental designs, for instance. We also note that our spreadsheet includes another tab (Tab 5 –*V&V*) with the validation and verification of the model according to standard practices; see Kleijnen (1995).

The model can be easily used to perform sensitivity analyses aimed at evaluating the impact of some of the parameters on the ripple effect and the overall performance of the supply chain (in Tab 6 - *Results*).

4 Conclusions

"*Tell me, and I will forget; show me, and I may remember; involve me, and I will understand*". This quote, generally attributed to the ancient Chinese philosopher Confucius, strongly resonates today in the discipline of supply chain learning. Games and simulations, such as the well-known Beer Game, are widely proven to be effective teaching and learning instruments. They allow students to perceive the complex dynamics of supply chains and may also help practitioners to re-evaluate their way of thinking and improve their problem-solving skills.

From this perspective, simple simulation models, such as those developed in spreadsheets, may be particularly useful to understand the underlying mechanisms behind the increasingly important ripple effect in supply chains. Experimenting with these simulation models allows students to evaluate the impact of the relevant parameters and test different solutions. This turns learning into an exploratory process that helps them consolidate the key ideas in a stronger way than traditional teaching methods, as advocated by the previous quote.

The spreadsheet that we have developed in this work focuses on a simple supply chain with two echelons in series, besides the consumer. The same procedure may be applied to study the ripple effect in more complex supply chain structures. This would allow users to test several well-known solutions to mitigate the ripple effect in supply chains, including dual sourcing, backup facilities, or postponement, which would be an interesting next step.

Acknowledgements. This work was financially supported by the State Research Agency of the Spanish Ministry of Science and Innovation (MCIN/AEI/10.13039/501100011033), via the project "Speeding Up the transition towards Resilient circular economy networks: forecasting, inventory and production control, reverse logistics and supply chain dynamics" (SPUR, grant ref. PID2020-117021GB-I00).

References

Ivanov, D.: Introduction to Supply Chain Resilience: Management, Modelling, Technology. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-70490-2

The Economist: The shortage economy–The world economy's shortage problem, 9 October 2021. https://www.economist.com/leaders/2021/10/09/the-world-economys-shortage-problem

Dolgui, A., Ivanov, D., Sokolov, B.: Ripple effect in the supply chain: an analysis and recent literature. Int. J. Prod. Res. **56**(1–2), 414–430 (2018)

Boute, R.N., Lambrecht, M.R.: Exploring the bullwhip effect by means of spreadsheet simulation. INFORMS Trans. Educ. **10**(1), 1–9 (2009)

Ivanov, D., Dolgui, A.: OR-methods for coping with the ripple effect in supply chains during COVID-19 pandemic: managerial insights and research implications. Int. J. Prod. Econ. **232**, 107921 (2021)

Gaalman, G.: Bullwhip reduction for ARMA demand: the proportional order-up-to policy versus the full-state-feedback policy. Automatica **42**(8), 1283–1290 (2006)

Cannella, S., Ciancimino, E.: On the bullwhip avoidance phase: supply chain collaboration and order smoothing. Int. J. Prod. Res. **48**(22), 6739–6776 (2010)

Kleijnen, J.P.: Verification and validation of simulation models. Eur. J. Oper. Res. **82**(1), 145–162 (1995)

FRAM in the Construction Sector

José Marcelo Tierra-Arévalo(✉), María del Carmen Pardo-Ferreira, Virginia Herrera-Pérez, and Juan Carlos Rubio-Romero

School of Industrial Engineering, Universidad de Málaga, C/Dr. Ortiz Ramos s/n (Teatinos), 29071 Málaga, Spain
{josetierra,carmenpf,juro}@uma.es, virginia.herrera.p@gmail.com

Abstract. In this study, a literature review about the application of the Functional Resonance Analysis Method (FRAM) in the construction sector is performed. Complex Sociotechnical Systems (CSS) require accurate tools from Resilience Engineering (RE) to determine the variability in the system and adjust its performance to the reality of the construction sector. The databases reviewed were: Scopus, Wos, ScienceDirect and PubMed with the guidance of the PRISMA methodology, using the following advanced search criteria by title, abstract and key words. The RE was presented as an alternative to remedy safety deficiencies in construction and with FRAM it was proposed to improve safety deficiencies and even in combination with other tools would help to control variability to manage CSS. The contributions of FRAM would serve as a solid basis for an in-depth and systematic analysis of the daily performance in the construction sector.

Keywords: Complexity · Safety II · Tools · FRAM · Construction

1 Introduction

1.1 Background

The difficulty of understanding the constant behavior of processes makes them complex [1] hence, they are called Complex Sociotechnical Systems (CSS) [2] that most of the time work well but rarely fail [3] and which have become a factor of interest in many areas [4].

The support of systems engineering it has been proposed to build meta models [5] or as in the case of the Functional Resonance Analysis Method (FRAM) support for the proposal of a software that helps to handle this complexity and allows to safely manage the system [6] or also in combination with other tools [7].

Safety is associated with freedom from harm and all safety management focuses on reducing or eliminating adverse elements [8] considering that systems are variable [9] and processes are non-linear, there is a holistic approach to analyzing the things that went wrong and also the things that went right [10].

Therefore, the main difference between Safety I and Safety II is that Safety I focuses on failures while Safety II focuses on both failures and successes and tries to make sure

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 473–477, 2023.
https://doi.org/10.1007/978-3-031-27915-7_83

that the day-to-day processes run smoothly most of the time with tools to measure and evaluate them [8].

It is precisely here that Resilience Engineering (RE) takes this approach that things that go right and things that go wrong come from the same source [8, 11], and thus becomes a paradigm shift [12] of safety management to deal with the complexity of CSS trying to balance productivity and safety in daily work [13].

Some of the tools used by the RE to work on complexity in CSS may include the following: Critical Incident Technique (CIT), Critical Decision Method (CDM), Resilience Analysis Grid (RAG) [14], State Assessment Tool (SAT) [1], FRAM [8], Analytic Hierarchy Process (AHP) [15], Metamodel of Sociotechnical System Processes (MSSP) [5] and Technical, Organizational and Environmental (TOE) Framework [16].

Sectors such as oil and gas, healthcare, air traffic management, aviation, maritime, subsea, as well as construction are increasingly involved in complexity analysis to manage the variability of CSS [1, 5, 8, 14–16].

The construction industry is characterised by high levels of occupational accidents [17], constant changes, deteriorating working conditions, temporary jobs that require coordination at different levels from contractors, subcontractors to operators who are exposed to different risks that need to be quantified [18].

Therefore, in the construction sector, it is proposed to conceptualise resilient safety culture by integrating the principles of RE [19] with tools suitable for CSS [20] to provide construction organisations with a framework of safety practices to assess site safety management capabilities [21].

2 Related Works

In 2009, accidents in the construction sector were seen as a linear succession of causes and risks as elements arising from unreliable components such as operators and technology, to remedy the shortfalls of construction safety RE was introduced as a new and proactive approach to safety management that analysed FRAM in a given scenario [12].

In 2014, it was proposed to analyse the variability from a comparative point of view between the characteristics of Lean Construction (LC) with the Value Stream Mapping (VSM) and RE with FRAM, where opportunities for joint improvement were identified [22].

In 2015 a combination of FRAM with AHP was presented where it was highlighted that unexpected results were not necessarily failures, which allowed the identification of phenotypes of performance variability as well as the aggregation of variability in safety performance that could even assess the sustainability of the construction because safety is seen here as a fundamental part of sustainability [23].

In the same year it was highlighted that the construction sector is a typical example of a CSS with multiple contractors and work groups subject to constant unforeseen events that can affect their safety, therefore FRAM determines how the coupling of functions, plus the variability of performance, plus malfunctioning creates an occupational hazard [18].

In 2016 FRAM provided a constructive means to communicate and develop strategies to support the ongoing practice of human-centred design of an asphalt truck for road construction to monitor and optimise performance and system [24].

In the same year and although the control of variability is a fundamental theme of the LC, the FRAM results pointed to the fact that the impact of small intentional or unintentional changes in the functions involved could be anticipated [25].

In 2017 a combination of FRAM with AHP, allowed for the recognition of potential out-of-control situations that led to the improvement of CSS indicators that could be used to assess and quantify performance variability [26].

This combined technique could help to assess performance variants that could lead to occupational or environmental accidents and suggest how processes should operate in a way that minimises production losses and accidents [26].

The combination of FRAM with AHP allowed in the first instance with FRAM to assess the potential variability, couplings and barriers to dampen this variability and with AHP to prioritise these different functions [27].

In order to improve the management of resilient safety in the construction of concrete structures in 2020 with the application of FRAM, it was determined that the delivery of in-situ concrete and crane operations were key factors in variability and issues were highlighted that had not been appreciated until that time [28].

3 Methods

The databases reviewed were: Scopus, Wos, ScienceDirect and PubMed with the guidance of the PRISMA methodology, using the following advanced search criteria by title, abstract and key words: “Functional Resonance Analysis Method” OR “Functional Resonance Analysis Model” OR “FRAM” OR “F.R.A.M” AND “Construction”.

4 Results and Conclusions

The RE approach differed from traditional views that considered accidents as a linear succession of causes which, due to the complexity of the construction sector, is proposed as an alternative to remedy its shortcomings.

The combination of tools for variability analysis identified opportunities for learning and improvement originating from the RE to the LC.

The combination of FRAM and AHP could assess the sustainability of construction by highlighting that unexpected outcomes are not only failures as had been considered in traditional safety.

Given the dynamism characteristic of the construction sector due to the complex coupling of its activities, FRAM could be applied instead of traditional tools to assess CSS.

Mapping the interrelated FRAM functions could help to develop strategies to control and optimise system performance by allocating the necessary resources and suggesting the appropriate management activities according to the realities of the CSS.

Resonance analysis in FRAM would allow to control the variability in CSS and in combination with AHP, which could recognise possible out-of-control situations, would allow to improve the indicators.

The application of FRAM visualises key factors of CSS variability that have not been considered before, presenting a solid and reliable basis for a thorough and systematic analysis of daily performance in the construction sector.

5 Acknowledgments

Special thanks to the "Ministerio de Ciencia e Innovación del Gobierno de España" and the "Programa Estatal de Generación de Conocimiento y Retos de la Sociedad" for funding the project: PID2020-114502GB-I00; entitled: "Complejidad y resiliencia: Un enfoque sistémico para la monitorización y mejora de la gestión de la seguridad en la construcción".

References

1. Patriarca, R., Di Gravio, G., Costantino, F.: Resilience engineering to assess risks for the air traffic management system: a new systemic method. Int. J. Reliab. Saf. **10**(4), 323–345 (2016). https://doi.org/10.1504/IJRS.2016.084477
2. Ham, D.H.D.-H.: Safety-II and resilience engineering in a nutshell: an introductory guide to their concepts and methods. Saf. Health Work (2021). https://doi.org/10.1016/j.shaw.2020.11.004
3. Martins, J.B., Carim, G., Saurin, T.A., Costella, M.F.: Integrating Safety-I and Safety-II: learning from failure and success in construction sites. Saf. Sci., **148**, 105672 (2022). https://doi.org/10.1016/j.ssci.2022.105672
4. MacKinnon, R.J., Pukk-Harenstam, K., Kennedy, C., Hollnagel, E., Slater, D.: A novel approach to explore Safety-I and Safety-II perspectives in in situ simulations-the structured what if functional resonance analysis methodology. Adv. Simul. (London, England) **6**(1), 21 (2021). https://doi.org/10.1186/s41077-021-00166-0
5. Said, S., Bouloiz, H., Gallab, M.: A new structure of sociotechnical system processes using resilience engineering. Int. J. Eng. Bus. Manag. **11**, 184797901982715 (2019). https://doi.org/10.1177/1847979019827151
6. Carvalho, E.A., Gomes, J.O., Jatobá, A., Silva, M.F., Carvalho, P.V.R.: Software requirements elicitation for complex systems with the Functional Resonance Analysis Method (FRAM) (2021). https://doi.org/10.1145/3466933.3466950
7. Qiao, W., Li, X., Liu, Q.: Systemic approaches to incident analysis in coal mines: comparison of the STAMP, FRAM and '2–4' models. Resour. Policy **63**, 101453 (2019). https://doi.org/10.1016/j.resourpol.2019.101453
8. Hollnagel, E.: Safety-II in practice: developing the resilience potentials. In: Safety-II Practice Developing the Resilience Potentials, pp. 1–130, January 2017. https://doi.org/10.4324/9781315201023
9. Rutkowska, P., Krzyzanowski, M.: FRAM modelling of the transfer of control over aircraft. Sci. J. Sılesıan Univ. Technol. Transp. **101**, 159–166 (2018). https://doi.org/10.20858/sjsutst.2018.101.15
10. Ratnitsky, A., Havranek, J., Mohr, G.L., Rüther-Wolf, K., Schwendimann, R.: Safety-II in daily clinical practice. Z. Evid. Fortbild. Qual. Gesundhwes. **162**, 10–15 (2021). https://doi.org/10.1016/j.zefq.2021.02.003
11. Costella, M.F., Stanisci, R.B., Martins, J.B., Lantelme, E.M.V., Pilz, S.E.: Exploring Safety-II in practice: a case study of the construction industry. Int. Rev. Civ. Eng. **12**(2), 69–77 (2021). https://doi.org/10.15866/irece.v12i2.19385
12. Schafer, D., Abdelhamid, T.S., Mitropoulos, P., Mrozowski, T.: Resilience engineering: A new approach for safety managment. In: Building a Sustainable Future - Proceedings of the 2009 Construction Research Congress, pp. 766–775 (2009). https://doi.org/10.1061/41020(339)78

13. Patriarca, R.: resilience engineering for sociotechnical safety management. In: Multisystemic Resilience: Adaptation and Transformation in Contexts of Change, Department of Mechanical and Aerospace Engineering, Sapienza University, Rome, Italy, pp. 477–492 (2021)
14. Hegde, S., Hettinger, A.Z., Fairbanks, R.J., Wreathall, J., Wears, R.L., Bisantz, A.M.: Knowledge elicitation for resilience engineering in health care. Proc. Hum. Factors Ergon. Soc. **2015**, 175–179 (2015). https://doi.org/10.1177/1541931215591036
15. Falegnami, A., et al.: A multicountry comparative survey about organizational resilience in anaesthesia. J. Eval. Clin. Pract. **24**(6), 1347–1357 (2018). https://doi.org/10.1111/jep.13054
16. Peñaloza, G.A., Saurin, T.A., Formoso, C.T.: Monitoring complexity and resilience in construction projects: the contribution of safety performance measurement systems. Appl. Ergon. **82**, 102978 (2020). https://doi.org/10.1016/j.apergo.2019.102978
17. Machfudiyanto, R.A., Latief, Y., Robert: Critical success factors to ımprove safety culture on construction project in Indonesia. IOP Conf. Ser. Earth Environ. Sci. **258**(1), 012016 (2019). https://doi.org/10.1088/1755-1315/258/1/012016
18. Rosa, L.V., Haddad, A.N., de Carvalho, P.V.R.: Assessing risk in sustainable construction using the Functional Resonance Analysis Method (FRAM). Cogn. Technol. Work **17**(4), 559–573 (2015). https://doi.org/10.1007/s10111-015-0337-z
19. Trinh, M.T., Feng, Y.: Measuring resilient safety culture of construction projects. In: Arezes, P.M.F.M. (ed.) AHFE 2018. AISC, vol. 791, pp. 580–586. Springer, Cham (2019). https://doi.org/10.1007/978-3-319-94589-7_56
20. Di Gravio, G., Costantino, F., Falegnami, A., Patriarca, R.: Actionable safety analyses in socio-technical systems with myFRAM. In: 2019 4th Internatıonal Conference On System Relıabılıty And Safety(ICSRS 2019), pp. 504–508 (2019)
21. Trinh, M.T., Feng, Y., Mohamed, S.: Framework for measuring resilient safety culture in Vietnam's construction environment. J. Constr. Eng. Manag. **145**(2), 04018127-1–04018127-12 (2019). https://doi.org/10.1061/(ASCE)CO.1943-7862.0001602
22. Saurin, T.A., Sanches, R.C.: Lean construction and resilience engineering: Complementary perspectives of variability. In: 22nd Annual Conference of the International Group for Lean Construction: Understanding and Improving Project Based Production, IGLC 2014, pp. 61–71 (2014)
23. Haddad, A.N., Rosa, L.V.: Construction sustainability evaluation using AHP and FRAM methods. In: IIE Annual Conference and Expo 2015, pp. 556–565 (2015). https://www.scopus.com/inward/record.uri?eid=2-s2.0-84971014012&partnerID=40&md5=fcd39eaed6244e1682e42104a9f149ed
24. Pazell, S., Burgess-Limerick, R., Horberry, T.: Application of functional resonance analysis method to sustain human-centered design practice in road construction. In: Proceedings of the Human Factors and Ergonomics Society, pp. 875–879 (2016). https://doi.org/10.1177/1541931213601200
25. Saurin, T.A.: The FRAM as a tool for modelling variability propagation in Lean Construction. In: IGLC 2016 - 24th Annual Conference of the International Group for Lean Construction, pp. 3–12 (2016)
26. Rosa, L.V.L.V., França, J.E.M.J.E.M., Haddad, A.N.A.N., Carvalho, P.V.R.P.V.R.: A resilience engineering approach for sustainable safety in green construction. J. Sustain. Dev. Energy, Water Environ. Syst. **5**(4), 480–495 (2017). https://doi.org/10.13044/j.sdewes.d5.0174
27. Alboghobeish, A., Shirali, G.A.: Integration of functional resonance analysis with multicriteria analysis for sociotechnical systems risk management. Risk Anal. (2021). https://doi.org/10.1111/risa.13796
28. del Carmen Pardo-Ferreira, M., et al.: Using functional resonance analysis method to understand construction activities for concrete structures. Saf. Sci. **128**, 104771 (2020). https://doi.org/10.1016/j.ssci.2020.104771

Does the Firm's Size Matter on Organizational Resilience?

José Sevilla Ruiz[1](✉), Adolfo López-Paredes[2], and José Juan Nebro Mellado[2]

[1] Universidad de Valladolid, Valladolid, Spain
pepe.sevilla@uma.es
[2] Universidad de Málaga, Málaga, Spain
{loppar,jjnm}@uma.es

Abstract. In this paper we analyze any kind of relationship between the firm's size and the organizational resilience. First, we present two existing frameworks of organizational resilience that propose a set of resilience indicators. Then we discuss on data published by the Spanish Institute for the Statistics if the firm's size has been a relevant factor for organizational survival during the last two world economic crisis: 2008 financial crisis and the recent COVID 19 pandemic.

Keywords: Organizational resilience · Indicators · Models · Firm

1 Introduction

Reviewing the resilience indicators proposed by some authors such as McManus, Werner and Twigg [1–3] we realized that all of them are high order constructs or fuzzy concepts that are hard to define and to measure. Surprisingly, a simple, empirical and directly measurable indicator as it is the size (in the sense of its number of employees) of the community or the organization is not directly considered. The aim of this paper is to explore if the organization's size can be a factor that contributes to the organization's resilience.

To achieve our goal first, we will make a small review of two of the most significant resilience frameworks. Secondly, we will present some research and statistical information that we think is relevant to our purpose and later we will discuss on it. Finally, we will expose our conclusions and some further research suggestions.

2 Resilience Frameworks Review

As a starting point we will focus on two resilience frameworks proposed the first one in 2007 [1] and the second one in 2021 [2]. The reasons why we have chosen those frameworks are that, first of all, the first framework is widely regarded as one of the most relevant resilience frameworks, with more than 1000 citations of the paper and it subsequent works, and, secondly, the last one takes into account some of the latest proposals in the organizational resilience researches, so we think the last 14 years of research on organizational resilience are considered.

The following table shows the relationship between the indicators proposed by the two works and if they are directly measurables or not (Table 1).

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 478–481, 2023.
https://doi.org/10.1007/978-3-031-27915-7_84

Table 1. McManus and Werner resilience indicators. M states for Directly Measurable.

	McManus	M	Werner	M
1	Roles and responsibilities	No	Agility	No
2	Understanding hazard	No	Collaboration	No
3	Connectivity awareness	No	Information sharing	No
4	Insurance awareness	No	Trust	No
5	Recovery priorities	Yes	Supply chain design	No
6	Planning strategies	No	Flexibility	No
7	Participation in exercises	Yes	Financial strength	No
8	Capability and Capacity of Internal Resources	No	Knowledge management	No
9	Capability and Capacity of External Resources	No	Redundancy	Yes
10	Organizational Connectivity	No	Robustness	No
11	Silo Mentality	No	Security	No
12	Communications and Relationships	No		
13	Strategic Vision and Outcome Expectancy	No		
14	Information and Knowledge	No		
15	Leadership, Management and Governance Structures	No		

We can see that no simple, empirical and directly measurable indicators are proposed by none of the authors. Most of them are higher order or fuzzy constructs that in the best cases can only be indirectly estimated.

3 Discussion

The fact that the reviewed frameworks expose relevant indicators for the organizational resilience study is not under discussion. Both works present statistical evidence that support the relevance of those concepts. What we present here is the fact that the indicators proposed by the frameworks shock with the authors' professional careers and experience in a few private companies for over 25 years, spanning from the dot com bubble in the early 2000 to the 2019 COVID pandemic and including the 2008 financial crisis. Our experience suggest that the size of the organizations is relevant from the point of view of the business continuity and the way the organization handles the uncertainty. It is not a complex or fuzzy concept and, obviously, it can be directly measured, so it is surprising for us that such a simple indicator is not considered in any of the two mentioned frameworks (nor in any other considered for the writing of this paper but omitted for the shake of concision).

Our hypothesis is supported by two facts. First, according to the OECD [4] 70% to 80% of small and medium business in all over 32 countries has lost between the 30% and the 50% in its revenues. Bigger companies have experience a less severe impact, but the main difference can be seen on the world leading companies. Following that paper in the U.S. the 10% biggest companies had a flat economic result between the third quarters of 2019 and 2020. On the same period, the rest of the companies fall by a 11%.

The second fact can be shown in the following table. It shows the percentual variation in the active companies is Spain in the years 2009–2013 and 2021 according to the information available at the Spanish National Institute for Statistics.

Table 2. Active companies' variation in Spain by its employee number.

Employees	2021	2013	2012	2011	2010	2009
1–2	1.45%	6.35%	2.31%	−5.05%	−2.84%	−4.13%
3–5	−0.62%	−2.86%	−7.82%	−1.49%	−4.36%	−3.81%
6–9	−3.70%	−5.24%	−4.42%	−3.48%	−5.43%	−5.75%
10–19	−7.10%	−6.21%	−6.74%	−4.03%	−13.00%	−7.94%
20–49	−8.87%	−8.27%	−6.69%	−5.34%	−12.36%	−9.83%
50–99	−9.91%	−7.52%	−4.36%	−3.39%	−8.82%	−7.19%
100–199	−3.63%	−4.72%	−2.29%	−7.23%	−7.48%	−4.83%
200–999	−2.38%	4.48%	−1.47%	−2.66%	−5.67%	−18.51%
1000–4999	−1.48%	−3.89%	−1.47%	4.30%	−3.98%	−6.48%
>5000	−0.58%	−3.81%	−1.87%	5.94%	−9.01%	−0.89%

The information displayed on the table is coherent with the OECD report and there can be shown that the small and medium size companies suffer more severely the adverse economic conditions and the biggest companies, usually, surf in a more tranquil water.

4 Conclusions and Further Research

According to what we have presented we think it is reasonable to consider the organization's size as a relevant factor when studding the organizational resilience. The OECD report and the Spanish statistics of active companies show clearly that the biggest companies are less prone to interrupt their activity than the medium and small size and they are a direct support to our proposal: The size of the organization (in terms of its number of employees) is a relevant issue for the organizational resilience.

The reason why the organization's size seems to be a relevant issue on facing the adversity, and thus have a direct impact on the organization resilience, is not the purpose of this paper. We just wanted to point out that the common approach on the literature when identifying the factors that are committed in the resilient capacity of the organizations lead to models and constructs that are hard to use and with little practical utility. In addition, we suggest that is because the indicators and constructs used to model the resilience that the frameworks are too fuzzy and abstract and with little practical use.

Future work has to be done to fully prove the hypothesis about the firm's size relevance on the organizational resilience. The firm's survival data analysis must be extended to cover as long as possible and it should include more regions and countries. As there may not be enough information available due to the lack of registers an extensive literature analysis should be done. There is a large number works focused on the death of firms in different countries that can provide evidences to support the initial hypothesis. Two examples of this kind of works can are the papers from Franco and Box [5, 6], which present firm survival data in Germany and Sweden.

Our professional experience made us think that there may be some other empirical and easily measurable indicators that can be used to address the study of the organizational resilience and additional future research can be done in analyzing if any of the higher order constructs proposed on the resilience frameworks can be split into more fine-grained and measurable items because one can infer that the organization's size is related with some of the indicators proposed in the reviewed frameworks.

Finally, according to the Table 2 companies with less than 5 employees present even a better continuity ratio than the big ones. This can be due to the fact that the creation of really small companies is faster and more frequent than bigger ones. Future research is needed to clarify if that is the case or, conversely, the smallest companies survive more and perform better than the medium ones on extremely adverse conditions.

References

1. McManus, S., Seville, E., Brunsdon, D., Vargo, J.: Resilience management. A framework for assessing and improving the resilience of organisations, Christchurch, New Zealand (2007)
2. Werner, M.J.E., Yamada, A.P.L., Domingos, E.G.N., Leite, L.R., Pereira, C.R.: Exploring organizational resilience through key performance indicators. J. Ind. Prod. Eng. **38**, 51–65 (2021). https://doi.org/10.1080/21681015.2020.1839582
3. Twigg, J.: Characteristics of a disaster-resilient community: a guidance note (version 2) (2009)
4. OECD: One year of SME and entrepreneurship policy responses to COVID-19: Lessons learned to "build back better": OECD (2021)
5. Franco, C., Weche Gelübcke, J.P.: The death of German firms: what role for foreign direct investment? World Econ. **38**, 677–703 (2015)
6. Box, M.: The death of firms: exploring the effects of environment and birth cohort on firm survival in Sweden. Small Bus. Econ. **31**, 379–393 (2008)

Reference Optimisation Models for Facility Layout Planing in the Metal-Mechanic Industry

Pablo Perez-Gosende[1,2], Josefa Mula[1](✉), and Manuel Diaz-Madroñero[1]

[1] Research Centre on Production Management and Engineering (CIGIP), Universitat Politècnica de València, Alarcón, 1, 03801 Alcoy, Alicante, Spain
pabpego3@doctor.upv.es, {fmula,fcodiama}@cigip.upv.es
[2] Universidad Politécnica Salesiana, Guayaquil, Ecuador

Abstract. In recent years, the layout of industrial plants has been a much-discussed topic in the scientific literature. However, many of the optimisation models used to formulate the problem have been applied to hypothetical test instances by adopting simplifications of reality, which makes their application in the metal-mechanic industries difficult. In this context, the present article presents a set of five optimisation models that can constitute a reference framework for creating an optimisation model that applies to case studies in the metal-mechanic sector.

Keywords: Facility layout planning · Optimisation model · Multi-objective modelling · Dynamic layout · Metal-mechanic industry

1 Introduction

Facility layout planning (FLP) involves the process of finding the best arrangement scheme for the elements making up the production system so that certain relevant qualitative and quantitative factors are satisfied [1]. Given its importance and its impact on organisations' productivity and competitiveness, FLP is an important stream of research in the production management and industrial engineering field [2]. However, contributions to solve FLP have barely been applied in practice [3]. This is mainly because most of the contributions available in the literature have concentrated on finding solutions to the problem by considering test instances or hypothetical case studies [1, 4].

The situation described above particularly affects metal-mechanic industries. A recent review has shown that of the 232 articles indexed in the Web of Science (WoS) for the 2010–2019 time window, approximately 20% have addressed real case studies, of which only five have dealt with case studies in the metal-mechanic sector [1].

In this context, the present article seeks to analyse optimisation models that can constitute a reference framework for creating a new optimisation model that facilitates layout planning decisions in metal-mechanic companies.

The article is organised as follows. Section 2 presents the strategy to follow to select reference optimisation models, as well as the considered inclusion criteria. Section 3 shows a comparative analysis between the selected reference models. Finally, Sect. 4 ends with the conclusions drawn from the study.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 482–487, 2023.
https://doi.org/10.1007/978-3-031-27915-7_85

2 Collection of Reference Models

The starting point to identify relevant reference models was the literature review by Pérez-Gosende et al. [1]. It includes an analysis of the mathematical optimisation models for the different FLP variants in 209 research articles of the 232 articles published in the journals indexed in the WoS. The purpose is to identify good practices in formulating FLP as a mathematical optimisation problem that can: serve as a reference to formulate a new optimisation model to fit the operating conditions of the metal-mechanic industries; facilitate FLP decision making for these companies in practice.

When modelling the FLP as an optimisation problem, it is possible to consider that departments have the same area or have unequal areas [5]. The first case, usually modelled by discrete optimisation models such as the quadratic assignment problem (QAP) [6], applies to very few real manufacturing systems. Specifically, planning the layout in the metal-mechanical sector assuming equal-area departments when they are not can generate solutions with total material handling costs (TMHC) significantly lower than those incurred in reality. Hence, it is crucial to consider the departments' actual dimensions according to the operations that will take place in them. In those cases, considering unequal-area departments when formulating the FLP, optimisation models allowing layout representation in the continuous space are generally used [7, 8], enabling operating conditions simulation closer to reality.

Taking into account the arguments mentioned above, the inclusion criteria considered in the models' selection were to: (1) be recently published (time window: from 2010 to date); (2) include elements aligned with the operating conditions of metal-mechanic industries, such as rectangular and unequal-area departments; (3) address the plant layout representation in the continuous space.

The selected reference models were then characterised according to the following analysis criteria defined in [1]: planning approach (static FLP or dynamic FLP); planning phase (block or detailed layout); departments' dimensions (fixed, variable or mixed); material handling configuration (single-row, dual-row, parallel-row, multi-row, loop, or open-field configurations); the location of pick-up/drop-off points (on the centroid or the boundary of departments); the representation technique used to allocate departments in the continuous space (slicing tree, sequence-pair representation, flexible bay structure); model type; objective function type (single- or multi-objective); and the objective function description.

3 Comparative Analysis

The five selected benchmark optimisation models by applying the inclusion criteria were: Meller et al. [3], McKendall et al. [7], Mazinani et al. [8], Abedzadeh et al. [9] and Jolai et al. [10]. The results of comparing these models according to the previously mentioned analysis criteria are summarised in Table 1.

Meller et al. [3] presented an MINLP model to address the unequal-area FLP by considering sequence-pair representation to avoid overlapping departments in the continuous space. This model introduced a novel layout planning approach called the bottom-up approach, which addresses the two classic phases in layout planning, namely block layout (BL) and detailed layout (DL), in reverse to the traditional top-down approach, and in a more aligned way to how this process is conceived by layout planners in practice [11]. However, one of the model's disadvantages is to assume that product demand is deterministic and known in advance. As product demands do not vary over time, a single layout consequently is obtained for the entire time planning horizon, which is known in the literature as the static facility layout problem (SFLP) [12]. These assumptions can be impractical in most industrial sectors, including metal-mechanic, because the demand, and therefore, the flow of materials are often uncertain and time-varying. In an increasingly globalised business environment, it is more realistic to consider dynamic conditions [13], mainly due to the constant need to readjust production capacity because of fluctuations in demand, shorter product life cycles, the adoption of technological changes in manufacturing systems, and disruptive events in supply chains, among other factors.

Table 1. Reference models' characteristics.

References	Planning approach	Planning phase	Dept. Dimensions	Material handling configuration	P/D points location	Representation technique	Model type	Objective function type	Objective function description
Meller et al. [3]	S	B, D	V	OF	C	SP	MINLP	SO	a
Mckendall et al. [7]	D	B	F	OF	C	–	MILP	SO	a, b
Mazinani et al. [8]	D	B	M	MR	C	FBS	MILP	SO	a, b
Abedzadeh et al. [9]	D	B	V	MR	C	FBS	MILP	MO	a, b, c, d
Jolai et al. [10]	D	B	F	OF	B	–	MINLP	MO	a, b, d, e

Note: Planning approach: SFLP (static FLP), DFLP (dynamic FLP); planning phase: B (block layout), D (detailed layout); departments´ dimensions: F (fixed), V (variable), M (mixed); Material handling configuration: MR (multirow configuration), OF (open-field configuration); P/D points location: C (on the centroid of departments), B (on the boundary of departments); Representation technique: SP (sequence-pair representation), FBS (flexible bay structure); Model type: MINLP (mixed-integer non-linear programming), MILP (mixed-integer linear programming); objective function type: SO (single-objective), MO (multi-objective); objective function description: a (minimise total material handling cost, TMHC), b (minimise total rearrangement cost, TRAC), c (minimise aspect ratio), d (maximise total closeness rating, TCR), e (maximise distance requests)

Another of the model's limitations is to consider the minimisation of the TMHC as a single objective function. It is common to use the cost of materials handling between each department or workstation as a single-objective function of a quantitative nature [2]. However, FLP is a multi-objective problem given the many quantitative and qualitative factors involved in the final decision [13, 14]. These include, in addition to the cost of materials handling, occupational health and safety, the handling of waste and hazardous substances, staff satisfaction, and flexibility for future distribution, among others. Along the same line, another of the model's characteristics that limits its application to companies in the metal-mechanic sector is the consideration that P/D points are located at the centroid of departments, and not on their edges or borders, which is generally the case in reality. This assumption may generate suboptimal solutions with significantly lower TMHCs than those that incur in real situations.

McKendall et al. [7] presented an MILP optimisation model that addresses only the BL phase, but considers dynamic demand conditions in line with the reality of many industrial sectors, such as the metal-mechanic industry. Based on this approach, and known in the literature as DFLP, an optimal layout for each period that makes up the time planning horizon is sought so that the TMHC and total rearrangement cost (TRAC) are minimised [15–17]. This models' limitations include its single-objective nature and the sole consideration of the BL planning phase and P/D points located at the centroids of departments.

Mazinani et al. [8] also presented an MILP model for BL planning in DFLP. It considers a flexible bay structure (FBS) as a technique to allocate departments on the continuous plant floor to avoid them overlapping. First introduced in [18], the FBS allows the placing of departments in parallel horizontal or vertical bands (called bays) of variable width along the available floor space. The width of each bay depends on the total area of the departments in the bay, and all departments located in each bay must have the same width, which limits the number of possible layout configurations [19].

The latter model's limitations include its single-objective nature, the aforementioned limitations of the FBS, the sole consideration of the BL planning phase, not considering demand uncertainty and the location of P/D points at the centroids of departments.

The MILP model introduced by Abedzadeh et al. [9] approaches the unequal-area DFLP through the FBS from a multi-objective perspective which, in addition to minimising TMHC and TRAC, seeks to minimise the aspect ratio of departments and to maximise TCR. The latter objective function is based on subjective criteria defined by the analyst that are difficult to quantify. In layout planning, these considerations, expressed on an ordinal qualitative rating scale, should be satisfied to the greatest extent possible. The TCR aims to bring the most relation-intensive departments closer together in the final allocation scheme by guaranteeing the principle of circulation; the safety and satisfaction of the workforce; the minimum distance covered by the flow of materials, transport means and personnel; among other factors. This feature would be very useful to consider when making layout decisions in metal-mechanic companies since, in addition to the costs associated with the material handling system, a more significant degree of flexibility for future changes is needed. Similarly, in metalworking plants, there are mechanical, physical and chemical safety risks that must be minimised when determining the best layout scheme for the departments.

Finally, the model presented by Jolai et al. [10] approaches unequal-area DFLP from a multi-objective perspective. It implies the particularity of considering that the flow of materials occurs between the P/D points located on the edges of departments. In this way, the model better simulates the operating conditions of metal-mechanical companies and minimises the risk of generating solutions with far from real TMHC values.

4 Conclusions

This article addresses five mathematical optimisation models that can serve as a reference for determining a mathematical optimisation model, which best fits the actual context of the metal-mechanic industrial sector and facilitates facility layout decision making.

After the comparative analysis, it can be concluded that a mathematical optimisation model for facility layout decision making in the metal-mechanic sector must meet the following technical specifications at least: (i) be dynamic (i.e., by considering several periods as part of the planning horizon in response to demand variability); (ii) start from demand forecasts under uncertainty conditions; (iii) consider regular and unequal-area departments; (iv) contemplate that the flow of materials occurs between the P/D points located on the edges of work cells, and not at their centroids; (v) consider a multi-objective optimisation approach that takes both qualitative and quantitative factors into account; (vi) contemplate a bottom-up planning approach that firstly takes into account the detailed design of the work cells making up the production system and then the BL or, alternatively, takes into account both phases concurrently. A forthcoming work will be oriented to formulate a new bottom-up multi-objective optimisation approach to DFLP.

Acknowledgments. The research leading to these results received funding from the Regional Department of Innovation, Universities, Science and Digital Society of the Generalitat Valenciana entitled "Industrial Production and Logistics Optimization in Industry 4.0" (i4OPT) (Ref. PROMETEO/2021/065)", and from the European Union H2020 programs with grant agreements No. 825631 "Zero-Defect Manufacturing Platform (ZDMP)" and No. 958205 "Industrial Data Services for Quality Control in Smart Manufacturing (i4Q)".

References

1. Pérez-Gosende, P., Mula, J., Díaz-Madroñero, M.: Facility layout planning. An extended literature review. Int. J. Prod. Res. **59**, 1–40 (2021). https://doi.org/10.1080/00207543.2021.1897176
2. Hosseini-Nasab, H., Fereidouni, S., Fatemi Ghomi, S.M.T., Fakhrzad, M.B.: Classification of facility layout problems: a review study. Int. J. Adv. Manuf. Technol. **94**(1–4), 957–977 (2017). https://doi.org/10.1007/s00170-017-0895-8
3. Meller, R., Kirkizoglu, Z., Chen, W.: A new optimization model to support a bottom-up approach to facility design. Comput. Oper. Res. **37**, 42–49 (2010). https://doi.org/10.1016/j.cor.2009.03.018
4. Pérez-Gosende, P., Mula, J., Díaz-Madroñero, M.: Overview of dynamic facility layout planning as a sustainability strategy. Sustainability (Switzerland) **12**, 8277 (2020). https://doi.org/10.3390/su12198277
5. Liu, J., Liu, J., Yan, X., Peng, B.: A heuristic algorithm combining Pareto optimization and niche technology for multi-objective unequal area facility layout problem. Eng. Appl. Artif. Intell. **89**, 103453 (2020). https://doi.org/10.1016/j.engappai.2019.103453
6. Loiola, E.M., de Abreu, N.M.M., Boaventura-Netto, P.O., Hahn, P., Querido, T.: A survey for the quadratic assignment problem. Eur. J. Oper. Res. **176**, 657–690 (2007). https://doi.org/10.1016/j.ejor.2005.09.032

7. McKendall, A.R., Hakobyan, A.: Heuristics for the dynamic facility layout problem with unequal-area departments. Eur. J. Oper. Res. **201**, 171–182 (2010). https://doi.org/10.1016/j.ejor.2009.02.028
8. Mazinani, M., Abedzadeh, M., Mohebali, N.: Dynamic facility layout problem based on flexible bay structure and solving by genetic algorithm. Int. J. Adv. Manuf. Technol. **65**, 929–943 (2013). https://doi.org/10.1007/s00170-012-4229-6
9. Abedzadeh, M., Mazinani, M., Moradinasab, N., Roghanian, E.: Parallel variable neighborhood search for solving fuzzy multi-objective dynamic facility layout problem. Int. J. Adv. Manuf. Technol. **65**, 197–211 (2013). https://doi.org/10.1007/s00170-012-4160-x
10. Jolai, F., Tavakkoli-Moghaddam, R., Taghipour, M.: A multi-objective particle swarm optimisation algorithm for unequal sized dynamic facility layout problem with pickup/drop-off locations. Int. J. Prod. Res. **50**, 4279–4293 (2012). https://doi.org/10.1080/00207543.2011.613863
11. Meller, R., Kleiner, B.M., Nussbaum, M.A.: The facility layout problem: a new model to support a bottom-up approach to facility design. In: Progress in Material Handling Research, pp. 399–414. Material Handling Institute, Charlotte, EUA (2004)
12. Moslemipour, G., Lee, T.S., Loong, Y.T.: Performance analysis of intelligent robust facility layout design. Chin. J. Mech. Eng. **30**(2), 407–418 (2017). https://doi.org/10.1007/s10033-017-0073-9
13. Bozorgi, N., Abedzadeh, M., Zeinali, M.: Tabu search heuristic for efficiency of dynamic facility layout problem. Int. J. Adv. Manuf. Technol. **77**(1–4), 689–703 (2014). https://doi.org/10.1007/s00170-014-6460-9
14. Singh, D., Ingole, S.: Multi-objective facility layout problems using BBO, NSBBO and NSGA-II metaheuristic algorithms. Int. J. Ind. Eng. Comput. **10**, 239–262 (2019). https://doi.org/10.5267/j.ijiec.2018.6.006
15. Turanoğlu, B., Akkaya, G.: A new hybrid heuristic algorithm based on bacterial foraging optimization for the dynamic facility layout problem. Expert Syst. Appl. **98**, 93–104 (2018). https://doi.org/10.1016/j.eswa.2018.01.011
16. Pournaderi, N., Ghezavati, V.R., Mozafari, M.: Developing a mathematical model for the dynamic facility layout problem considering material handling system and optimizing it using cloud theory-based simulated annealing algorithm. SN Appl. Sci. **1**(8), 1–17 (2019). https://doi.org/10.1007/s42452-019-0865-x
17. Erik, A., Kuvvetli, Y.: Integration of material handling devices assignment and facility layout problems. J. Manuf. Syst. **58**, 59–74 (2021). https://doi.org/10.1016/J.JMSY.2020.11.015
18. Tong, X.: SECOT: a sequential construction technique for facility design (1991)
19. Kulturel-Konak, S., Konak, A.: A new relaxed flexible bay structure representation and particle swarm optimization for the unequal area facility layout problem. Eng. Optim. **43**, 1263–1287 (2011). https://doi.org/10.1080/0305215X.2010.548864

False Alarm Detection with K-NN Algorithm for Wind Turbine Maintenance Management

Ana María Peco Chacón, Isaac Segovia Ramírez(✉), and Fausto Pedro García Márquez(✉)

Ingenium Research Group, Universidad Castilla-La Mancha, 13071 Ciudad Real, Spain
{anamaria.peco,isaac.segovia,faustopedro.garcia}@uclm.es

Abstract. The operation and maintenance management are critical for the efficiency and competitiveness of the wind farms. The detection of false alarms is a significant variable for wind turbine maintenance. This paper proposes a novel approach based on K-nearest neighbour algorithms that compares different k-fold cross-validation values. It is presented a real case study based on three wind turbines to test the methodology. The data obtained with supervisory control and data acquisition is analyzed and compared with the alarm log as a response variable. The behaviour of the three turbines has been demonstrated to be analogous, implying that the methodology is robust. It is demonstrated that the increase of the K-cross validation value does not increase the accuracy. The results achieved an accuracy of 98%, and the method can detect more than 22% of false alarms. These outcomes demonstrates that the suggested approach can detect false alarms in wind turbines.

Keywords: K-nearest neighbours · Algorithm · Machine learning · Wind turbine · Cross validation · Alarm

1 Introduction

Global warming has led to the government to promote a rapid development of renewable sources of energy. Wind energy production has increased significantly in recent decades, reaching 743 GW of installed global wind power capacity in 2020 [1]. New wind turbines (WTs) are becoming larger and the analysis of wind farms is also more complex [2, 3]. In addition, the situation of wind farms in sites of difficult access causes greater difficulty for monitoring the status of the WTs [4]. Unexpected failures increase significantly the number of maintenance operations [5], and it is required new fault diagnosis to improve maintenance management and reduce operating and maintenance costs [6, 7]. Several types of condition monitoring system (CMS) are widely applied to control the operating conditions of WTs [7, 8]. The supervisory control and data acquisition (SCADA) system integrates various types of CMS, obtaining signals and alarms from critical components [9, 10]. False alarms are activated although the WT does not present any failure, causing unnecessary maintenance operations and increased costs [11, 12].

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 488–493, 2023.
https://doi.org/10.1007/978-3-031-27915-7_86

Machine learning methods are usually used for the analysis of large datasets of WTs [13, 14]. K-Nearest Neighbour (K-NN) is one of the most applied techniques for classification and regression due to high accuracy in data analysis [15, 16]. K-NN is a nonparametric, lazy learning algorithm that makes no assumptions about the main dataset [16]. Jimenez et al. [17] applied different classifiers for ice detection in WTs and KNN, and achieved a 99% of accuracy, being one of the most relevant techniques. The K-NN approach has been used in several studies for diagnosis and detection, but it has not yet been applied to the analysis of alarm generating. The implementation of a data-based study to predict and detect false alarms using K-NN algorithms is the main contribution of this paper. This method can be used to increase the reliability of WTs using past SCADA data as well as real-time data.

2 Approach

The analysis presented in this article combines the results obtained by K-NN with the maintenance and alarm records. Different partition sizes in k-fold cross validation (CV) are used to validate different instances of K-NN algorithms by varying the classifier, and the optimal classification method is chosen based on the accuracy of the model. The confusion matrix shows the results, and the misclassifications are studied analyzing the maintenance and alarm logs to determine their causes and to detect false alarms.

The number of necessary neighbours K must be carefully chosen because it is determined by the classifying metrics. The distances between the point and the points in the training data set are determined by the K-NN algorithm [18]. The Euclidean distance is the most used distance metric. Table 1 shows the K-NN models and the number of neighbours defined for this paper.

Table 1. K-NN models and parameters.

Classifier	Model adaptability	Distance metric	Neighbours
Fine	Precise divisions between classes	Euclidean	1
Medium	Medium divisions between classes	Euclidean	10
Coarse	Gross divisions between classes	Euclidean	100
Cosine	Medium divisions between classes	Cosine	10
Cubic	Medium divisions slow prediction speed	Minskowski	10
Weighted	Medium divisions between classes	Euclidean	10

3 Case Study and Results

This research uses SCADA data from the European project OPTIMUS from three real WTs, called as WT1, WT2 and WT3. SCADA signals were measured every 10 min for two months. Null or empty values have been removed, resulting in almost 8500 observations. The predictor variables are 34 SCADA variables measured by sensors in WT such as temperatures, voltage, etc. The alarm log is the response variable, and it presents two labels: alarm activation and alarm deactivation. The SCADA variables and the alarm log are displayed on the same time scale. The different K-NN algorithms are validated with different k-fold CV values, as it is shown in Table 2 and various values of cross validation. The accuracy values are similar for WT1 and WT3, being the best result obtained by the weighted K-NN algorithm. Fine K-NN obtains the highest accuracy for WT2.

Table 2. Accuracy of the different K-NN algorithms and various values of cross validation.

K-NN classifier type	Fold cross validation (%)											
	WT1				WT2				WT3			
	K = 2	K = 5	K = 10	K = 50	K = 2	K = 5	K = 10	K = 50	K = 2	K = 5	K = 10	K = 50
Fine	98,2	98,6	98,6	98,6	**98,4**	**98,6**	**98,6**	**98,5**	96,8	96,9	96,9	96,9
Medium	97,8	98,2	98,4	98,4	98,2	98,3	98,3	98,3	96,4	96,4	96,4	96,4
Coarse	96,2	96,9	97	97	96,9	97	97,1	97	95,3	95,4	95,4	95,4
Cosine	97,9	98,1	98,3	98,3	98,1	98,3	98,2	98,3	96	96,2	96,4	96,3
Cubic	97,8	98,1	98,2	98,2	98,1	98	98,1	98	97,8	97,9	97,8	97,9
Weighted	**98,3**	**98,7**	**98,8**	**98,7**	98,3	98,4	98,4	98,4	**98,3**	**98,2**	**98,3**	**98,3**

Table 2 shows that increasing the value of K does not imply a higher accuracy. The validation used is 10-fold CV, because it implies a reasonable balance between computational time and accuracy. Table 3 shows the confusion matrix for the 3 WTs of the study with 10-fold CV, and for the method with the highest accuracy.

Table 3. Confusion matrix for WT1, WT2 and WT3.

True class						
0	WT1		WT2		WT3	
	8216	15	8181	50	8204	27
1	91	321	72	340	118	294
	0	1	0	1	0	1
	Predicted class					

The K-NN algorithms generate false positives, that appear when the algorithm predicts an alarm, but it is not activated in reality. These values are produced when the predicted class is 1 but the true class is 0. Values of 15, 50 and 27 false positives are generated by WT1, WT2, and WT3, respectively, see Table 3. This is caused by a mismatch between the start and end of the alarm period and the times predicted by the classifier algorithms.

The false negatives cases are examined to determine the causes of this prediction miscalculation. Figure 1 (a) shows that the alarm produced by a high amount of turbulence is difficult to detect by the K-NN algorithms. A lack of synchronization between the alarm log and classification systems might also lead to misclassifications, see Fig. 1 (b). Another main cause of false negative are alarms only triggered for a few seconds, as it is shown in Fig. 1 (c). This type of misclassifications are considered a false alarm caused by the SCADA system.

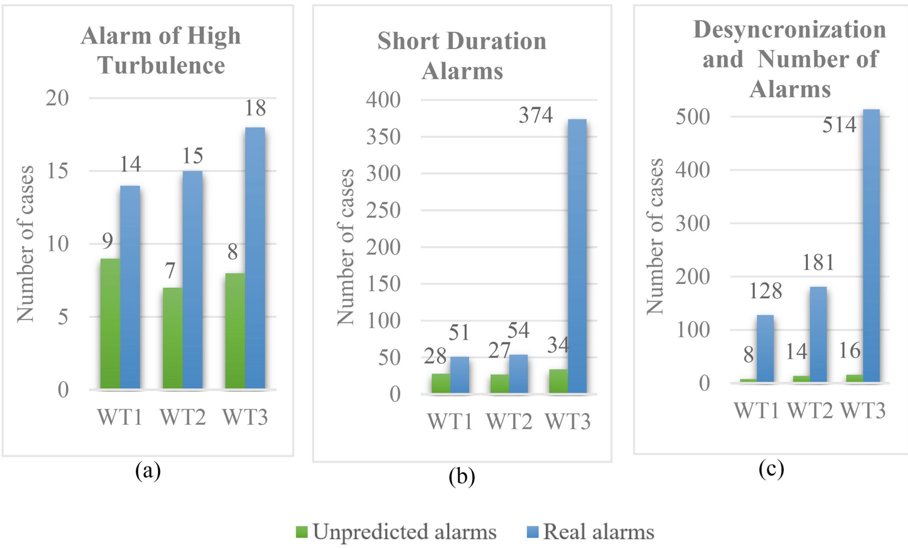


Fig. 1. Main causes of false negatives.

The number of false alarms uncovered for WT1, WT2, and WT3 were 26,41%, 22,13% and 23,45%, respectively, according to the analysis of misclassification cases combined with the maintenance records and alarm records. False alarms are those that have a very short activation period and cannot be handled by the operator or the system. The K-NN classifier is unable to detect them, where the WT will continue to function without failure, resulting in a reduction in WT downtime.

4 Conclusions

The maintenance management of wind farms requires new fault diagnosis methods and false alarm detection techniques. Current condition monitoring systems generate large volumes of data that require of new machine learning approaches. These techniques can classify large amounts of complex data with high accuracy. Several machine learning methods have been used in wind turbines to detect faults and predict energy demand, but these techniques are not widely applied for alarm classification. This paper proposes the implementation of the K-Nearest Neighbour algorithm for alarm detection and classification. A real dataset from three real wind turbines is used to test the methodology. The causes of the detected misclassifications are studied combining the maintenance record and the alarm log. The results provided an accuracy greater than 98%, and the case studies demonstrated that the suggested methodology can detect over 22% of false alarms. The research could involve classification of alarm types and the application of other artificial intelligence algorithms.

Acknowledgements. The work reported herein was supported financially by the Ministerio de Ciencia e Innovación (Spain) and the European Regional Development Fund, under Research Grant WindSound project (Ref.: PID2021-125278OB-I00).

References

1. Joyce Lee, F.Z.: Global wind report 2021; Global Wind Energy Council (2021)
2. Jiménez, A.A., Zhang, L., Muñoz, C.Q.G., Márquez, F.P.G.: Maintenance management based on machine learning and nonlinear features in wind turbines. Renew. Energy **146**, 316–328 (2020)
3. Márquez, F.P.G., Chacón, A.M.P.: A review of non-destructive testing on wind turbines blades. Renew. Energy **161**, 998–1010 (2020)
4. Acaroğlu, H., Márquez, F.P.G.: High voltage direct current systems through submarine cables for offshore wind farms: a life-cycle cost analysis with voltage source converters for bulk power transmission. Energy **249**, 123713 (2022)
5. Márquez, F.P.G., Tobias, A.M., Pérez, J.M.P., Papaelias, M.: Condition monitoring of wind turbines: techniques and methods. Renew. Energy **46**, 169–178 (2012)
6. García Márquez, F.P., Segovia Ramírez, I., Pliego Marugán, A.: Decision making using logical decision tree and binary decision diagrams: a real case study of wind turbine manufacturing. Energies **12**, 1753 (2019)
7. Gonzalo, A.P., Benmessaoud, T., Entezami, M., Márquez, F.P.G.: Optimal maintenance management of offshore wind turbines by minimizing the costs. Sustain. Energy Technol. Assess. **52**, 102230 (2022)
8. García Márquez, F.P., Bernalte Sanchez, P.J., Segovia Ramírez, I.: Acoustic inspection system with unmanned aerial vehicles for wind turbines structure health monitoring. Structural Health Monitoring **21**, 485–500 (2021). 14759217211004822
9. Garcia Marquez, F.P., Pliego Marugan, A., Pinar Pérez, J.M., Hillmansen, S., Papaelias, M.: Optimal dynamic analysis of electrical/electronic components in wind turbines. Energies **10**, 1111 (2017)
10. Pliego Marugán, A., García Márquez, F.P.: Advanced analytics for detection and diagnosis of false alarms and faults: a real case study. Wind Energy **22**, 1622–1635 (2019)
11. Peco Chacón, A.M., Segovia Ramírez, I., García Márquez, F.P.: State of the art of artificial intelligence applied for false alarms in wind turbines. Arch. Comput. Methods Eng. **29**, 2659–2683 (2021)
12. Chacón, A.M.P., Ramírez, I.S., Márquez, F.P.G.: False alarms analysis of wind turbine bearing system. Sustainability **12**, 7867 (2020)
13. Stetco, A., et al.: Machine learning methods for wind turbine condition monitoring: a review. Renew. Energy **133**, 620–635 (2019)

14. Marugán, A.P., Chacón, A.M.P., Márquez, F.P.G.: Reliability analysis of detecting false alarms that employ neural networks: a real case study on wind turbines. Reliab. Eng. Syst. Saf. **191**, 106574 (2019)
15. He, Q.P., Wang, J.: Fault detection using the k-nearest neighbor rule for semiconductor manufacturing processes. IEEE Trans. Semicond. Manuf. **20**, 345–354 (2007)
16. García Márquez, F.P., Peinado Gonzalo, A.: A comprehensive review of artificial intelligence and wind energy. Arch. Comput. Methods Eng. **29**, 2935–2958 (2021)
17. Jiménez, A.A., García Márquez, F.P., Moraleda, V.B., Gómez Muñoz, C.Q.: Linear and non-linear features and machine learning for wind turbine blade ice detection and diagnosis. Renew. Energy **132**, 1034–1048 (2019)
18. Wu, X., et al.: Top 10 algorithms in data mining. Knowl. Inf. Syst. **14**, 1–37 (2008)

Theoretical Advances in the Supply Chain Operations Strategy with a Circular Economy Approach

Darwin Aldás[1,2], Josefa Mula[1], and Manuel Díaz-Madroñero[1](✉)

[1] Research Centre on Production Management and Engineering (CIGIP), Universitat Politécnica de Valencia, Alarcon, 1, Alcoy, Alicante, Spain
daldsal@doctor.upv.es, {fmula,fcodiama}@cigip.upv.es
[2] Universidad Técnica de Ambato, Ambato, Ecuador
darwinsaldas@uta.edu.ec

Abstract. The challenges that industries face today in a competitive global world involve not only economic strategies, but also operations strategies with the tendency to care for the environment. In this context, the present article describes supply chain operations strategies with a circular economy approach, investigated by other authors in literature reviews. It also systematically examines the current trend to address this issue and evaluates each article based on the employed keywords, such as operations strategy, supply chain, and global, sustainable, and circular economy. The main findings show 13 review articles of the 62 identified in the main academic databases, and indicate that manufacturing industries are mainly implemented operations strategies based on sustainability, green product design, reverse logistics, performance indices, servitisation, among others.

Keywords: Operations strategy · Supply chain · Global · Sustainability · Circular economy

1 Introduction

Integrating circular economy practices into the supply chain is a challenging task because of the many involved risks and uncertainties [1]. Adopting circular economy principles suggests new operational strategies whose implementation is substantial from the sustainability point of view [2] because every industrial process generates waste at different pollution levels and it is companies' duty to mitigate them by sustainable operations strategies [3]. To reduce these effects, industries are rapidly and increasingly implementing innovative strategies, such as reverse logistics, to ensure sustainable practices and to increase companies' competitiveness, but they also pose significant challenges [4, 5]. Some studies also show the use of Industry 4.0 initiatives to improve the resource consumption rate and to reduce waste and pollution through improved sustainable supply chain operations [6]. In this regard, today's industries are concerned with optimising scarce natural resources by aligning supply chain operations with economic, environmental and social factors [7]. The main contribution of this article is to identify trends

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 494–500, 2023.
https://doi.org/10.1007/978-3-031-27915-7_87

in terms of the literature reviewed by other authors on this subject by considering the defined key words, the addressed operations strategies, and the applications fields.

The rest of the article is structured as follows. Section 2 explains the work methodology. Section 3 presents the results obtained by reviewing the selected articles. Section 4 offers the conclusions.

2 Methodology

For the present study, a search of existing literature reviews was carried out in the Scopus and Web of Science (WoS) databases. The following keywords were used: operations strategy (OS), supply chain (SC), global (G), sustainability (ST) and circular economy (CE). They were combined to generate search strings on a time horizon spanning from 2012 to the present-day, ever since industries have made efforts to implement ST actions into their SC since that time limit [8]. This allowed us to initially find 145 articles. Subsequently, duplicates were eliminated, which left 126. Each article was reviewed by taking these exclusion criteria: firstly, they explicitly addressed OSs and were aligned with at least two of the keywords, this leaves 62 papers for the study; secondly, the research methodology was conceptual and specifically based on a literature review modelling approach. In the end, 13 articles remained.

3 Results

Figure 1 shows the number of items for each of the keywords and their respective combinations, where OS-SC-ST comprises the highest number of items, followed by OS-ST-CE and OS-SC-CE with equal percentage. This result shows that the revised operations strategies are preferentially aligned with supply chain, sustainability and circular economy.

Table 1 shows the articles coded as LR*n* and consecutively numbered by indicating the association of each one with the keywords, the percentage of articles per keyword and the followed operation strategy. Under principles of circular economy and green products, the research highlights current strategies used by the manufacturing industry in its supply chain, especially, strategies directly involved in product and process design. Furthermore, this work focuses on strategies that intervene directly with the after-sales service, such as servitization. In addition, it is important to mention that the study did not find governmental policy interventions that boosted the practice of these kinds of strategies.

Table 2 shows the main findings of each of the operations strategies reviewed, as well as the main limitations that the authors mention regarding each strategy. The authors of the articles propose including new operations strategies throughout the supply chain, both in sourcing, production, sales and after-sales service [12]. The main proposals within the strategies are oriented to include principles of circular economy, Industry 4.0, reverse logistics, reduction of energy and resource consumption, reuse and remanufacturing of products and global supply chains.

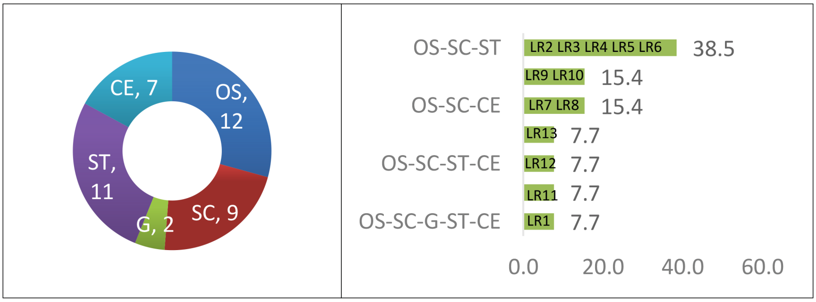


Fig. 1. Articles by keywords

Table 1. Reviewed articles on operations strategy in the supply chain

Article code	Source	Application field	Operations strategy
LR1	[9]	Manufacturing industry	Global sourcing management via efficient outsourcing
LR2	[10]	Agri-food industry	Social dimension by including SC stakeholders in the process
LR3	[7]	Manufacturing industry	Implementing the transportation and packaging of ST principles aligned with economic considerations in SCs
LR4	[11]	Energy sector	Including performance indices in sustainable SC management
LR5	[12]	Manufacturing industry	Applying reverse logistics in SCs
LR6	[13]	Manufacturing industry	Product design with multiple life cycles considering recovery alternatives and competitive new and remanufactured product pricing
LR7	[14]	Industry and product design	Linking servitisation with the SC to develop a circular SC
LR8	[15]	Manufacturing industry	Implementing product remanufacturing with Product-Service-System upgrading
LR9	[16]	Manufacturing industry	Analysing a strategy from three principles: productivity and innovation, corporate citizenship, and economic resilience
LR10	[17]	Manufacturing industry	Using green products in the SC
LR11	[18]	Manufacturing industry	Implementing a triple R (reduce, reuse, recycle) model into global manufacturing

(*continued*)

Table 1. (*continued*)

Article code	Source	Application field	Operations strategy
LR12	[19]	Manufacturing industry	Applying Industry 4.0 and circular economy principles
LR13	[20]	Manufacturing industry	Applying circular economy principles and the ReSOLVE method (Re-generate, Share, Optimise, Loop, Virtualise and Exchange)

Table 2. Main findings and limitations

OS	Main findings	Limitations
LR1	Enables asset cost reduction, production costs, facilitates strategic flexibility, and reduces administrative and overhead costs	Integration problems, opportunistic behaviour, increased transaction and coordination costs, limited innovation
LR2	Include the social dimension within the supply chain at all stages, mainly those related to fair working conditions, inclusion, and attention to consumer needs	Difficulty in making a political decision to include the social dimension, as priority is only given to the economic and environmental ones
LR3	Indicates that logistics managers should prioritize the planning and improvement of packaging, packing and distribution of products, reducing environmental impacts in transportation	High transportation costs under environmental standards
LR4	Proposes a composite index metric, through performance indicators to improve sustainable supply chain management	Inventory management in the sustainable supply chain is little explored and needs to be studied prior to implementation
LR5	Proposes cost reduction, reduced resource consumption and improved customer-supplier relationships	Increased labour, product returns, material returns
LR6	Managers need to carefully select the appropriate model for the product's design, evaluation of recovery alternatives, and prices of new and remanufactured products keeping in mind return uncertainty, quality, and volume of used products	High cost, need for ongoing training, generation of waste, etc.
LR7	Business models in circular supply chains by increasing product longevity, closing resource loops and resource efficiency	Servitisation requires increased product longevity, which implies an increase in cost
LR8	Promotes more sustainable industrial practices, such as reuse and remanufacturing, highlighting potential environmental benefits	Obsolescence of re-manufactured products, especially in case of fast technology cycles

(*continued*)

Table 2. (*continued*)

OS	Main findings	Limitations
LR9	Includes outsourcing as an outsourcing strategy for improved supply chain performance with special reference to measures and metrics	High transaction, acquisition, and coordination costs, as well as limited innovation
LR10	Proposes eliminating green products that generate high production costs	There must be alternatives to replace the green products eliminated
LR11	Triple R methodology allows maximize the robustness of operations, maximize responsiveness by generating operational flexibility at the minimum cost, use of inventories and environmental impact, and to build resilience in global manufacturing, in order to achieve strategic flexibility	Should be implement more advanced modelling and solution methods, which cover not only logistics and transports, but also the integration of concurrent engineering (CE)
LR12	Sustainable operations management, and the ReSOLVE framework	The technology is expensive and requires ongoing training
LR13	Three frameworks are generated; max-min policy of waste and max-max policy of utility – maximising the effort to minimise waste and maximising the effort to maximise utility	The limits of the circular economy are not defined and it is constantly evolving

4 Conclusions

The main findings include having determined that most of the literature reviews are approached from OS, ST and SC, with very few from circular economy and globality. The involved study sectors are mainly manufacturing, energy and agri-food industries. Most of the literature reviews were developed based on the systematic literature review methodology proposed by Denyer and Tranfiel [21].

It is important to highlight that SCs' OPs are applied in different SC stages and are related mainly to global supply management, reverse logistics, the implementation of multiple life cycle products, SC servitisation, product remanufacturing, Industry 4.0 technologies, circular economy principles and the ReSOLVE model. For this reason, it is necessary to apply different strategies for different sectors.

It should be noted that this research has some limitations. The databases consulted, such as Scopus and Web of Science, are constantly updated and the data provided correspond to those obtained at the time the research was conducted. The review focused on peer-reviewed articles written in English, so results published in other languages were not taken into account. Furthermore, despite having conducted a systematic literature review, it is possible that some valuable articles may have been overlooked for this review. In any case, some limitations that became apparent during the conduct of the study are an opportunity for further research that is worth noting. In this sense, future work is aimed at extending the current literature review based on other modelling approaches and search methodologies, as well as generating from the current information conceptual and quantitative models to better understand the behaviour of operations strategies with sustainability and circular economy approaches in global supply chains.

Acknowledgments. The research leading to these results received funding from the Regional Department of Innovation, Universities, Science and Digital Society of the Generalitat Valenciana entitled “Industrial Production and Logistics Optimization in Industry 4.0” (i4OPT) (Ref.PROMETEO/2021/065) and "Resilient, Sustainable and People Oriented Supply Chain 5.0 Optimization Using Hybrid Intelligence" (RESPECT) (Ref. CIGE/2021/159).

References

1. Borges, V.B., Caruso, F.D.: Optmising tank capacity for unconventional oil resources. In: 2015 Rio Pipeline Conference and Exposition. Instituto Brasileiro de Petroleo, DNV GL Software, London, United Kingdom (2015)
2. Agarwal, S., Tyagi, M., Garg, R.K.: Conception of circular economy obstacles in context of supply chain: a case of rubber industry. Int. J. Product. Perform. Manag. (2021, In press)
3. Zanjirani Farahani, R., Asgari, N., Van Wassenhove, L.N.: Fast fashion, charities, and the circular economy: challenges for operations management. Prod. Oper. Manag. **31**, 1089–1114 (2021)
4. Münch, C., von der Gracht, H.A., Hartmann, E.: The future role of reverse logistics as a tool for sustainability in food supply chains: a Delphi-based scenario study. Supply Chain Manag. (2021, In press)
5. Makarova, I., Shubenkova, K., Buyvol, P., Shepelev, V., Gritsenko, A.: The role of reverse logistics in the transition to a circular economy: case study of automotive spare parts logistics. FME Trans. **49**, 173–185 (2021)
6. Bag, S., Wood, L.C., Telukdarie, A., Venkatesh, V.G.: Application of Industry 4.0 tools to empower circular economy and achieving sustainability in supply chain operations. Prod. Plan. Control 1–23 (2021)
7. Vega-Mejía, C.A., Montoya-Torres, J.R., Islam, S.M.N.: Consideration of triple bottom line objectives for sustainability in the optimization of vehicle routing and loading operations: a systematic literature review. Ann. Oper. Res. **273**(1–2), 311–375 (2017)
8. Mejias, A.M., Bellas, R., Pardo, J.E., Paz, E.: Traceability management systems and capacity building as new approaches for improving sustainability in the fashion multi-tier supply chain. Int. J. Prod. Econ. **217**, 143–158 (2019)
9. Gunasekaran, A., Irani, Z., Choy, K.-L., Filippi, L., Papadopoulos, T.: Performance measures and metrics in outsourcing decisions: a review for research and applications. Int. J. Prod. Econ. **161**, 153–166 (2015)
10. Desiderio, E., García-Herrero, L., Hall, D., Segrè, A., Vittuari, M.: Social sustainability tools and indicators for the food supply chain: a systematic literature review. Sustain. Prod. Consum. **30**, 527–540 (2022)
11. Hassini, E., Surti, C., Searcy, C.: Literature review and a case study of sustainable supply chains with a focus on metrics. Int. J. Prod. Econ. **140**, 69–82 (2012)
12. Govindan, K., Soleimani, H., Kannan, D.: Reverse logistics and closed-loop supply chain: a comprehensive review to explore the future. Eur. J. Oper. Res. **240**, 603–626 (2015)
13. Nag, U., Sharma, S.K., Kumar, V.: Multiple life-cycle products: a review of antecedents, outcomes, challenges, and benefits in a circular economy. J. Eng. Des. **33**(3), 173–206 (2022)

14. Kuhl, C., Bourlakis, M., Aktas, E., Skipworth, H.: How does servitisation affect supply chain circularity? - A systematic literature review. J. Enterp. Inf. Manag. **33**, 703–728 (2020)
15. Chierici, E., Copani, G.: Remanufacturing with upgrade PSS for new sustainable business models. Procedia CIRP **47**, 531–536 (2016)
16. Smart, P., Hemel, S., Lettice, F., Adams, R., Evans, S.: Pre-paradigmatic status of industrial sustainability: a systematic review. Int. J. Oper. Prod. Manag. **37**, 1425–1450 (2017)
17. Zhu, Q., Shah, P., Sarkis, J.: A paler shade of green: implications of green product deletion on supply chains. Int. J. Prod. Res. **58**, 4567–4588 (2020)
18. Kristianto, Y., Gunasekaran, A., Helo, P.: Building the "Triple R{"} in global manufacturing. Int. J. Prod. Econ. **183**, 607–619 (2017)
19. de Sousa Jabbour, A.B., Chiappetta Jabbour, C.J., Godinho Filho, M., Roubaud, D.: Industry 4.0 and the circular economy: a proposed research agenda and original roadmap for sustainable operations. Ann. Oper. Res. **270**, 273–286 (2018)
20. Nadeem, S.P., Garza-Reyes, J.A., Anosike, A.I., Kumar, V.: Spectrum of circular economy and its prospects in logistics. In: Proceedings of the International Conference on Industrial Engineering and Operations Management, pp. 440–451 (2017)
21. Denyer, D., Tranfield, D.: Producing a systematic review. In: The SAGE Handbook of Organizational Research Methods, pp. 671–689, Los Angeles, California [u.a.]. SAGE (2009)

A Conceptual Framework for Lean Manufacturing Under Uncertainty Conditions in the Graphic Industry

Tania Rojas[1,2], Josefa Mula[1], and Raquel Sanchis[1](✉)

[1] Research Centre on Production Management and Engineering (CIGIP), Universitat Politècnica de València, c/ Alarcón, 1, 03801 Alcoy, Alicante, Spain
taropar@doctor.upv.es, trojas@ups.edu.ec, {fmula,rsanchis}@cigip.upv.es

[2] Industrial Engineering Department, Universidad Politécnica Salesiana, Chambers 227, 090114 Guayaquil, Ecuador

Abstract. This article presents a conceptual framework that serves as a reference to propose a quantitative approach based on lean manufacturing (LM) techniques in an uncertainty context. To develop it, five input factors are defined with an influence in such a context: top management, supply chain, machines, processes, human resources. In addition, their interaction with LM tools and quantitative models for production planning under uncertainty is identified. It also determines the performance outputs obtained with the proper management of LM tools and quantitative models in each identified input factor. The objective of the application of such a conceptual framework is oriented towards improving an organisation's performance from a LM perspective under uncertainty because it is an under researched topic that requires future research efforts, particularly in the graphic industry.

Keywords: Lean manufacturing · Uncertainty · Modelling

1 Introduction

According to the reviewed literature, its application and implementation of the lean manufacturing (LM) context in many industrial and service sectors, such as health, have been reported [1], but with only a few applications in the printing industry [2]. Furthermore, the printing industry is characterised by inefficient process cycles due to different uncertainty factors [3] that are inherent in the production planning process, such as top management, supply chain, machines, processes and human resources [4].

According to Mula et al. [5], uncertainty comes as two main types: system uncertainty or environmental uncertainty. System uncertainty refers to those that are inherent to the production process itself, and environmental uncertainties that arise beyond production processes, such as demand and supply uncertainties [6]. Another recommendation for recognising uncertainties and proposing solutions is to apply the last planner system (LPS) [7], whose objective is to reduce risks to improve quality and increase productivity.

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 501–506, 2023.
https://doi.org/10.1007/978-3-031-27915-7_88

Therefore, the objective of this paper is to establish a conceptual framework that allows LM techniques to be applied in a production planning context under uncertainty in the industrial graphics.

The remainder of the article is structured as follows. Section 2 describes the related works. Section 3 presents the problem statement. Section 4 provides the conceptual framework. Finally, Sect. 5 includes some conclusions and further research lines.

2 Related Works

Sharma et al. [1] mention that there are only a few models for applying LM in the manufacturing industry sector, but they identify certain analytical models that enable multicriteria decision making: interpretive structural modeling (ISM) and interpretive ranking process (IRP). In addition, eight criteria for implementation are identified: 5S, single minute exchange of die (SMED), value stream mapping (VSM), just in time (JIT), computer integrated manufacturing (CIM), recurrent engineering, training and enterprise resource planning (ERP).

Ledón et al. [8] indicate that adopting LM helps to boost competitiveness. To do so, they used Pearson's correlation and show a positive and moderate relation between LM and business performance (process control and improvements, HR development and customer focus), and between LM and market performance, which is not the case for financial performance. Tayyab et al. [9] define an optimal production policy under demand uncertainty in a multistage imperfect LM process, which produces defects at an uncertain rate and leads to rework the produced products, which affects quality. So they propose fuzzy theory as the modelling approach, and consider both economic and environmental sustainability based on a metaheuristic approach, which evidences increased customer satisfaction, lower costs and reduced CO_2 emissions. They also mentioned five applicable lean tools: Poka Yoke, Kanban, visual control, JIT and 5S [10–12]. Some of the tools coincide with Ainul et al. [2] who, in the printing industry context, report improvements when applying VSM, Kaizen, total productive maintenance (TPM), SMED, autonomation and statistical process control (SPC).

In the context of closed-loop supply chains under uncertainty, Zeballos et al. [13] apply a multistage stochastic programming model. They apply GAMS 23.6.3 and CPLEX 12.2 to estimate the effects of demand and supply, and define 81 possible scenarios to minimise the expected cost of facilities, purchasing, storage, transport and emissions, minus the expected revenue due to returned products.

Thus it is evident that LM applications in the printing industry are scarce [2, 3] and have not been addressed in an uncertainty context to date.

3 Problem Statement

The current conditions under which industries operate demand resource savings to guarantee economic stability by means of employing techniques or tools that help to improve productivity. Shorter production times are necessary in all types of industries. In addition, the global and/or local market is extremely changeable with increasing demands for more flexibility, lower costs, variety and product customisation to meet customers' increasingly demanding requirements and to ensure competitiveness on markets [14]. The problem is significantly aggravated in the printing industry as it is a non-primary manufacturing sector, and whose main activities include printing of books, magazines, food packaging, newspapers, shopping bags, flyers, and other printed products. In this context, printing companies usually operate according to a strategy based on orders or intermittent orders. This means that long-term planning cannot be accurately carried out, and how long production resources will be occupied cannot be predicted. All this creates an uncertainty environment that causes system disruptions.

It should also be noted that the graphics sector tends to show lower economic efficiency, which is caused mainly by long production times that affect final deliveries [14]. It is normally an industry that generates direct jobs and is transversal to many productive sectors for being a supplier of labels, notebooks, wrapping,, and a wide variety of other products. It is an increasingly competitive sector because the post-COVID-19 pandemic effect has increased the use of digital tools and contents. So it is important to emphasise the importance of production planning that is appropriate for uncertain demands to generate products that meet customer requirements and, in this way, to promote customer satisfaction. It is essential to establish that the production is effective, with no delays in delivery and with quick responses to comply with the quality requirements. For this reason, LM techniques have become a benchmark for obtaining good results, and for eliminating not only waste and operations that do not add value to a product or processes, but also anything that is not required. This increases the value of each performed activity and is evidenced in improvements in organisations' economic performance.

4 Conceptual Framework

The proposed conceptual framework (Fig. 1) includes five important factors that influence the quantitative modelling approach for LM under uncertainty: top management, supply chain, HR, machines and processes.

The commitment and leadership maintained by top management is fundamental for reducing uncertainty in the organisation, in which the quality management system (QMS) can guarantee this commitment together with other tools, such as total quality management (TQM), VSM and ISM. Additionally, the supply chain involves the sourcing of raw materials, which is considered very influential in an uncertainty environment because it can trigger low-quality or out-of-specification raw materials. JIT, statistical process control (SPC), ERP and stochastic programming can be used as tools to model this factor [13].

Machines are another relevant input factor for the conceptual framework because their availability and good conditions for processing raw materials must be considered for production planning, and the reliability for the production of finished products must be guaranteed. TPM, SMED and Kanban can be used as tools to reduce uncertainty in a system that can be caused by this factor. The factor: processes that encompass the work procedures and standards that must be complied with to develop products, for which the application of VSM tools and the modelling approach based on fuzzy logic is proposed.

The last factor to be considered within this conceptual framework refers to human resources given the importance of their skills and experience, plus the knowledge that they must possess to develop production. This is why it is proposed to apply models based on 5S, Poka Yoke and visual control techniques.

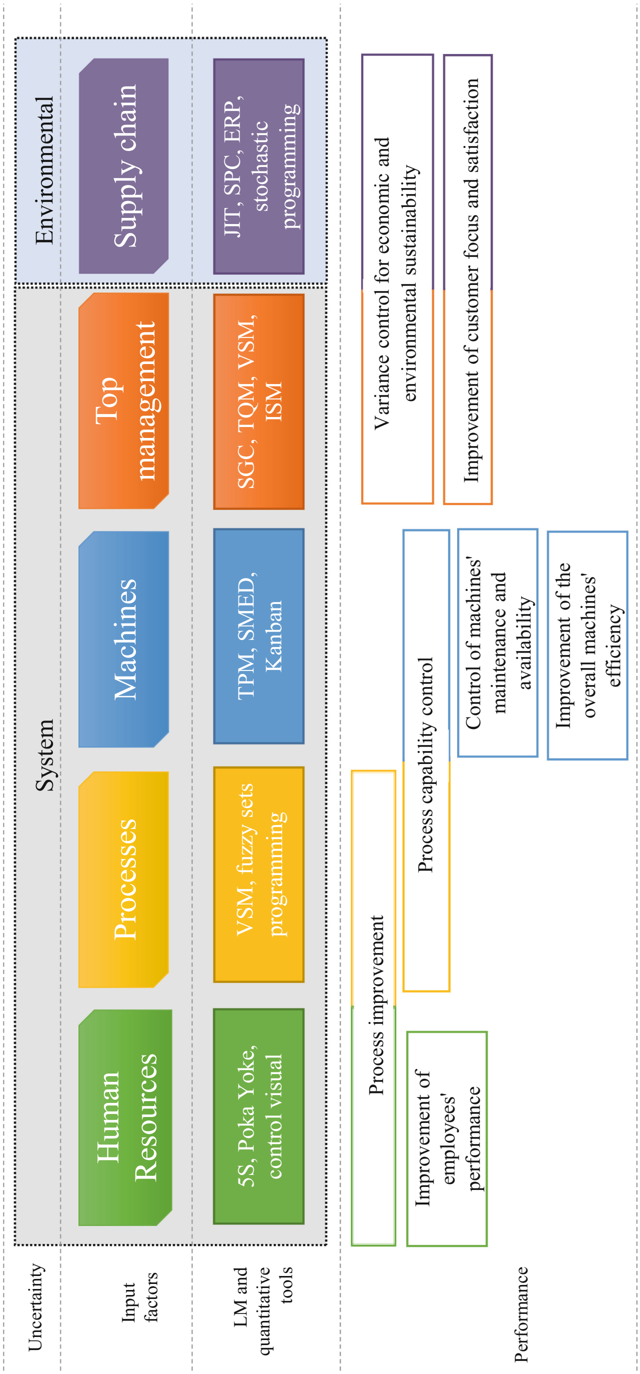


Fig. 1. Conceptual framework for LM under uncertainty

5 Conclusions

In this paper, a conceptual framework is been put forward as a basis for proposing quantitative LM with an uncertainty approach based on the most relevant factors. Thus, managerial implications are aimed at providing a reference starting point for practitioners and researchers to develop new models and algorithms to ensure customer satisfaction and improve organisational performance, which is mainly oriented to production planning in the printing industry. The benefits that can be obtained from combining LM tools, analytical models and fuzzy set theory-based models are considered a benchmark.

There is an excellent opportunity to apply this model as a starting point to create other specific models to different industrial sectors. Finally, a mathematical programming model oriented to apply and validate the conceptual framework will be a forthcoming work.

Acknowledgment. The research leading to these results received funding from the Regional Department of Innovation, Universities, Science and Digital Society of the Generalitat Valenciana entitled "Industrial Production and Logistics Optimization in Industry 4.0" (i4OPT) "(Ref. PROMETEO/2021/065)", and from the European Union H2020 programs with grant agreements No. 825631 "Zero-Defect Manufacturing Platform (ZDMP)" and No. 958205 "Industrial Data Services for Quality Control in Smart Manufacturing (i4Q)".

References

1. Sharma, V., Dixit, A.R., Qadri, A.: Modeling lean implementation for manufacturing sector. J. Model. Manag. **11**(2), 405–426 (2016)
2. Ainul-Azyan, Z.H., Pulakanam, V., Pons, D.: Success factors and barriers to implementing. J. Manuf. Technol. Manag. **28**(4), 458–484 (2017)
3. Rai, S.: Implementation of lean document production in the printing industry. Int. J. Perform. Eng. **9**(1), 85–96 (2013)
4. Del Monte, C., Zanchi, M., Gaiardelli, P.: Exploring the link between lean practices and sources of uncertainty in supply chain. In: Dolgui, A., Bernard, A., Lemoine, D., von Cieminski, G., Romero, D. (eds.) APMS 2021. IAICT, vol. 630, pp. 748–757. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-85874-2_82
5. Mula, J., Poler, R., Garcia-Sabater, J.P., Lario, F.C.: Models for production planning under uncertainty: a review. Int. J. Prod. Econ. **103**(1), 271–285 (2006)
6. Mula, J., Peidro, D., Diaz-Madroñero, M., Vicens, E.: Mathematical programming models for supply chain production and transport planning. Eur. J. Oper. Res. **204**(3), 377–390 (2010)
7. Qiu, X.: Uncertainty in project management based on lean construction implementation. Adv. Mater. Res. **328–330**, 194–198 (2011)
8. Abreu-Ledón, R., Luján-García, D., Garrido-Vega, P., Escobar-Perez, B.: A meta-analytic study of the impact of lean production on business performance. Int. J. Prod. Econ. **200**, 83–102 (2018)
9. Tayyab, M., Sarkar, B., Ullah, M.: Sustainable lot size in a multistage lean-green manufacturing process under uncertainty. Mathematics **7**(1), 20 (2018)
10. Kamble, S., Gunasekaran, A., Dhone, N.: Industry 4.0 and lean manufacturing practices for sustainable organisational performance in Indian Manufacturing Companies. Int. J. Prod. Res. **58**(5), 1319–1337 (2020)

11. Sposito, L., Santos, A.: Lean 4.0: a new holistic approach for the integration of lean manufacturing tools and digital technologies. Int. J. Math. Eng. Manag. Sci. **5**, 851–868 (2020)
12. Singh, S., Kumar, K.: Review of literature of lean construction an lean tools using systematic literature review technique. Ain Shams Eng. J. **11**, 456–471 (2020)
13. Zeballos, L., Mendez, C., Barbosa, A., Novais, A.: Multi-period design and planning of closed-loop supply chains with uncertain supply and demand. Comput. Chem. Eng. **66**, 151–164 (2014)
14. Becerra, A., Villanueva, A., Núñez, V., Raymundo, C., Dominguez, F.: Lean manufacturing model in a make to order environment in the printing in Perú. Adv. Intell. Syst. Comput. **971**, 100–110 (2019)

Serverless Architecture for Online Fault Detection in a Vertical Shaft Multistage Centrifugal Pump

Mauricio Leonardo Villacís(✉), Diego Cabrera, René Vinicio Sánchez, and Mariela Cerrada

Universidad Politécnica Salesiana, Cuenca, Ecuador
mvillacism@ups.edu.ec

Abstract. This paper proposes an architecture to online fault detection in a vertical axis multistage centrifugal pump. This is based on a serverless approach due to its advantages such as being able to create and execute applications and services without having to manage an infrastructure, besides being easily scalable. The purpose of this work is to expose the development of the architecture and its implementation in a well stablished cloud provider. Thus, performance tests were applied to an implementation of the proposed architecture with data acquired from the machine running in normal and faulty condition. The results showed that the proposal is feasible to be used for the fault detection task.

Keywords: Fault detection · Cloud computing · Centrifugal pump

1 Introduction

Fault detection and diagnosis have become a broad research field due to the growing demand for early assessment of the machinery condition to reduce scheduled downtime. Several techniques have been developed based on data processing, statistical analysis, and generation of models able to estimate the system behavior. A next step is to apply these techniques to generate systems capable of performing on-line fault detection. Thus, this paper deals with the development of an online fault detection architecture for a rotating machine, specifically a vertical axis multistage centrifugal pump. As a starting point, a methodology for fault detection has already been developed, where the necessary models were generated locally to accomplish this task. Information on the development of this methodology can be found in [1].

The design of the serverless architecture was generated to use these trained models and deploy them in cloud services. There are several works developed in this area [2–10] where different cloud architectures used for data analysis and model training for online fault detection and diagnosis tasks in different systems are deployed.

These works have in common that the data storage, data analysis and model training is performed in the cloud unlike our approach, where the models training are performed locally, and the deployment is performed in the cloud. Furthermore, in contrast to our

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 507–512, 2023.
https://doi.org/10.1007/978-3-031-27915-7_89

approach, these works use data analysis tools specific to the cloud services they employ in their architecture.

Section 2 introduces a description of the architecture, and each service used is explained in detail. In Sect. 3, the results of the fault detection system tests are presented. Finally, Sect. 4 presents the conclusions.

2 Architecture

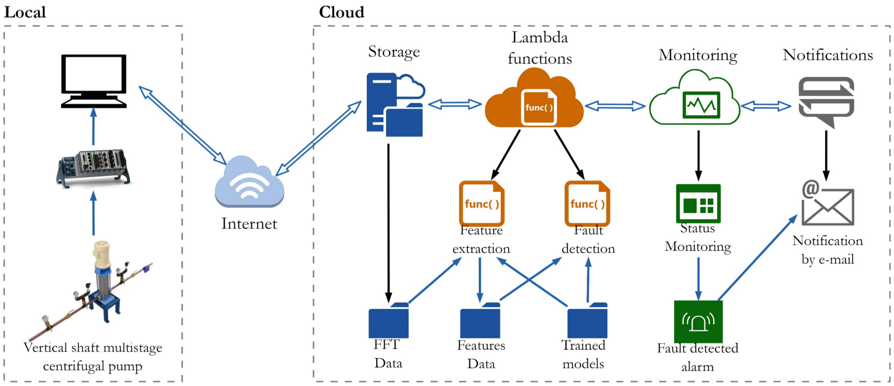


Fig. 1. Proposed serverless architecture

The proposed architecture depicted in the Fig. 1 consists of two main sections, the first one implemented locally and the second one implemented in the cloud. Section 1 (local) contains the pump test bench, a data acquisition system (cDAQ) and a computer in charge of managing the data acquisition and sending it to the cloud storage system. Section 2 (cloud) is composed by the cloud computing services, i.e., storage, lambda functions, monitoring, and notifications. The details of the previous elements will be detailed below.

2.1 Data Acquisition and Storage

As previously mentioned, the case study for the proposed architecture is a pump test bench. It has been developed at the Salesian Polytechnic University (UPS) by the Research and Development Group in Industrial Technologies (GIDTEC). The main component of the pump test bench is a vertical axis multistage centrifugal pump, in addition to different measuring instruments arranged along the bench to capture vibration signals, pressure, acoustic emission, flow and current. More details about the test bench can be found in [11]. However, only the vibration signal acquired by one of the accelerometers arranged in the pump test bench was used for the fault detection task with a sampling frequency of 50 kS/s.

For the acquisition system, an application was implemented to perform the acquisition process automatically, which consists of the following steps:

1. Acquire the signals every certain time interval assigned by the user and during a predefined time of 10 s. This results in a signal of 500000 samples.
2. The acquired signal is processed to extract 10 sub-signals. For this, a window of 8600 samples and a displacement of 50000 samples is used.
3. Then, the acquired time domain sub-signals are processed to transform them to the frequency domain. Thus, fast Fourier transform is used to obtain a set of 10 sub-signals of 4300 samples each in the frequency domain.
4. Using the sub-signals set, a data matrix is generated to be stored in the local computer and this file is sent to a cloud storage repository named “FFT data”.

2.2 Cloud

Within the cloud group are the services used to storage data and trained models, execute the feature extraction, execute the fault detection, visualize the results and generate the notifications. The task performed by each of the services is detailed below:

Storage Service. It’s used to stores the data in the repositories “FFT Data” and “Feature Data”, as well as stores the models trained for feature extraction and fault detection.

Lambda Functions Execution Service. Two lambda functions were created for the proposed architecture, the first one called “Feature extraction”, which extracts features from the last data batch stored in “FFT Data” using the previously trained models. This function is automatically executed when a new file is stored in the cloud data repository. Once these data are processed the results are stored in the “Features Data” repository. The second lambda function called “Fault detection” uses an inference model to process the last data stored in the “Features Data” folder and determine the centrifugal pump condition. Then, this service manages and coordinates the execution of the created lambda functions.

Monitoring Service. It is used to visualize the centrifugal pump condition and generate alarms when a failure is detected. Sending this alarm to the notification service.

Notification Service. This service generates the notifications through an e-mail when an instruction is received by the monitoring service.

3 Results

The following services provided by Amazon Web Services (AWS) were used for the deployment of the architecture:

- AWS S3 as Storage Service.
- AWS Lambda as Lambda function execution service.
- AWS Cloudwatch as Monitoring service.
- AWS SNS as Notification Service.

Thus, the results obtained once the deployment of the architecture was completed are detailed below.

The system was tested first with data coming from the machine working in normal condition, and second with data coming from the machine working in faulty condition. One hundred percent correct classifications were obtained. The results of these tests can be seen in Fig. 2 where the Y-axis represents the pump condition (1 normal condition and 0 faulty condition) based on the evaluation of the data coming from the test bench.

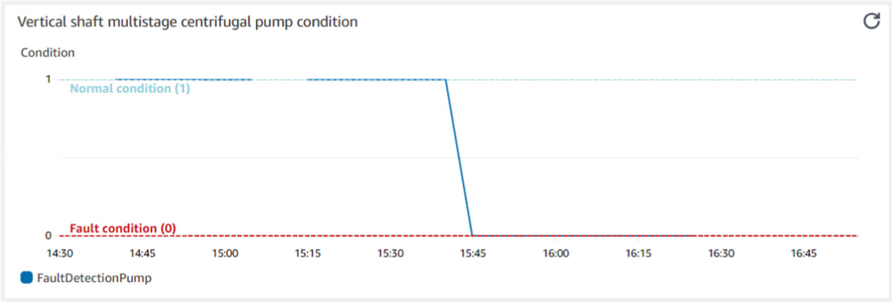


Fig. 2. Test results

The whole system worked correctly generating the pertinent alarms and notifications in a fault of the pump. For each execution of the lambda functions, metrics of the execution time of each of the functions are generated as shown in Fig. 3.

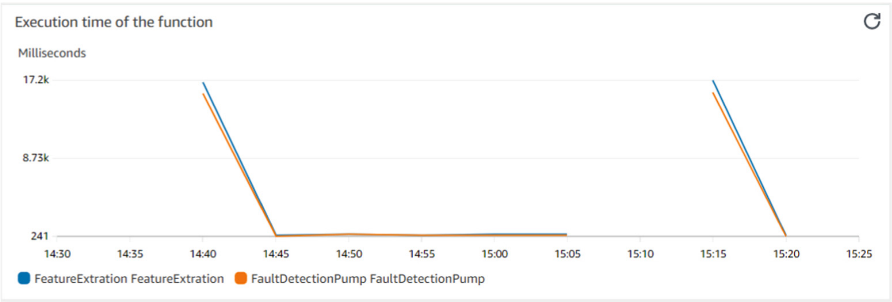


Fig. 3. Execution time of the functions

At the beginning the function execution of the lambda function "Feature extraction" is approximately 17 s and for the lambda function "Fault detection pump" execution time is 16 s. This means that the total time to determine the pump condition was around 33 s measured after the data store in "FFT Data". However, it's observed that the time of subsequent executions in a period of 10 min is less than 500 ms. This suggests that the lambda functions store the cache of the previous execution for, at least, 10 min.

These metrics are important because the cost of the service is computed according to the execution time of each function. Furthermore, this time must be considered during the design of the architecture because it could influence the real time response. In our case, since it is not a critical system that requires immediate responses in the order of seconds, it is not a decisive factor when evaluating the architecture performance. For these reasons, it can be considered that the deployed architecture worked successfully.

4 Conclusions

The serverless architecture developed in this work focused on performing online fault detection in a multistage centrifugal pump. The system performed the online fault detection task from the data provided to it. As could be seen in the results section, the accuracy in determining the machine status was 100% for both conditions, when the machine was operating under normal conditions and when it was operating under fault conditions. Furthermore, the response time of the system is satisfactory for the proposed case. Finally, the proposed serverless architecture has the advantage of having an easily scalable system that could be used to implement fault detection systems for other machines or use other models trained by different methodologies.

Acknowledgment. This work is supported in part by the MOST Science and Technology Partnership Program (KY201802006), and National Research Base of Intelligent Manufacturing Service Chongqing Technology and Business University and the Universidad Politécnica Salesiana through the GIDTEC research group.

References

1. Villacís, M.L.: Modelamiento basado en datos para la detección de fallos en una bomba hidráulica centrífuga multietapa vertical a partir de señales multimodales en condición normal (2020)
2. Khodabakhsh, A., Ari, I., Bakir, M.: Cloud-based fault detection and classification for oil & gas industry. arXiv preprint arXiv:1705.04583 (2017)
3. Lee, H.: Framework and development of fault detection classification using IoT device and cloud environment. J. Manuf. Syst. **43**, 257–270 (2017). https://doi.org/10.1016/j.jmsy.2017.02.007
4. Maeda, D., Gaur, S.: Poster:lambda architecture for robust condition based maintenance with simulated failure modes. In: 2020 IEEE/ACM Symposium on Edge Computing (SEC), pp. 152–154 (2020). https://doi.org/10.1109/SEC50012.2020.00019
5. Chang, L., Wang, H., Wang, L.: Cloud-based parallel implementation of an intelligent classification algorithm for fault detection and diagnosis of HVAC systems. In: 2017 International Smart Cities Conference (ISC2), pp. 1–6 (2017). https://doi.org/10.1109/ISC2.2017.8090835
6. Wallace, C., Ackels, S., Benavidez, P., Jamshidi, M.: Real-time distributed ensemble learning for fault detection of an unmanned ground vehicle. In: 2020 IEEE 15th International Conference of System of Systems Engineering (SoSE), pp. 463–468 (2020). https://doi.org/10.1109/SoSE50414.2020.9130511
7. Yu, W., Dillon, T., Mostafa, F., Rahayu, W., Liu, Y.: A global manufacturing big data ecosystem for fault detection in predictive maintenance. IEEE Trans. Industr. Inform. **16**(1), 183–192 (2020). https://doi.org/10.1109/TII.2019.2915846

8. Nastic, S., et al.: A serverless real-time data analytics platform for edge computing. IEEE Internet Comput. **21**(4), 64–71 (2017). https://doi.org/10.1109/MIC.2017.2911430
9. Karácsony, T., Loesch-Biffar, A.M., Vollmar, C., Noachtar, S., Cunha, J.P.S.: DeepEpil: towards an epileptologist-friendly AI enabled seizure classification cloud system based on deep learning analysis of 3D videos. In: 2021 IEEE EMBS International Conference on Biomedical and Health Informatics (BHI), pp. 1–5 (2021). https://doi.org/10.1109/BHI50953.2021.9508555
10. Zhang, Y., Wang, X., He, J., Xu, Y., Zhang, F., Luo, Y.: A transfer learning-based high impedance fault detection method under a cloud-edge collaboration framework. IEEE Access **8**, 165099–165110 (2020). https://doi.org/10.1109/ACCESS.2020.3022639
11. Calderón, J.C., Montalván, F.I.: Adquisición de señales acústicas y vibracionales para el diagnóstico de fallos en una bomba centrífuga multietapa de eje vertical (2019)

Evaluation of Video Signals for Coupling Fault Detection Using the Mirror Technique

Renán Xavier Montesinos Loaiza, René-Vinicio Sanchez(✉), Cristian Carrión, Mariela Cerrada, and Diego Cabrera

Universidad Politécnica Salesiana, Cuenca, Ecuador
rsanchezl@ups.edu.ec

Abstract. This study presents the evaluation of video signals for coupling fault detection using the mirror technique. The characterization of the mirror technique in video signal processing is key to establish the methodologies proposed in this study; the first one deals with the acquisition and processing of signals and the second one allows to evaluate the video signal technique regarding to the traditional technique which is the vibration monitoring through of contact sensors. The results obtained allow to consider that the mirror technique within the condition monitoring, with the appropriate methodology allows the reproducibility of data acquisition and processing, to issue a diagnosis of the machine condition and avoid unscheduled stops in the plant production.

Keywords: Mirror technique · Maintenance · Condition monitoring · Vibrations

1 Introduction

In recent decades, various sensors have been employed to measure dynamic responses that occur in rotating machinery. The parameters generally measured by these sensors can be vibrations, temperature, electric current and magnetic field and others [1]. Because of this, there is a great interest in intelligent fault diagnosis methods capable of estimating machine conditions with high accuracy and in a short time [2].

Vibration analysis is one of the most powerful and reliable condition monitoring techniques to determine failures during the operation of rotating machinery [3, 4]. However, condition monitoring in rotating machinery nowadays is possible to be performed by video signals, studies such as: "Application of motion-augmented video for machinery diagnosis" which is based on the evaluation of high-resolution and high-speed video taken from the machinery in operation. This method provides information equivalent to a high sensor count ODS by treating each pixel as an accelerometer, using pixel light intensity modulation to determine the local vibration displacement frequency spectrum [5].

Vibration analysis performed using accelerometers requires installation of the accelerometer and access to the measurement point; which is not always possible due to the location of the measurement point or risks to personnel. These limitations can be overcome if video signals are used. Then, the development of systems based on video

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 513–520, 2023.
https://doi.org/10.1007/978-3-031-27915-7_90

signals allows the remote estimation of vibration, simplifying the installation of the measurement system [6–9]. In Table 1, a comparison of video signals regarding to vibration signals acquired by means of contact sensors is presented:

Table 1. Comparison of video vibration signals within condition monitoring on rotating machinery.

Comparison of video versus vibration signals within condition monitoring on rotating machinery	
Video signals	Vibration signals (contact sensors)
Non-invasive (non-contact) technique	Invasive (contact) technique
Short processing times	Longer processing times
Frequency range dependent on fps	Frequency range dependent on the sampling frequency of the contact sensor
Light susceptible	Susceptible to shock

In the present article, video signals processed by means of a software, called DragonVision®, will be evaluated. It starts from a comparison of vibration signals acquired by accelerometer and video signals acquired by a video camera; applied to failures performed couplings, which provide information on a baseline in normal conditions and failure conditions in the aforementioned element.

2 Methodology

For the evaluation of the video signals with respect to the vibration signals, two methodologies were proposed, the first one for the acquisition of vibration and video signals presented in Fig. 1. And consists of eight stages. (1) Conditioning of the test bed; (2) Sensor and camera placement; (3) Conditioning of data acquisition software, such as camera and lighting; (4) Acquisition of vibration and video signals under normal and fault conditions; (5) Export of vibration signals (Matlab), and transfer of the video to DragonVision® software; (6) Conditioning of data processing software; (7) Baseline survey; and (8) Database of vibration and video signals in normal condition and with faults.

From the methodology presented in Fig. 1, it is important to emphasize the data acquisition stage, because if the data for both vibration signals and video signals are not correctly acquired, the results would not be valid for the study of the condition of the equipment to be analyzed.

In vibration signals the site starts with the connection of the accelerometer (see Fig. 2), this is connected directly to the data acquisition module through a cable with four-pin input MIL-C-5015 type and BNC type output.

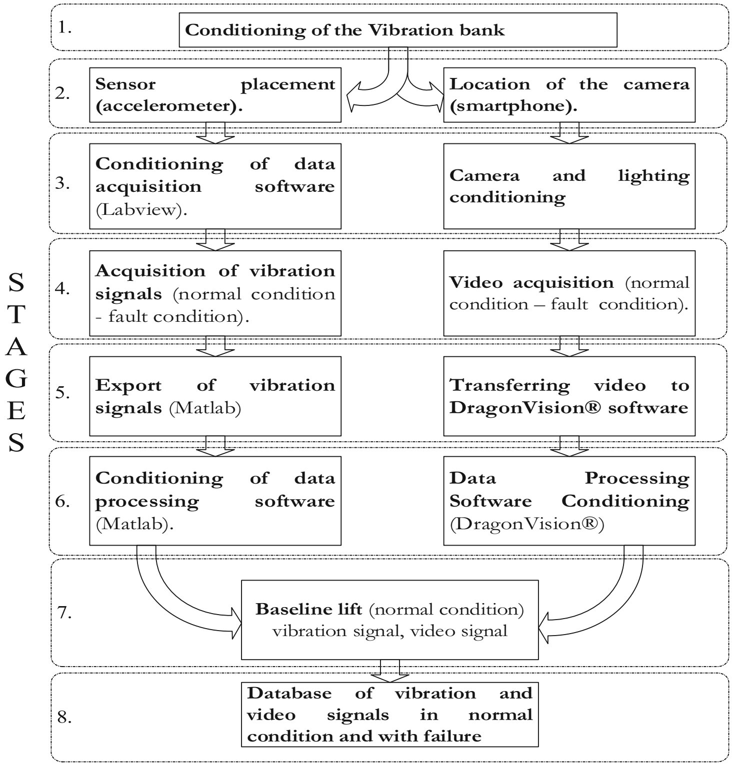


Fig. 1. Experimental process for the acquisition of vibration and video signals [10].

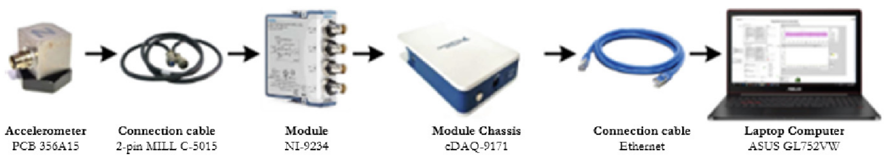


Fig. 2. Connection sequence of the vibration signal acquisition system [10].

The NI-9234 four-channel acquisition module receives accelerometer signals at a frequency of 50 kHz/s for each channel. This is located in a NI cDAQ-9171 module chassis, which is connected to the laptop computer via Ethernet cable. It controls the data acquisition through the program developed in LabVIEW, and then performs the analysis of the vibration signals through the program developed in Matlab by members of the Research and Development Group in Industrial Technologies (GIDTEC).

On the other hand, in Fig. 3, for video signals, the connection sequence begins with the placement of the video camera, for the placement of the camera, the illumination kit is positioned in front of the vibration bench, to later place the camera at a distance of 0.5 m. The video camera should be placed as fixed as possible, that is why it is placed on a tripod parallel to the axial axis of the motor. Once the camera and the illumination kit are in place, the level of luminosity is measured with the L-120 luxmeter, since illumination is considered to be fundamental in the detection of the micromotions that occur between pixels [10].

Fig. 3. Video signal acquisition system connection sequence.

In Fig. 4, the video camera attachment plane is presented; there is a video acquisition view, which encompasses the largest number of pixels of the test bed.

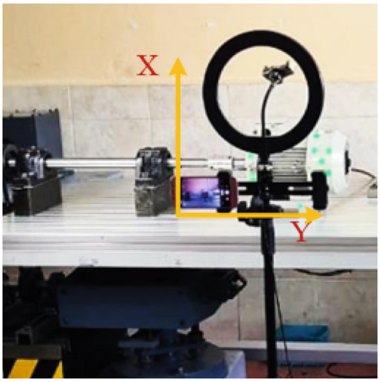


Fig. 4. Location plan of the vibration bench video camera.

The second methodology, presented in Fig. 5, allows the evaluation of vibration and video signals. It consists of five stages: (1) Vibration and video signal, in this stage the vibration signals are entered to Matlab and the video signals to DragonVision® software from the databases acquired with the first methodology; (2) and (3) Processing of the vibration and video signals, the FFT algorithm is applied in order to obtain the vibration spectrum of the vibration and video signal; (4) Frequency comparison: characteristics-vibration signals, in this stage the vibration and video signals acquired in the experimentation are validated with the characteristic frequencies of the vibration bench; (5) Comparative evaluation of peaks, harmonics, frequencies: Vibration signals - Video, with this stage it is determined how feasible it is to use the video signals applied to condition monitoring in rotating machinery.

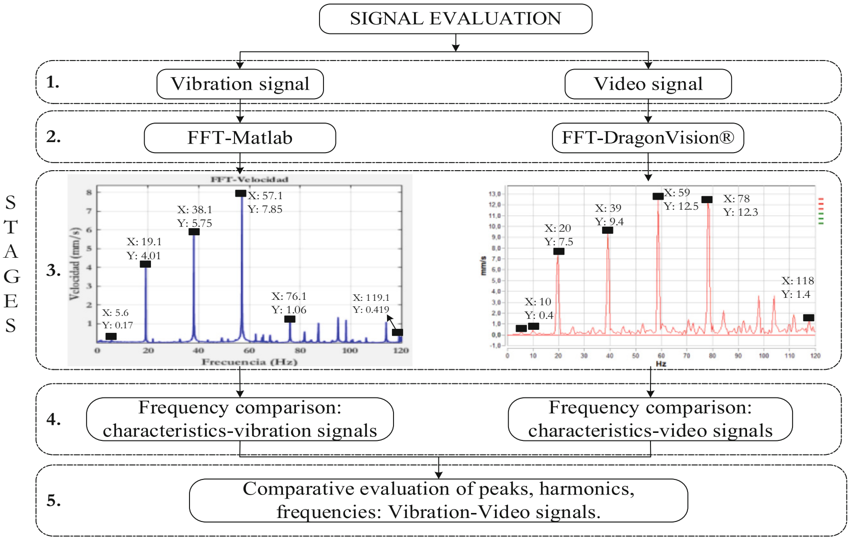


Fig. 5. Methodology for the evaluation of vibration and video signals [10].

3 Results

Table 2 shows the vibration spectra of the vibration signals and video signals in normal conditions and fault conditions of the vibration bench, this table contains information according to the methodology applied in the evaluation of signals. In the first instance, it can be seen that the spectra are similar, so for a more exhaustive analysis, Table 3 is presented.

In Table 2, when comparing the spectra of the vibration signal in parallel misalignment failure condition with respect to the baseline under normal conditions, it can be seen that the 1X peak decreases its amplitude, but it is the predominant peak in the spectrum. In the same way, this behavior is reflected in the spectrum obtained from the video signals, although the amplitudes are not comparable due to the displacement of the points identified by the Dragon Vision software.

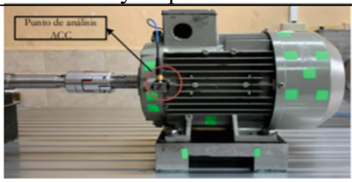
Table 3 shows the characteristic frequencies of the vibration bench. Only the natural frequency of the band is not detected by the video signals. However, there are differences between the values of the amplitudes of the frequencies detected by the accelerometer and the video signals, especially in the frequency of the rolling elements, the frequency of the BSF defect shows a slight variation in values due to the misalignment present in the motor coupling.

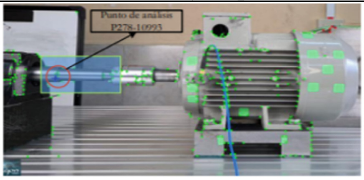
Likewise, the values of the frequency peaks show a maximum relative error between data of 4.71% and a minimum relative error of 0.52%, which makes video signals a technique with a wide expectation of development and implementation in the industrial field.

Table 2. Comparison of vibration and video signals with parallel misalignment at coupling.

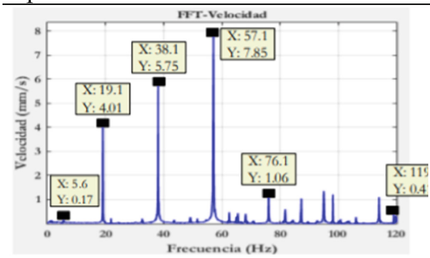
Comparison signals vibration test bed

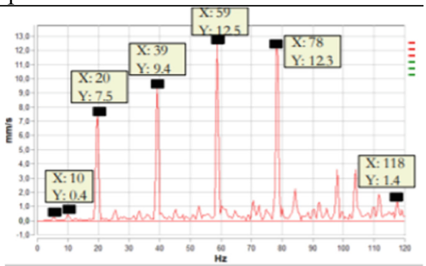
Vibration signal	**Video signal**
Analysis point ACC	Video Analysis point



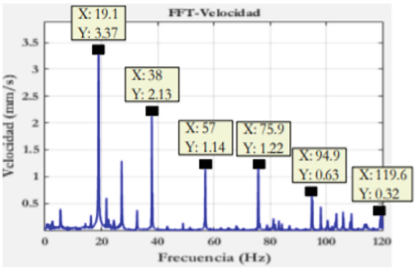


Spectrum under normal conditions	Spectrum under normal conditions





Spectrum under fault conditions	Spectrum under fault conditions



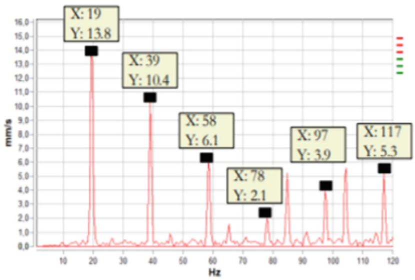


Table 3. Results of vibration and video signals.

Denomination	View	Position	Axis	Vibration signal frequency value (Hz)	Video signal frequency value (Hz)
Motor rotation	Frontal	Horizontal	x	19,2	20
Frequency of rotation of the rollers	Frontal	Horizontal	x	57,3	59
BSF defect frequency	Frontal	Horizontal	x	114	118

(*continued*)

Table 3. (*continued*)

Denomination	View	Position	Axis	Vibration signal frequency value (Hz)	Video signal frequency value (Hz)
Natural band frequency	Frontal	Horizontal	x	5,6	Not displayed
Parallel misaligment of the coupling					
Motor rotation	Frontal	Horizontal	x	19,1	19
Frequency of rotation of the rollers	Frontal	Horizontal	x	57	58
BSF defect frequency	Frontal	Horizontal	x	114	118
Natural band frequency	Frontal	Horizontal	x	5,6	Not displayed

4 Conclusions

The methodology was implemented and evaluated in the processing of the video signals, which was carried out with comparative tables between the vibration spectrum and the video, which were the result of processing the signals in Matlab and DragonVision® software, respectively. From the spectra, frequency values were obtained that allowed comparing the vibration and video signals, where it is observed that the frequency values are similar, as well as the spectral behavior for both vibration and video signals. A priori the vibration signals through video are useful for an initial diagnosis, it is necessary more experiments to evaluate in industrial conditions and at higher frequencies the condition of the equipment under study.

Acknowledgments. This work is supported in part by the MOST Science and Technology Partnership Program (KY201802006), and National Research Base of Intelligent Manufacturing Service Chongqing Technology and Business University and the Universidad Politécnica Salesiana through the GIDTEC research group.

References

1. Goyal, D., Pabla, B.S., Dhami. S.S.: Non-contact sensor placement strategy for condition monitoring of rotating machine-elements. Eng. Sci. Technol. Int. J. **22**(2) 489–501 (2019)
2. De Sá Só Martins, D.H.C., et al.: Diagnostic and severity analysis of combined failures composed by imbalance and misalignment in rotating machines. Int. J. Adv. Manuf. Technol. **114**(9), 3077–3092 (2021)
3. Peeters, C., et al.: Review and comparison of tacholess instantaneous speed estimation methods on experimental vibration data. Mech. Syst. Signal Process. **129,** 407–436 (2019)
4. Watson, M, et al.: A comprehensive high frequency vibration monitoring system for incipient fault detection and isolation of gears, bearings and shafts/couplings in turbine engines and accessories.Turbo Expo: Power for Land, Sea, and Air. **47942** (2007)

5. Marscher, W.D., y Chad, R.P.: «Motion magnified video application to machinery diagnosis». Int. J. COMADEM **23(**3) (30 de june de 2020), 37–42 (2020)
6. Cigada, A., Mazzoleni, P., Zappa, E.: Vibration monitoring of multiple bridge points by means of a unique vision-based measuring system. Exp. Mech. **54(**2), 255–271 (2014)
7. Kim, S.W., Kim, N.S., Kim, Y.M.: Application of vision-based monitoring system to stay cables. İn: Bridge Maintenance, Safety, Management, Resilience and Sustainability: Proceedings of the Sixth International IABMAS Conference, Stresa, Lake Maggiore, Italy (2012)
8. Lee, J.J., Shinozuka, y.M.: «Real-time displacement measurement of a flexible bridge using digital ımage processing techniques». Exp. Mech. **46**, (1), 105–114 (2006). https://doi.org/10.1007/s11340-006-6124-2
9. Djagarov, N., et al.: Ship's induction motors fault diagnosis. In: 2019 16th Conference on Electrical Machines, Drives and Power Systems (ELMA). IEEE (2019)
10. Alberca, C., Andrés, C., Xavier, R., Loaiza, M.: Evaluación de las señales de vídeo para la detección de fallos en rodamientos y acoplamientos empleando la técnica espejo. BS thesis (2021)

Audit Model for the Management of Physical Assets Maintenance. Case Study: Mechanical Laboratories at Ecuadorian University

Anderson Andrés Mogollón Espinoza, René-Vinicio Sanchez(✉), Mayra Puedmag, Mariela Cerrada, and Diego Cabrera

Universidad Politécnica Salesiana, Cuenca, Ecuador
rsanchezl@ups.edu.ec

Abstract. The development and execution of an ideal and feasible model to evaluate the maintenance management of physical assets has become a topic of great importance for the achievement of the proposed objectives. An audit allows to identify those weak points that affect the performance of the organization, in order to know the degree of maturity of the maintenance processes and take corrective actions based on opportunities for improvement. In this context, the purpose of this document is to provide an audit model flexible to the realities of each company that requires quantitative and qualitative evaluation of the current state of maintenance management. Within the model, the Network Analytical Process (ANP) was applied, to quantitatively weigh the audit criteria, and thus better understand the complex relationships that exist between each of them, in order for the decision maker to identify those areas or processes where greater control is necessary and focus efforts on processes where important gaps in maintenance management have been detected. For the validation of the audit model, it was applied in the laboratories of a university in Ecuador.

Keywords: Audit model · Assets · Maintenance management

1 Introduction

When we talk about a physical asset we associate it throughout its life cycle, starting from the conceptual engineering, incorporation of the equipment, project, implementation, incorporation, up to its disincorporation. Although a proper maintenance, management is expected to ensure the proper functioning of the physical asset in any production process, maximizing productivity and economic profitability of the business throughout the life cycle. The reality is that bad optimization decisions are made due to the inadequate evaluation of the performance managed by the organization itself, derived from the poor definition of pertinent technical evaluation criteria [4, 9–11].

Maintenance management is usually planned at the strategic, tactical and operational level. Therefore, at each level, organizations look for models that allow them to measure the degree to which resources are managed (people, materials, technology, etc.), especially in the area of maintenance [3]; but, due to a lack of regulation in terms

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 521–526, 2023.
https://doi.org/10.1007/978-3-031-27915-7_91

of regulations, limited bibliographic information and the operational context of each organization, a systematic and rigorous audit model that ensures effective results and opportunities for improvement for the company has not been capitalized. Table 1 presents several proposals based on the literature; its characteristics are analyzed for several case studies within the context of industrial maintenance.

Table 1. Audit model proposals.

Authors	Proposal
Duffuaa y Raouf [8]	Two-step audit process: The first step was the clarification of the maintenance areas, and the next step was to obtain an audit score
Duffuaa y Ben-Daya [7]	They propose the use of statistical control tools to improve the quality of maintenance
De Groote [6]	Based on a quality audit approach, it evaluates maintenance performance. The quality audit is composed of four stages, data study, data analysis and an improvement plan
Price Water House Coopers [6]	He developed questionnaire to evaluate maintenance programs, in wich they include ten evaluation criteria. Each question receives a score from 0 to 4
Clark [5]	He suggests that the results of the audit should be reflected by a maintenance radar (spider chart), where human and economic aspects are visualized

This paper proposes an audit model to assess the unemployment of the maintenance management of physical assets, framed to the ISO 55001 [2] standard for asset management and ISO 19011:2018 [1] for the audit process. This model is supported as a tool for continuous improvement that allows identifying those processes or areas where greater control is necessary by comparing the current state against the ideal. Once those opportunities for improvement have been identified, the actions that are proposed must allow the organization to take corrective actions, in order to comply with the strategies and objectives proposed. As the main contribution of the work, maintenance audit criteria were selected under the context of asset management for each organizational level (strategic, tactical, and operational). In the same way, audit criteria and sub-criteria were prioritized through the Network Analytical Process (ANP), developed by Saaty as a decision-making method with multiple criteria [4]; the ANP method has proven to be effective for real maintenance applications [11]. Finally, an evaluation instrument will be developed according to the level of requirement determined for each of the audit criteria. It should be noted that the audit model was applied in the laboratories of a University in Ecuador.

2 Literature Review

Currently, the competitiveness and performance of organizations depend exclusively on the availability, reliability, and productivity, and the costs associated with maintaining their physical assets throughout the life cycle [12]. Asset management and maintenance are emerging as the key axis of the competitiveness of world-class organizations. Incorporating maintenance into asset management will help the organization in the process of defining the best strategies to apply for each physical asset throughout the lifecycle, to achieve the goal: to increase the economic profitability of the business. The better the management of assets, the lower the costs associated with their maintenance.

An audit, according to ISO 19011:2018, is a systematic, independent, and documented process to obtain objective evidence by comparing against relevant criteria or standards. This standard provides guidelines for managing an audit program and conducting the activities of an audit, following a series of stages aligned to the continuous improvement cycle (PHVA). Within the same context, a systematic evaluation of maintenance management as an optimization tool allows to assess performance as a multidisciplinary process, creating a "roadmap" towards maintenance excellence within the asset management approach. Optimizing the performance of maintenance practices and processes can contribute positively to the success of any organization.

3 Model Proposal

The proposed model involves four stages: (1) selection of the audit criteria; (2) weighting of the evaluation criteria using the Analytical Network Process (ANP); (3) development of the evaluation instrument; and (4) validation of the model by applying it to the case study. Figure 1 shows the proposed model for auditing the management of physical asset maintenance. The model is structured in four stages; in stage one, a literature search is performed for the collection of audit criteria and subcriteria under the context of the international standard ISO 55001:2014, and then, through experts involved in the maintenance area, the relevant criteria are selected. The selected criteria were: General Organization, Maintenance Outsourcing, Maintenance Financial Monitoring and KPIS, Risk-based Hierarchy Models, Human Talent, Scheduling and Planning Processes of Maintenance Plans, Maintenance Management, Maintenance Execution and Spare Parts Warehouse Inventory Management.

In stage two, the analytical network process (ANP) method was applied to determine the weightings of the audit criteria and sub-criteria. For the construction of the general structure of the ANP, the opinion of competent managers in the area of industrial maintenance was required to mitigate the possible biased attitude of a single decision-maker, and thus, to establish the level of importance among the audit criteria [10]. In stage three, once the audit criteria have been prioritized, the evaluation tool is developed prior to the validation of the questions by experts in industrial maintenance and asset management, to verify the acceptance or rejection of the same. Finally, in the final phase of the process, the audit model is executed under the ISO 19011:2018 standard at a university in Ecuador to validate the model.

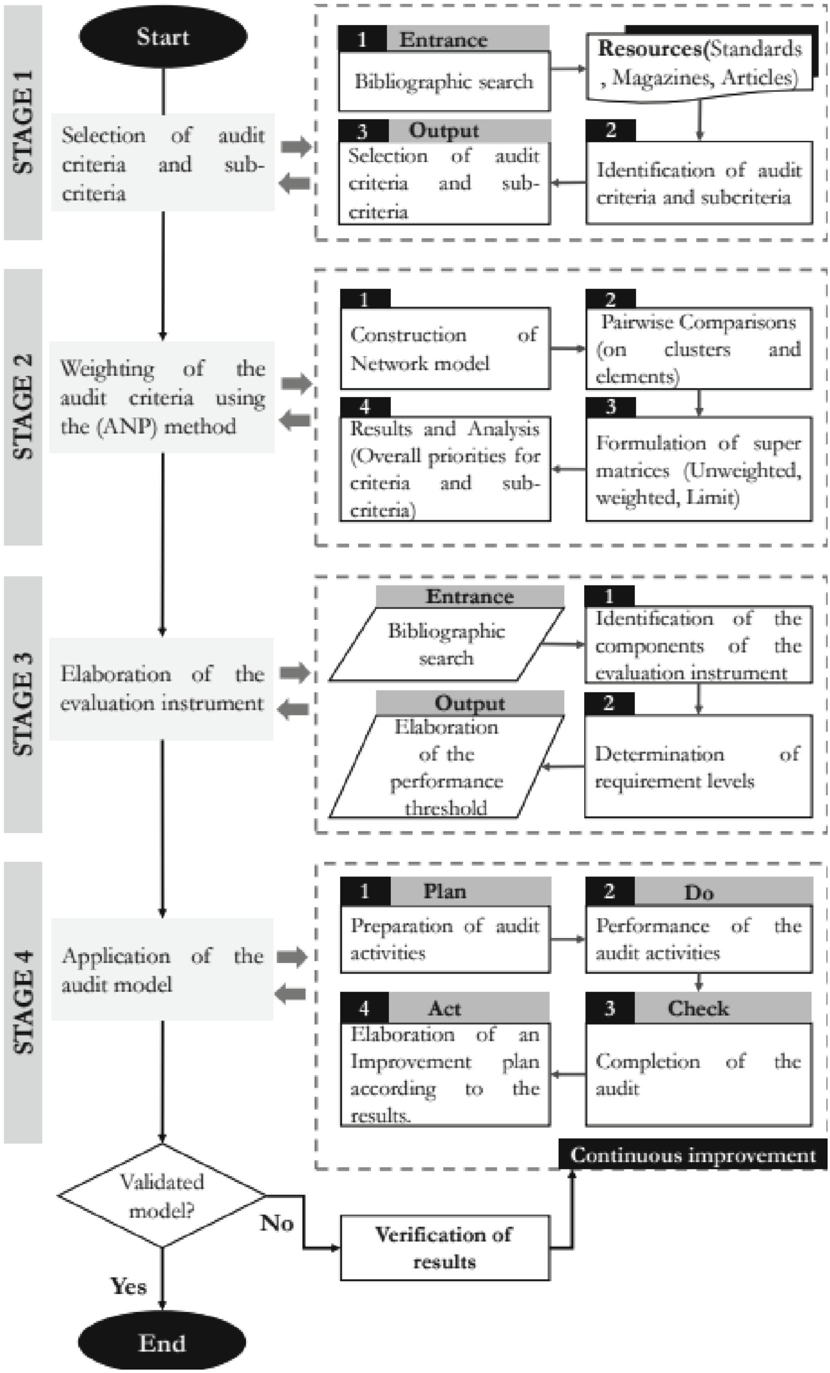


Fig. 1. Schematic framework of the audit model. **Adapted from:** [9].

4 Results and Conclusions

The support of bibliographic information and standards related to asset maintenance and management made it possible to select nine criteria and thirty-one sub-criteria.

In accordance with the requirements of the proposed method (ANP), the audit criteria were prioritized, where the three most important criteria were: human talent (30%), maintenance execution (21%) and general organization (12%). This indicates that during the audit these were the criteria that carried the most weight. Consequently, the valuation instrument was prepared based on the documents provided by the auditee and the university's response. After applying the evaluation instrument and, according to the level of performance achieved by the audit criteria and the requirements (weights), the university laboratories were evaluated and it was determined that there are criteria in which they should be improved, although each of them to a different extent and sub-criteria as shown in Fig. 2.

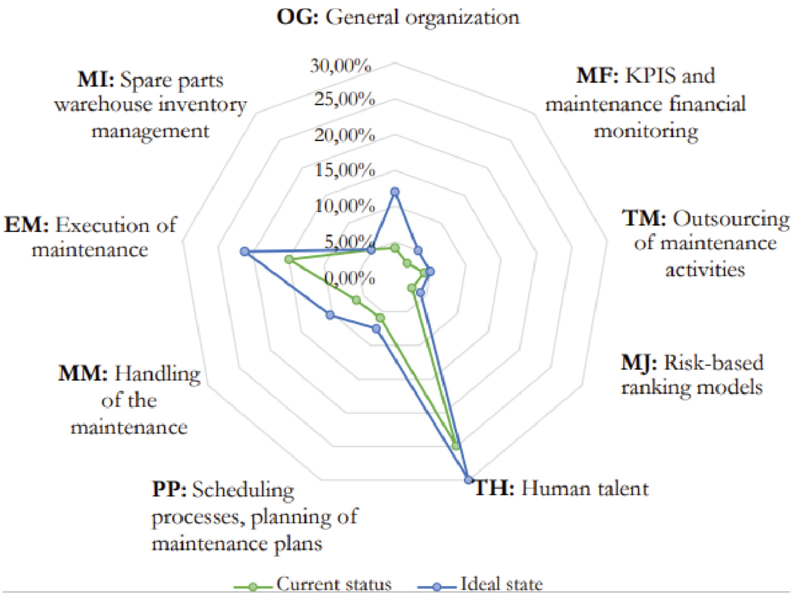


Fig. 2. Radar diagram, representing the performance of the audit criteria.

The Human Resources criterion showed a performance of 24.91% of the 30% required, followed by the maintenance execution criterion with 14.1% of 21%, and the maintenance management criterion with 6.19% of the 10%. Finally, it was identified that currently the university does not perform according to the desired level of maintenance management; it reached a quantitative valuation of 70.8% of the 100% of the established compliance; therefore, according to the established valuation, qualitatively it represents a level below the average. With these results, it is necessary to immediately implement corrective actions to improve the performance level of the audited areas. A comprehensive audit model, based on the analytical network process (ANP), was presented to determine the relevant evaluation criteria, considering all levels of the organization (i.e., strategic, tactical and operational levels). Therefore, the audit model was applied based on the level of importance of the audit criteria.

Acknowledgments. This work is supported in part by the MOST Science and Technology Partnership Program (KY201802006), and National Research Base of Intelligent Manufacturing Service Chongqing Technology and Business University and the Universidad Politécnica Salesiana through the GIDTEC research group.

References

1. ISO 19011:2018 (en): Guidelines for auditing management systems (2018)
2. ISO 55001:2014 (en): Asset management — management systems — requirements (2014)
3. Ben-Daya, M., Duffuaa, S.O., Raouf, A., Knezevic, J., Ait-Kadi, D.: Handbook of Maintenance Management And Engineering, vol. 7. Springer, London (2009). https://doi.org/10.1007/978-1-84882-472-0
4. Carpitella, S., et al.: A risk evaluation framework for the best maintenance strategy: the case of a marine salt manufacture firm. Reliab. Eng. Syst. Saf. **205**, 107265 (2021)
5. Clark, C.H., Hurkmans, C.W., Kry, S.F., of Radiation, T.G.Q.A., Group, T.C.T.H.: The role of dosimetry audit in lung sbrt multi-centre clinical trials. Phys. Med. **44**, 171–176 (2017)
6. De Groote, E.: Auditory system involvement in Parkinson's disease: objective investigation of peripheral and central auditory processing. Ph.D. thesis, Ghent University (2021)
7. Duffuaa, S.O., Ben-Daya, M.: Turnaround maintenance. In: Ben-Daya, M., Duffuaa, S., Raouf, A., Knezevic, J., Ait-Kadi, D. (eds.) Handbook of Maintenance Management and Engineering, pp. 223–235. Springer, London (2009). https://doi.org/10.1007/978-1-84882-472-0_10
8. Duffuaa, S., Raouf, A.: An optimal sequence in multicharacteristics inspection. J. Optim. Theory Appl. **67**(1), 79–86 (1990)
9. Mogoll´on Espinoza, A.A., Puedmag P´erez, M.V.: Modelo de auditor´ıa para la gesti´on de mantenimiento de activos f´ısicos. Caso de estudio: laboratorios del a´rea Mec´anica de la Universidad Polit´ecnica Salesiana sede Cuenca. B.S. thesis, Universidad Polit´ecnica Salesiana (2021)
10. Saaty, T.L.: Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process. RWS Publications (1994)
11. Saaty, T.L.: Fundamentals of the analytic hierarchy process. In: Schmoldt, D.L., Kangas, J., Pesonen, M., Mendoza, G.A. (eds.) The Analytic Hierarchy Process in Natural Resource and Environmental Decision Making, pp. 15–35. Springer, Dordrecht (2001). https://doi.org/10.1007/978-94-015-9799-9
12. Van Horenbeek, A., Pintelon, L.: Development of a maintenance performance measurement framework—using the analytic network process (ANP) for maintenance performance indicator selection. Omega **42**(1), 33–46 (2014)

Author Index

F. P. García Márquez et al. (Eds.): CIO 2022, LNDECT 160, pp. 527–530, 2023.
https://doi.org/10.1007/978-3-031-27915-7