CSR, Sustainability, Ethics & Governance
Series Editors: Samuel O. Idowu · René Schmidpeter

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Helmut Faasch *Editors*

Resilience, Entrepreneurship and ICT

Latest Research from Germany, South Africa, Mozambique and Namibia

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Series Editors

Samuel O. Idowu, London Metropolitan University, London, UK
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Foreword

There is so much hype surrounding the Fourth Industrial Revolution (4IR) and its implications for society, often with special emphasis on the African continent. While it is currently feared that 4IR will result in many job losses, cybersecurity, and black box Artificial Intelligence, there is also hope that the Fifth Industrial Revolution will put humans back into the loop, in particular through the control of Artificial Intelligence.

COVID-19 has caused disruption on multiple fronts around the world since the beginning of 2020, but it has also placed the spotlight on rapid and emergency digitalization across multiple sectors. While the economic toll on the well-being of nations has been hefty, 2020 and COVID-19 have certainly highlighted the importance of resilience, entrepreneurship, and ICT. So the title of this book is apt, especially at a time when we are all examining the intersectional effects of COVID-19 and the Fourth Industrial Revolution on societies.

This book examines an array of research topics from Germany and three southern African countries, South Africa, Mozambique, and Namibia that speak to this intersection and that examine the multidimensional and complex nature of the various actors in the ecosystem made up by our communities.

The YEEES Research Center, an international and interdisciplinary network of universities and researchers from Germany and Southern Africa, should be commended for the work they have done on this volume and the understanding it provides of the resilience that our communities need.

Prof. Anicia Peters
Pro Vice Chancellor for Research
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University of Namibia
Windhoek, Namibia

Foreword

The YEEES project, in which the University of Oldenburg participated, covers a wide range of different research topics. The project connects researchers, students, and companies from the Sub-Saharan region (South Africa, Mozambique, and Namibia) with the University of Vechta and Oldenburg in Northern Germany. The project promotes higher education at the next academic level and the exchange of researchers to develop a solid base for sustainable, innovative entrepreneurial approaches.

The Department of Computing Science at the University of Oldenburg is proud to have contributed to and supported such an impressive project with such remarkable results. One of the results is the present anthology, in which we and our project partners present selected research topics. Exchanges of Ph.D. students from the fields of environmental studies and computer science have provided the scientists with a unique opportunity to further develop their research.

We are proud of the lasting results achieved within this project, e.g., the IT-based research groups, and look forward to future collaboration with our partner universities from South Africa, Mozambique, and Namibia.

Director Department of Computing Science
University of Oldenburg
Oldenburg, Germany

Prof. Dr. Sebastian Lehnhoff

Foreword

The YEEES project is an excellent example of the development of transformational ideas in collaboration with international partners. This anthology is one result of the fruitful joint work between researchers from Southern Africa and Germany. Under the umbrella of resilience research, the contributions cover various areas and perspectives—from computer science to teaching, from culture to smart solutions. Addressing the development of sustainable entrepreneurial solutions to meet today's urgent challenges, the anthology introduces current academic work that is highly relevant for future research and practical application.

The book showcases examples of successful international research collaboration and joint work with practitioners. In addition, we demonstrate strong linkages between research and teaching within the YEEES project. This has led to students being actively involved in research groups as participants. I am happy to see that the anthology is also giving young academics the opportunity to share their work.

Congratulations on this successful project and on the impressive results achieved—some of which are presented in this book. The University of Vechta is delighted to have led the YEEES project. We are looking forward to further strengthening our international collaboration and to supporting the expansion of the YEEES network.

President University of Vechta
Vechta, Germany

Prof. Dr. Burghart Schmidt

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This work is part of the project "YEEES—Yields of Evocative Entrepreneurial approaches on Environment and Society." Further information is available on the following website: https://yeees-project.org/.

The "YEEES—Yields of Evocative Entrepreneurial approaches on Environment and Society" project was possible, thanks to the funding by the Federal Ministry of Education and Research (BMBF) of Germany and the German Academic Exchange Service (DAAD). We sincerely thank both for the confidence in the vision and objective of the YEEES project. With our two centers, the YEEES Research Center and the YEEES Training Center, we were able to involve many different students, graduates, and researchers in our work and expand the YEEES network. This anthology is a proof of our network development and we want to thank all the collaborators. We also want to thank the more than 30 reviewers without whom the high quality of this anthology would not have been possible. We also would like to take this opportunity to express our appreciation to all participants of the YEEES activities as scholars, researchers, and lecturers.

Introduction: Perspectives on Resilience Research

> Do not judge me by my success, judge me by how many times I fell down and got back up again.—Nelson Mandela

Resilience is key to the ability to stand up again and again. Resilience is also the umbrella topic of this anthology and of the YEEES[1] project. YEEES focuses on resilience through entrepreneurial thinking and supported by information and communication technologies (ICT) particularly in urban and peri-urban areas. In this introductory article, we start with an overview of the YEEES project and of research supported within the YEEES Research Center. In the second part, we briefly introduce resilience research from different perspectives. We focus firstly on the geographical aspect as the initial starting point of our work was the resilience of urban and peri-urban areas, followed by other main fields of resilience research which are, however, often interconnected. Finally, we give an overview of the book's structure and the articles selected in this anthology.

Resilience Within the YEEES Project

"In addition to integrating across fields, sustainability must also be integrated across sectors or interests. It is clear that governments alone have neither the will nor the capability to accomplish sustainability on their own. The private sector, as the chief engine of economic activity on the planet, and a major source for creativity, innovation and entrepreneurship, must be involved in trying to achieve sustainability" (Robinson, 2004, p. 387). We have, thus, developed an inter- and transdisciplinary project that focuses on Yields of Evocative Entrepreneurial approaches on Environment and Society (YEEES). This project is based on the establishment of two interconnected centers, which are both seen as international

[1] Yields of Evocative Entrepreneurial approaches on Environment and Society; more information at www.yeees-project.org.

networks addressing a variety of topics: The YEEES Research Center and the YEEES Training Center.

Our international networks are based on long-term cooperation between German and Southern African universities: the University of Vechta, the Carl von Ossietzky University Oldenburg, and the Leuphana University Lüneburg in Germany, working in close partnership with the University of Windhoek (UNAM) in Namibia, the Nelson Mandela University (NMU) in Gqeberha, South Africa, and the Universidade Pedagogica in Maputo and Maxixe. Meanwhile, we have grown the network and integrated partners from different countries around the world—all connected by their research and teaching activities.

The YEEES project supports research and teaching on the development of innovative entrepreneurial approaches, e.g., the founding of sustainability start-ups and organizations in a variety of fields. Our work furthermore supports the development of skills and mindsets that lead to entrepreneurial behavior and thus helps future change agents identify and exploit opportunities for creative and innovative or "imovative"[2] solutions. We also contribute to broad and strong international collaboration with a specific focus on German-African connections, that allows mind-changing experiences, which on a short- and long-term perspective enable people to contribute to sustainable change.

The YEEES Research Center fosters research in sustainability entrepreneurship, ICT, and various related fields with the aim of developing sustainable solutions to promote resilient cities and peri-urban landscapes in sub-Saharan Africa. Our main research question is: *How can sustainability entrepreneurship, based on or using ICT in the fields of urban agriculture and mobility, for example, contribute to resilient city development in Africa?* Our aim is to be a long-term, visible, and renowned network of international researchers from a variety of disciplines. The Research Center's focus is on building trans- and interdisciplinary research groups of experienced senior and junior researchers, students, and practitioners conducting relevant research that contributes to resilience by developing solutions for the world's most pressing challenges. Since resilience can be seen to exist in different forms and is influenced by a range of factors, research can be conducted in a large number of fields.

Due to our focus on resilient area development, we have started structuring and selecting relevant areas by using the so-called city resilience framework proposed by Arup (2014). As well as defining urban resilience, the author identifies 12 goals that contribute to a city's "immune system," across four critical dimensions of city resilience. Goals and areas of focus for the YEEES Research Center were derived from workshop discussions and interviews with expert researchers and practitioners, as shown in Fig. 1.

[2]We define imovative as inspired by existing ideas, imitated, but adapted to new fields, environments, or problems.

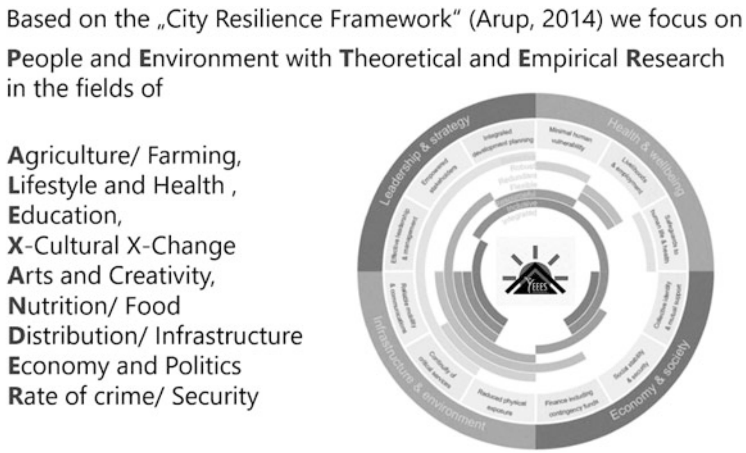

Fig. 1 YEEES Research Center—main areas of interest for resilient area development

These focus areas, however, will be addressed under the broader umbrella of entrepreneurship and/or ICT research as we finally carve out innovative solutions and practical implications based on our work.

Why Focus on Resilience? Understanding Various Forms of Resilience

Resilience is considered important for areas, systems, organizations, and people—making them strong in the face of attacks and challenges, allowing for adaptation and improvement in such difficult situations and even enabling them to be resisted when they arise. One of the main areas of research focuses on resilient area development. A significant tranche of work deals with city resilience (Arup, 2014; Labaka et al., 2019; Marana et al., 2018; Spaans & Waterhout, 2017). According to Arup (2014, p. 3), city resilience can be seen as "the capacity of cities to function, so that the people living and working in cities—particularly the poor and vulnerable—survive and thrive no matter what stresses or shocks they encounter." Maintaining a geographical perspective, academic work also deals with the development of broader areas, such as the resilience of communities and regions (Bristow & Healy, 2018; Rizzi et al., 2018; Stognief et al., 2019; Tim et al., 2021) or even countries and at a global level (Haile et al., 2019; Kammouh et al., 2018; Rockenbauch & Sakdapolrak, 2017; Russo et al., 2017). Within these fields, we find studies both on rural and on urban areas (Anthopoulou et al., 2017; Elmqvist et al., 2019; Ženka et al., 2017).

Several studies have already addressed the question of how resilient areas can be built and improved so that they are able to resist and absorb threats and are capable of adapting to and recovering from shocks in order to contribute to their citizens' overall well-being (Labaka et al., 2019). These threats and shocks can be caused by environmental factors, e.g., certain coastal hazards or earthquakes (Oktari et al., 2020; Toghyani et al., 2020), but also be traced back to political or economic challenges as well as human misadventure (Coaffee et al., 2018; Coaffee, 2016; Pilav, 2012; Vale & Campanella, 2005). In sum, we find various aspects that are connected to resilient area development in the form of factors to be avoided (to gain resilience or by being resilient) and goals to be achieved. Recent work has connected resilient development with the achievement of sustainable development goals (SDGs). As Croese et al. (2020, p. 1) underline with regard to the SDGs "[. . .] the concept of urban resilience has become key to local and global development agendas."

Some scholars, however, criticize the fuzziness of the concept and underline the need for context-dependent interpretations and applications (Borie et al., 2019; Meerow & Newel, 2019; Olsson et al., 2015). Nonetheless, city and area resilience has become increasingly relevant in research as well as for practice, e.g., policymakers, practitioners, and international and multilateral aid agencies and institutions (Bene et al., 2014; Brunetta et al., 2018; Monstadt & Schmidt, 2019).

Resilience research, however, can also be applied to systems, such as economic (Bristow & Healy, 2020; Hallegatte, 2014; Martin & Sunley, 2015), social (Cinner & Barnes, 2019; Fath et al., 2015), ecological (Cosens, 2013; Maltby et al., 2019), and political (Cai, 2008; Malkki & Sinkkonen, 2016; Tanner et al., 2017) systems, and socio-ecological (Adger & Hodbod, 2014; Berkes & Truner, 2006; Grêt-Regamey et al., 2019) and ecological-economic perspectives (Derissen et al., 2011). For example, there is a good deal of work on food and farming systems (Béné, 2020; Meuwissen et al., 2019), marine ecosystems (Bates et al., 2019; Darling & Côté, 2018; Hughes et al. 2005), and industrial areas (Chopra & Khanna, 2014; Rist et al., 2014; Zhu & Ruth, 2013). From a social perspective, there is quite a lot of work on social and/or cultural systems' resilience, but also on how social and cultural factors influence the development of people's and organizations' resilience within those systems (Crane, 2010; Lyon & Parkins, 2013; Read, 2005; Theron & Liebenberg, 2015). (Inter)cultural factors play an important role when it, e.g., comes to community resilience (Kirmayer et al., 2009; Krause, 2018; Magis, 2010; Rabinovich et al., 2019; Ungar & Theron, 2020).

Another stream of resilience research looks at the organizational level—with different forms of organizations and institutions in focus. One example is charities and nonprofit organizations and their resilience or their influence on resilience (Green et al., 2021; Moran, 2016). Academic work also investigates state-run facilities or the government itself (Ahrens & Ferry, 2020; John, 2014; Lowndes & McCaughie, 2013). Some of this work focuses on, among other things, the resilience of hospitals (Aguirre et al., 2005; Khanmohammadi et al., 2018; Li et al., 2020) and the resilience of educational institutions such as schools or universities (Ahiauzu & Ololube, 2016; Breaden & Goodman, 2020). Another area of focus is the resilience of churches and church organizations (Lueger-Schuster et al., 2014; Northmore-Ball & Evans, 2016; Rivera & Nickels, 2014). However, most work in this field focuses on the business and management context, primarily the resilience of or in start-ups and established companies or business clusters (Blanco & Botella, 2016; Fallah, 2020; Haase et al., Niemimaa et al., 2019; 2017; Pereira et al., 2020). Besides formal organizations and institutions, we also find studies focusing on the resilience of other groups of people, such as communities (Berkes & Ross, 2013; Koliou et al., 2020), families (Kim et al., 2020; Masten, 2018), and teams, e.g., sports (Decroos et al., 2017; Morgan et al., 2013) or entrepreneurial teams (Blatt, 2009; Schippers et al., 2019).

On the micro-level, resilience research concentrates on the resilience of people. There is extensive work in this area, especially in the field of psychology (IJntema et al., 2019; Maree, 2017; Schwarz, 2018). One research stream deals with the resilience of people in certain contexts or areas, such as disaster areas, organizations, or situations (Makwana, 2019; Masten & Motti-Stefanidi, 2020). Other studies examine the general resilience of different groups of people. Research specifically concentrates on children and young people (De Feyter et al., 2020; Jefferies et al., 2019; Masten & Motti-Stefanidi, 2020) or elderly people (Cosco et al., 2017; Hardy et al., 2004; Kamalpour et al., 2020). There is resilience research that explores various attributes, such as gender differences (Hartman et al., 2009; Masood et al., 2016), education (Clements-Nolle & Waddington, 2019; Frankenberg et al., 2013), age (Ong et a., 2009; Pearman et al., 2021), race/ethnicity (Fast & Collin-Vézina, 2019; Kim et al., 2020), and sexual orientation (Kosciw et al., 2015; McConnell et al., 2018; Singh, 2018).

Other authors are working on the resilience of people in specific jobs/professions, as work stress is considered a growing problem (Black et al., 2017). However, work in this area mainly focuses on those facing increased pressure and high levels of stress, such as (medical) staff in the health and care sector (Santarone et al., 2020; Smith & Plunkett, 2019; Wald, 2020; Wei et al., 2019) or social workers (Crowder & Sears, 2017; Newell, 2020; Rose & Palattiyil, 2020). There is also research relating to the security sector, for example, in military (Brooks et al., 2020; Campbell-Sills et al., 2018; Polusny et al., 2017; Sharma et al., 2017) or police (Chitra & Karunanidhi, 2018; Steenbeek et al., 2020; van der Meulen et al., 2018) contexts.

From the business perspective, resilience research looks at employees (Cooper et al., 2019; Shin et al., 2012; Tonkin et al., 2018; Wijewardena et al., 2010) and especially managers (Abbott et al., 2009; Cooper et al., 2013; David et al., 2016; Rahman & Cachia, 2021). Management studies have been conducted at a variety of levels (Salehi & Veitch, 2020). These look at the resilience of individuals ranging from senior managers in large companies (David et al., 2016) to small- and medium-sized enterprises (SMEs) and family businesses (Beech et al., 2020; Conz et al., 2020; Danes & Stafford, 2011) to entrepreneurs and owner-managers (Branicki et al., 2018; Bullough et al., 2014; Duchek, 2018; Wall & Bellamy, 2019).

Despite the variety of fields in resilience research and the adoption of micro (people), meso (groups of people and organizations), and macro level (systems' and area resilience) perspectives, strong interconnections can be identified. Research shows how the resilience of individuals influences the resilience of groups and organizations and also plays a role in area resilience (e.g., McManus et al., 2007; Marana et al., 2018; Martin, 2015; Rahman & Mendy, 2019). Conversely, area

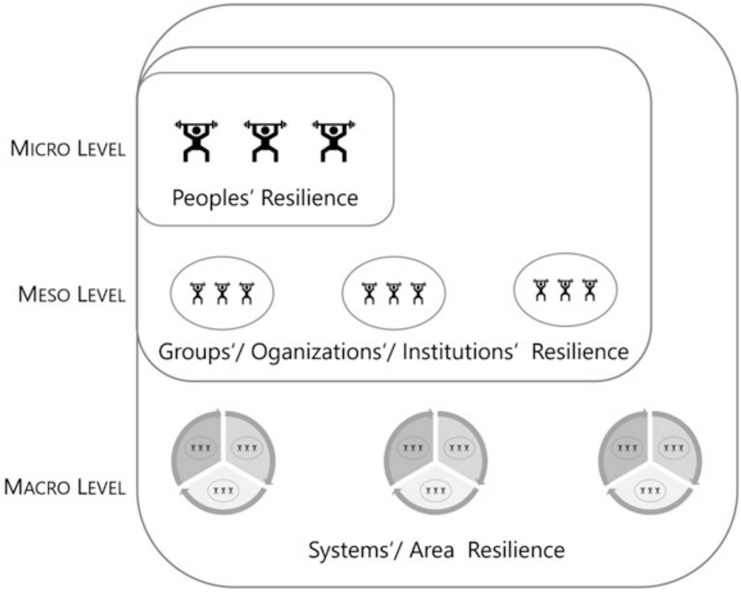

Fig. 2 Perspectives on resilience

and system attributes including resilience affect (the resilience of) organizations, communities, and the people working and living under the circumstances in question (e.g., Ahorlu et al., 2015; Fedele et al., 2017; Shahidullah et al., 2020). Figure 2 summarizes the resilience levels and their interconnections. The research examples introduced in this book address these areas in various ways as shown below.

How Our Research Contributes to Resilience?

In this book, we showcase selected work that contributes to resilience—mostly by introducing research questions and providing results from the YEEES research groups and related work.

So, what can readers expect from this anthology? As the title of the book illustrates, the articles cover a relatively wide range of perspectives that are interconnected in different ways. All articles deal with or at least touch on the global sustainability agenda in some way: be it entrepreneurial solutions creating future-oriented jobs in regions with low employment, ideas for sustainability-oriented companies, the improvement of educational opportunities, more prudent approaches to resources, or consideration and maintenance of a culture that can ensure or at least support social stability.

The articles in the first section deal with resilience and entrepreneurial activities. Starting with the topic of resilience and the entrepreneur, a research framework is introduced. Another article looks at universities as organizations that can help to build a more resilient Sub-Saharan Africa via the development of human capital, in which theory and practice are brought together by means of a case study. Other contributions look at how innovative ideas are being turned into entrepreneurial solutions and ICT is being used to promote sustainable development and the practices of software entrepreneurs in Namibia.

The focus of the second section is on topics related to learning (from each other) and teaching, which are fundamental to the resilience both of our communities and of the people in it. Among others, we have contributions on a game-like tool which is highly motivating and real fun and which teaches young children about the fascinating world of computer programming. Furthermore, the use of advanced ICT in teaching is investigated, in this case augmented reality to train livestock students. A further practical example is provided by a paper on developing enterprise resource planning (ERP) skills program to build ICT capacity for disadvantaged South African youths.

The third section focuses on smart communities. One article takes a closer look at the Nelson Mandela Bay area to determine the value for stakeholders of implementing smart cities. Another investigates how smart communities can use ICT to respond to the current COVID-19 pandemic, especially with the support of social networks which can reduce the social divide. A third paper looks at the resilience of urban food supplies and the associated organization of farmers. Experiences from Cape Town and Dar es Salam are compared. Two contributions from cases in Europe also propose options for building resilient communities in this region, one focusing on a smart energy sharing community with high participation and another dealing with how to foster more sustainable mobility (e.g., cycling) in developed communities.

Another important aspect of resilience is the sustainable use of resources, and this is the focus of the five articles in the fourth section. Especially in the African context, the control of soil erosion is important for nature conservation and to ensure crop growth. In the same way, monitoring of the groundwater level is of great importance. Water is becoming an increasingly critical commodity in many parts of the world. The second article introduces an approach that uses ICT to support groundwater monitoring. One tool in this section that could help with resource management is the development of an environmental information portal; another is a method for classifying tires using sidewall images that could be very helpful in the sustainable use of resources. Finally, an article focuses on improving energy use using neural networks.

The last section connects two topics that at first glance are not obviously directly related: resilience and culture. One shows how the transformation skills in culture-oriented companies can be supported and what role platforms of social networks can play in this. Finally, specific aspects of e-government in regard to the accessibility of Web for visually impaired persons are examined and the results are presented.

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University of Vechta, Vechta, Germany — Helmut Faasch
Leuphana University Lüneburg, Lüneburg, Germany

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Part I
Resilience and Entrepreneurial Activities

How to Make Entrepreneurs Strong: Introducing a Framework for Research on Entrepreneurs' Resilience

Jantje Halberstadt and Antonieta Alcorta de Bronstein

1 Introduction

The year 2020 demonstrated how important it is to know how to adapt, to adjust, and to persist, in other words, to be resilient. It is in moments of crisis and in the face of obstacles that the benefits of such ability become even clearer. Given that entrepreneurial activities are accompanied by high levels of stress and various obstacles leading to risks and uncertainty (Ligthelm, 2011), and that entrepreneurs have to deal with changing circumstances and contingencies by adjusting goals and strategies (Adeniran & Johnston, 2012; Bullough & Renko, 2013), resilience entrepreneurship is essential for entrepreneurs.

Resilience has been defined as both "an ability to go on with life, or to continue living a purposeful life, after hardship or adversity (Tedeschi & Calhoun, 2004)" and "a dynamic process encompassing positive adaptation within the context of significant adversity (Luthar, Cicchetti, & Becker, 2000)." According to Sutcliff and Vogus (2003), individuals build resilient abilities through everyday developments that are product of remarkable or unforeseen life happenings. Coutu (2002) further elaborated that developing such skills comes from having a positive outlook on life, facing reality, and learning to adapt to adverse circumstances. Without resilience, individuals are less able to engage in the necessary entrepreneurial behaviors required to start new ventures or pursue businesses. Instead, they tend to fail to take action and to perpetuate a cautious and fearful reaction in the business world to adverse economic circumstances (Korber & McNaughton, 2018).

Several studies underline that a resilient entrepreneur can influence the success of an enterprise (Ayala Calvo & Manzano García, 2010; Ayala & Manzano, 2014;

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Fisher et al., 2016). Therefore, to support entrepreneurial activity and promote the contribution of entrepreneurs as key agents of change—particularly in the field of sustainability entrepreneurship—it is necessary to foster entrepreneurial resilience. This is why resilience has recently gained importance in entrepreneurship research and is receiving more academic attention—in relation to the resilience both of entrepreneurial ventures and of entrepreneurs (Conz & Magnani, 2020). Studies show that personal resilience leads to increased stability and has positive effects on the success of entrepreneurial activities (Ayala Calvo & Manzano García, 2010; Chadwick & Raver, 2020; Fisher et al., 2016; Hayward et al., 2010). First studies also elaborate on factors that contribute to entrepreneurial resilience (Duchek, 2018; Lee & Wang, 2017; Liu, 2020). However, there is no common evidence in this field. In order to contribute to closing this gap we not only emphasize the importance of entrepreneurial resilience, but also elaborate on pinpoint factors that strengthen entrepreneurs' strength and resistance developing a research framework that takes a range of perspectives into account and identifies selected research questions.

The following article is structured into four main sections: having introduced the concept of resilience and its relevance for entrepreneurship, we look at possible influences on entrepreneurial resilience in greater detail, distinguishing between personal factors, venture specifics, and how far ventures are embedded into context-specific entrepreneurial ecosystems. These provide the basis for our research framework, delivering a structured perspective on our field, underlining interdependencies, and identifying possible areas for future research.

2 The Meaning of Entrepreneurial Resilience

2.1 Defining Entrepreneurial Resilience

Until a few decades ago, resilience was studied mainly in the context of psychology and ecology (Fleming & Ledogar, 2008; Masten, 2014). It is only recently that researchers from other areas have begun to study the construct of resilience within their own fields (Korber & McNaughton, 2018; Masten, 2014). Today it is not uncommon to read about resilient cities, resilient software design, resilient communities, and resilient entrepreneurs.

The word resilience, which derives from the Latin *resilire*, meaning to rebound, recoil, (Online Etymology Dictionary; Masten, 2014) and whose origins in the English language go back to the 1600s, has had various different definitions. Figuratively and in relation to people it was used from 1839 as the "capacity to recover from misfortune, shock, illness, etc." In 1857 the definition was extended to include "the quality or fact of being able to recover quickly or easily from, or resist being affected by, a misfortune, shock, illness, etc." (Oxford English Dictionary, n.d.). There are two lines of thinking, one that sees resilience as adaptability, and therefore also to some extent as the ability to change, and another that sees resilience as absorbing experience and returning to the original state (Bergström & Dekker, 2014).

When we talk about resilience today, we refer to a concept that goes beyond the above definitions, since it has developed into a social construct, and as such it does not have one single definition, but will depend on the context in which it is being used, and whether it is describing a resilient person, a resilient system, or an organization, for example (Masten, 2014; Southwick et al., 2014). Masten (2014) defines resilience in broad terms as the "capacity of a dynamic system to adapt successfully to disturbances that threaten system function, viability, or development. The concept can be applied to systems of many kinds at many interacting levels, both living and nonliving, such as a microorganism, a child, a family, a security system, an economy, a forest, or the global climate." According to the American Psychology Association (APA) Dictionary, resilience is "the process and outcome of successfully adapting to difficult or challenging life experiences, especially through mental, emotional, and behavioral flexibility and adjustment to external and internal demands. A number of factors contribute to how well people adapt to adversities, predominant among them (a) the ways in which individuals view and engage with the world, (b) the availability and quality of social resources, and (c) specific coping strategies" (American Psychology Association, n.d.). Psychological research also underlines that resilience can be cultivated and practiced. Norris et al. (2008) note that "most definitions emphasize a capacity for successful adaptation in the face of disturbance, stress, or adversity." Southwick et al. (2014) underline that, however different the definitions of resilience are, they all include the "concept of healthy, adaptive, or integrated positive functioning over the passage of time in the aftermath of adversity." Finally, resilience also implies an effort to move forward and learn from an adverse experience in an insightful, integrated and positive manner (Southwick et al., 2014); and Tedeschi and Calhoun (2004) add that resilience is understood as the ability to continue not just simply living but living a purposeful life after hardship. Resilience is variously understood as a trait, a process, and an outcome, which might or might not be present. Panter-Brick and Leckman (2013) define it as "the process of harnessing biological, psychosocial, structural, and cultural resources to sustain wellbeing." Connor and Davidson (2003) emphasize that "resilience embodies the personal qualities that enable one to thrive in the face of adversity." Others state that resilience "is the capacity to absorb and/or adapt to disturbance or stress" (Bergström & Dekker, 2014). A further characteristic of resilience is that it is something that is not either present or absent, but rather is present at different degrees in different aspects of a person's life, hence it is seen as a continuum (Pietrzak & Southwick, 2011). For example, a person with a high level of resilience in their personal life might be less resilient when dealing with stress at work. Resilience as a continuum also changes depending on the stage of life and the particular moment (Pietrzak & Southwick, 2011; Southwick et al., 2014). It can thus be seen as a process in which the person will "harness resources" and draw on experiences of adversity or stress, using them as opportunities to further develop resilience. A number of authors agree that resilience is therefore not static but multidimensional and that it will vary depending on several factors, for example, age, cultural background, life experiences (Connor & Davidson, 2003). One further aspect that many definitions have in common is that of the presence of a threat, stressor, danger, disturbance, or crisis (Bergström & Dekker, 2014).

Entrepreneurial resilience can relate to the entrepreneur (the individual), the venture (the organization), or the entrepreneurial ecosystem (the environment). In this article the focus lies on the resilience of the individual—the entrepreneur. The concept of entrepreneurs' resilience builds upon the definitions of personal resilience, which originate primarily in the field of psychology, as explained above (Southwick et al., 2014).

Given that every human being will encounter difficulties, adversities, and/or stress at one point or another in their lives (Southwick et al., 2014), the way a person reacts and deals with such situations will show how resilient they are, in other words if the person will learn from the experience and adapt. Since entrepreneurs face stress and adversities as part of the process of starting and maintaining a new endeavor and that this represents a risk (Cope, 2011; Shepherd, 2003), entrepreneurs need a high level of resilience to endure the stress and setbacks common to entrepreneurial activities. It becomes even more relevant for entrepreneurial activities in high risk contexts, such as wars, political or economic instability, and pandemics. Entrepreneurs' resilience, however, can be defined as the ability of an entrepreneur to overcome a crisis, adversity, stress, or other disruptions related to the entrepreneurial venture through adaptation and which results in a learning process that will lead to improvement.

One of the most famous instruments to measure resilience is the Connor Davidson Resilience Scale (CDRS) (Salisu & Hashim, 2017), which is also widely accepted in entrepreneurship research (Ayala & Manzano, 2014; Fatoki, 2018; Franco et al., 2020). This scale was designed in 2003 and consists of 25 self-report items. Its content was compiled from different previous scales. The main constructs are found in Table 1.

Table 1 Main components of Connor-Davidson Resilience scale (CD-RISC): Short Description. Based on Connor and Davidson (2003)

• Able to adapt to change • Close and secure relationships • Believe in fate or God • Ability to deal with whatever comes • Confidence with new challenges • Seeing the humorous side of things • Gaining strength through coping with stress • Bouncing back after illness or hardship • Believe that things happen for a reason • Best effort no matter what • Ability to achieve goals • Not giving up (even when it seems hopeless) • Knowing where to receive help	• Ability to think clearly and focus under pressure • Taking the lead in problem solving • Not easily discouraged by failure • Consider oneself as a strong person • Taking unpopular or difficult decisions • Ability to handle unpleasant feelings • Have to act on a hunch • Strong sense of purpose • Being in control of life • Liking challenges • Willingness to work to attain goals • Pride in achievements

Borrowing the resilience construct from other disciplines, such as psychology, has contributed to entrepreneurship research (Badzaban et al., 2020; Fatoki, 2018). However, analyzing entrepreneurs' resilience may require a more nuanced approach. While the CDRS measures a person's general or overall resilience, there are entrepreneurship-specific components that may differ from a person's general resilience and are thus worth considering more closely. As an example, the CDRS includes a person's self-efficacy, which is defined as an individual's self-perception and innermost thoughts on whether (s)he has the skills and abilities perceived as important to reach a certain goal, as well as the belief that (s)he can effectively convert them into a chosen outcome (Bandura, 1989, 1997). This self-perception impacts on an individual's affective state, motivations, and behaviors (Markman et al., 2005). Entrepreneurial self-efficacy, however, is a construct often used in entrepreneurship research, specifically to describe the self-confidence that one has the ability (necessary skills, competencies, resources) to successfully act entrepreneurially, e.g., by creating a successful business, by performing various roles and tasks of an entrepreneur, or by pursuing any entrepreneurial career (Chen et al., 1998; McGee et al., 2009; Wilson et al., 2007). Thus, entrepreneurial self-efficacy is a certain type of confidence that does not necessarily have to be at the same level as overall self-efficacy. While someone can, for instance, demonstrate high levels of self-efficacy in general, this does not mean that (s)he perceives her-/himself as being able to successfully act entrepreneurially—however, there most probably are correlations and there would be merit in further studies to examine this in greater detail.

In addition, we underline the dynamic nature of resilience and the specific role of contextual factors. This is the reason why we work on the context and suggest a framework below in order to motivate researchers to undertake additional work on entrepreneurial resilience considering various contextualized facets and factors.

2.2 *Relevance of Entrepreneurs' Resilience*

Literature sets out a number of reasons why resilience is advantageous for entrepreneurs—in general as well as specifically in times of crisis. Entrepreneurs' resilience is shown as an important personal characteristic that has a positive influence on the emergence of entrepreneurial activity and on the resilience and long-term success of the venture itself. According to Fisher et al. (2016), analysis of resilience at the individual level contributes to research in three ways:

- It increases knowledge about the nature and characteristics of the entrepreneur and his or her resilience (Ayala Calvo & Manzano García, 2010; Bullough et al., 2014; Roche et al., 2014). Resilient entrepreneurs are, for example, shown to be more self-sufficient and are more likely to avoid stress and burnout (Strümpfer, 2003).

- It provides insight into factors that promote or inhibit entrepreneurial resilience and contributes to the development of appropriate measures of entrepreneurial resilience (Ayala & Manzano, 2014; Gil-Monte & Manzano-García, 2015).
- In the same way as other fields underline the importance of developing resilience through teaching, entrepreneurship research also calls for educational approaches to support the development of entrepreneurs' resilience (González-López et al., 2019; Tempski et al., 2012; Winkel, 2013).

In addition, research on entrepreneurs' resilience contributes to work on entrepreneurship success factors, since the components of resilience lead not only to more resilient entrepreneurs, but also indirectly to successful entrepreneurial outcomes. Some studies have analyzed the influence of resilience on entrepreneurial performance and have shown it to be a major factor underlying success in entrepreneurial settings (Ayala Calvo & Manzano García, 2010; Envick, 2005; Hayward et al., 2010; Markman et al., 2005). Other work shows the positive influence resilient entrepreneurs have on the resilience of their firm, referring to findings underlining that characteristics of the entrepreneur have a strong direct impact on the ventures' structure, strategy, and performance (Miller, 1983; Miller & Toulouse, 1986). For example, Branicki et al. (2018) state that entrepreneurs are often highly resilient and demonstrate competencies that lead to increased company resilience. Studies also deal with the direct influence of resilience on venture success (Ayala & Manzano, 2014; Francis & Bekera, 2014; Hedner et al., 2011). In their study Abdullah et al. (2018) analyze different factors that impact entrepreneurial success and find resilience to be a significant success factor. According to Yang and Danes (2015), spousal commitment contributes to resilience of the entrepreneur and is shown to affect venture success as it reduces the time to reach the break-even point. D'Andria et al. (2018) demonstrate that resilience also has a positive influence on successful business takeovers. However, due to the number of studies showing a positive relation between resilience and venture performance, resilience is even suggested as a measure of entrepreneurial success when appropriate financial data is not available (Markman et al., 2005).

Most studies underline the specific value of entrepreneur resilience under certain circumstances. In recent studies, for instance, Becker and Kabongo (2020) point out how resilience is needed for entrepreneurs in developing countries, while Daou et al. (2019) explore the association between intellectual capital and resilience in torn societies. Others such as Santoro, Messeni-Petruzzelli, and Del Giudice (2020) and Zehrer and Leiß (2019) illustrate the importance of entrepreneurial resilience for family firms. Work has also been done on the influence on venture success of the resilience of female (Ayala & Manzano, 2014) and disadvantaged (D'Orio, 2019; Santoro, Ferraris, et al., 2020) entrepreneurs.

Fisher et al. (2016) also found entrepreneurs to be more resilient than other population segments. This may raise the question of whether resilient individuals demonstrate a higher level of entrepreneurial intention or whether people's resilience grows as a result of acting entrepreneurially and experiencing the associated challenges. Different factors, however, have already shown to influence entrepreneurial resilience. And given its relevance, it is desirable to foster the development of resilient characteristics. We elaborate below on the factors that contribute to resilience.

3 Factors Influencing Entrepreneurs' Resilience

3.1 Personal Factors

The adversities faced by an entrepreneur are different from traumatic events that are dealt with in broader resilience research. As Lee and Wang (2017) point out, there is a distinction, for example, between being able to overcome stress resulting from poor parenting and that resulting from (fear of) economic failure. They have therefore undertaken a literature review to identify the specific factors that influence the development of entrepreneurs' resilience. Various personal traits of the entrepreneur are said to have an influence on an entrepreneur's resilience. Perseverance, proactivity, need for autonomy, assertiveness, entrepreneurial skills, innovativeness, and problem solving-orientation, for example, have been shown to have an impact on business creation and success (Caliendo & Kritikos, 2008; Markman et al., 2005; Przepiorka, 2016; Rauch & Frese, 2007). However, whether and how this leads to resilience remains unclear. One explanation may be that the ability to see problems as opportunities to find innovative solutions has a positive influence on a person's stress tolerance, and thus, hardiness. At a more general level, the traits mentioned above lead to positive entrepreneurial experiences, which in turn are said to lead to resilience because they foster confidence, while the absence of these traits may cause negative entrepreneurial experiences leading to reduced resilience. As stated by Singh et al. (2015), business failure is a traumatic event that could cause negative impact and reduce entrepreneurs' levels of self-efficacy or confidence, which may cause them to fall into a downward spiral in challenging times. Interestingly, self-efficacy and stress tolerance are highlighted both as influencing resilience (Lee & Wang, 2017) and as major components of the construct of resilience (Connor & Davidson, 2003).

In the same vein, motivation and goal-commitment are also mentioned due to their positive influence on entrepreneurial intention and success (Lee & Wang, 2017; Przepiorka, 2016, 2017). The work of Yamakawa et al. (2015) shows that intrinsically driven entrepreneurs are more likely to build up resilience because their motivation increases the likelihood that they will rebound from failure, start another business, and achieve further growth. Lack of motivation, however, may lead to lower levels of commitment and greater dissatisfaction, which decreases the effort expended in achieving the desired business performance or reviving a sinking enterprise and leads individuals to give up more easily (Carter & Wilton, 2006; Hammer & Khelil 2014; Omri & Frikha, 2011). Other characteristics, such as age or gender, are also shown to have an influence on entrepreneurial outcomes and entrepreneurial resilience. Studies show that age has an impact on the development of resilience, although the findings are equivocal in this area (Ayala & Manzano, 2014; Burns & Anstey, 2010; Campbell-Sills et al., 2009; Karaırmak, 2010). Gender can also have an influence on resilience due to its effects on entrepreneurial support, risk, and success (Akanji, 2016; Allen, 2000; Powell & Eddleston, 2013; Shepherd & Patzelt, 2015; Wing-Fai, 2016).

When it comes to entrepreneurial competence, studies underline the value of the level of education and entrepreneurial experience. A high level of education supports entrepreneurial success, whereas a lower level of education seems to decrease it and there is thus a similar correlation with resilience (Coleman et al., 2013; Hsu, 2007; Lee & Wang, 2017; Mas-Tur et al., 2015; Williams & Shepherd, 2016). Prior experience of start-ups is seen as a particularly critical factor for entrepreneurial success and for bouncing back from failure (Amaral et al., 2011; Hsu, 2007; Lafontaine & Shaw, 2016; Monsson & Jørgensen, 2016; Omri & Frikha, 2011; Zhang et al., 2011). While it is not surprising that positive experience leads to increased entrepreneurial self-efficacy, the authors also underline the positive effect on resilience of negative experiences and failure; as entrepreneurs get used to dealing with failure, they learn and can gain a deeper understanding of the complex and challenging nature of business. They also acquire additional skills required to set up and run a new business and use their know-how to set up new enterprises (Politis, 2008). However, an entrepreneurs' personal characteristics, and the number and extent of their negative experiences and entrepreneurial failure, can also lead to reduced resilience (Jenkins et al., 2014; Yamakawa et al., 2015).

Finally, values and beliefs have an impact on entrepreneurial resilience. For example, a positive attitude, optimism, hope, and flexibility are frequently cited as important factors for increasing resilience of an entrepreneur (Pollack et al., 2012; Przepiorka, 2016, 2017; Trevelyan, 2008; Yang & Danes, 2015). Spirituality can also have positive influence on resilience. If individuals show an awareness of something beyond the individual self, this connects not only with increased consciousness, which supports entrepreneurial (re)action, but also with decreased negative effects of failure; furthermore, it supports the development of self-esteem (Pavlovich & Corner, 2014; Singh et al., 2015, 2016). In contrast, a negative attitude, self-stigmatization, internal attribution, and negative emotions such as fear of failure, guilt, remorse, impotence, shame, and embarrassment are shown to have a negative impact on entrepreneurs at various levels including resilience (Cope, 2011; Eggers & Song, 2015; Holienka et al., 2016; Mantere et al., 2013; Singh et al., 2015; Yamakawa & Cardon, 2015).

3.2 Venture-Specific Factors

In addition to the personal characteristics of entrepreneurs, venture-specific factors also have an influence on entrepreneurial resilience. As an example, studies have shown that the age and size of a company can have an influence on its success, e.g., the performance rates of businesses (Wiklund & Shepherd, 2005). The age of a venture also determines the time the entrepreneur has had to amass experience and thus build entrepreneurial resilience. In a similar way, growth rates can come into play. On the one hand, larger companies can be the result of entrepreneurial success and may lead to the development of a wider set of skills, competences, and resources—leading to increased resilience. On the other hand, increased size may mean entrepreneurs face greater risks and challenges, leading to increased entrepreneurial stress.

Industry sector and venture type may also influence entrepreneurial resilience. The competitiveness of an industry and macro-economic conditions are shown to have a strong impact on businesses, including the level of entrepreneurial opportunity and risk (Carter & Wilton, 2006; Hammer & Khelil, 2014; Miaoulis et al., 2005). This may also hold true for differences in the core aim of the entrepreneurial endeavors, since actual and perceived circumstances such as risk and ambiguity can vary when the focus is on profit maximization in business entrepreneurial contexts, or when mainly focusing on social and/or ecological impact generation in the field of sustainability entrepreneurship (Adnan et al., 2016; Austin et al., 2006; Bacq et al., 2013; Halberstadt & Hölzner, 2018). These differences can also lead to dissimilarities in motivation and commitment (Ashe et al., 2011; McMullen & Bergman Jr, 2017; Miller et al., 2012) with effects on resilience as described above. Entrepreneurial activity in certain areas can thus lead to different experiences and be accompanied by varying risks of failure—all of which influence resilience development. In addition, if an entrepreneur switches from one business area to another after failure, (s)he might not able to apply previous experience or transfer all advanced knowledge; this could lower the chances of success and make it more difficult to build up resilience (Eggers & Song, 2015; Yamakawa & Cardon, 2015).

3.3 Context Factors/Resilience of the Entrepreneurial Ecosystem

As shown, resilience contributes to entrepreneurs' ability to cope with negative influences, stressful situations and, as a consequence, to thrive despite restrictive social, cultural, economic, and political constraints and/or related challenging situations, such as severe poverty, terrorism, war, etc. (Branzei & Abdelnour, 2010; Bullough et al., 2014; Loh & Dahesihsari, 2013). However, since entrepreneurs are embedded in a particular entrepreneurial ecosystem and have always been embedded in specific (private as well as professional) surroundings, social, environmental, cultural, and political factors also play a role, affecting personal characteristics and entrepreneurs' resilience directly and/or moderating the influence of different variables. Researchers thus largely agree that resilience is not only dependent on internal factors, such as personal characteristics, but on structural and external factors. They see resilience as the result of individuals' interaction with their environments and the processes that either promote well-being or protect them against the overwhelming influence of risk factors (Hedner et al., 2011; Zautra et al., 2010). It is thus the result of the combination of entrepreneurs' personal characteristics and their environment (Bulmash, 2016; Markman & Baron, 2003; Zamfir et al., 2018). Resilience is more likely to develop when protective or supportive factors exist, e.g., help offered by supporting families, schools, communities, and social policies (Leadbeater et al., 2005; Ungar et al., 2008). When these factors are missing or individuals experience a negative environment, it can have the opposite effect on resilience development. In order to better reflect cultural and contextual differences in how people in various systems express resilience, Hedner et al. (2011, p. 1) broaden the definition of individual resilience to "[. . .] both the capacity of individuals to navigate their way to the psychological, social, cultural, and physical resources that sustain their well-being and their capacity individually and collectively to negotiate for these resources to be provided and experienced in culturally meaningful ways." In the following we thus briefly elaborate on the possible role played by these contextual factors.

Economic Factors

The level of economic and political stability in an environment shapes the entrepreneurial ecosystem. Both economic and political factors have been shown to influence entrepreneurship in various ways. Examples include access to resources, the financial situation—both in general and in relation to the specific situation of (potential) entrepreneurs—the markets in which entrepreneurs operate, and investment in (entrepreneurship) education and support; these all have different impacts on entrepreneur resilience.

Every economic environment is shaped by the availability of resources required for business formation. This holds true for human resources—which are dependent on the overall quality of the educational system—as well as for material and financial resources. When experiencing difficulties in obtaining capital from financial institutions or venture capitalists, entrepreneurs with their own financial resources are shown to have a higher probability of survival, while financial difficulties, such as liquid constraints, equity capital insufficiency, or a large amount of debt tend to jeopardize the business (Carter & Wilton, 2006; Coleman et al., 2013; Holtz-Eakin et al., 1994; Jenkins et al., Hammer & Khelil, 2014; Miaoulis et al., 2005; Omri & Frikha, 2011). These problems can impact negatively on resilience, with negative experiences or lack of resources restricting options and reducing entrepreneurial self-efficacy. However, it can also be argued that negative experiences can foster entrepreneurial resilience, for instance, through preparing/habituating entrepreneurs to deal with challenges or giving them confidence as a result of having successfully managed challenging situations.

The economic environment also has an indirect influence on resilience when individual perceptions of entrepreneurship-related costs and gains are perceived as favorable for entrepreneurial activity and thus for the decision to enter self-employment in specific economic conditions (Carmona et al., 2016; Dvouletý, 2017). Other indirect influences can result from entrepreneurs' (early) experiences. Loh and Dahesihsari (2013), for example, highlight the importance of the experiences of female entrepreneurs for their success and resilience in a developing country. These experiences are often related to the labor market: For example, periods of unemployment or fear of unemployment can affect individuals' sense of entrepreneurial security and their long-term entrepreneurial or career plans (Arulampalam et al., 2001; Dvouletý et al., 2018; Eilam-Shamir & Yaakobi, 2014; Røed & Skogstrøm, 2014). The nature of the effect varies, however, with some studies showing that unemployment has a positive effect on entrepreneurship and others emphasizing a negative effect due to fear of failure and reduced resilience components, such as entrepreneurial self-efficacy (Kautonen et al., 2010; Minola et al., 2014; Wennberg et al., 2013).

In addition to the experiences of (potential) entrepreneurs in specific economies and the influence of the economy on access to resources and support, we also find there is evidence for resilience being influenced by the specific business environment of the entrepreneurial venture. According to Biswas and Baptista (2012) among others, it is presumed that a competitive business environment will weed out inefficient new entrants from markets and make the remaining ones more resilient. Moreover, the work of Zamfir et al. (2018) shows that the economic context has a significant influence, with resilient entrepreneurship being more likely to be found in sectors characterized by high competition.

Political Factors

The overall economic situation is also said to influence political decisions concerning support for entrepreneurs and investment in entrepreneurial education. Many governments are actively and systematically supporting entrepreneurship in general or small- to medium-sized enterprises, e.g., offering direct financial help or support through microfinance institutions (Ngoasong & Kimbu, 2016). One important area of focus is fostering entrepreneurship education in order to build up and strengthen entrepreneurial competencies (Halberstadt, Schank, et al., 2019; Halberstadt, Timm, et al., 2019; Matlay et al., 2012; O'Connor, 2013). Many authors, meanwhile, underline that national policies need to support both entrepreneurial competence development and the reduction of the bureaucracy, since this is important for entrepreneurial sustainability and resilience (Ghenta & Matei, 2018; Zamfir et al., 2018). However, studies show no consistency in the results for different economies. On the one hand, wealthy countries can afford to invest in entrepreneurial activity and are thus said to provide better preconditions for entrepreneurs, while on the other hand, poorer countries are shown to specifically foster entrepreneurship in order to solve existing problems and make a sustainable contribution to much needed economic growth and societal well-being (April, 2009; Desai, 2011; Leitão & Baptista, 2009; Lingelbach et al., 2005; Williams & Gurtoo, 2016).

Social and Cultural Factors

The social embeddedness of a person shapes his or her character through different experiences, education, and role models. A favorable social environment thus helps to build resilience. Social networks can contribute to increase self-efficacy and persistence by providing emotional and/or professional support, including relevant information, access to resources, and connections to other people (Brüderl & Preisendörfer, 1998; Elfring & Hulsink, 2003; Jenssen & Koenig, 2002; Hammer & Khelil, 2014; Newbert & Tornikoski, 2012; Omri & Frikha, 2011; Vissa & Chacar, 2009). Supportive family members and friends, including networks, can provide financial and material support and emotional/psychological encouragement—all of which are shown to be important for entrepreneurial resilience and success (Allen, 2000; Powell & Eddleston, 2013; Wing-Fai, 2016; Yang & Danes, 2015). Formal relationships, e.g., with venture capitalists or professional business support services, also have the potential to increase the success and resilience of entrepreneurs (Bocken, 2015; Duffner et al., 2009; Holienka et al., 2016; Hammer & Khelil, 2014; Mas-Tur et al., 2015; Zhang et al., 2011).

Network relations, however, can also be disruptive and increase the probability of business failure and negative effects on entrepreneurial resilience (Lee & Wang, 2017; Yang & Danes, 2015). Individuals may become too closely involved or entrepreneurs may become dependent on the support of others, or they might change their behavior, e.g., by investing more time in the relationships than their business (Mas-Tur et al., 2015; Omri & Frikha, 2011). A challenging social environment can lead to problems in personal and professional development and thus have a negative impact on entrepreneurial resilience (Acevedo & Hernandez-Wolfe, 2014; Yeung & Li, 2019; Zamfir et al., 2018). Social needs, however, may not only reduce resilience. There are also habituation effects: for instance, when people are used to handling difficult circumstances and incidents, they are more likely to be able to deal with challenges and failure. This can lead to an improved ability on the part of entrepreneurs to deal with challenging experiences and reduced fear of entrepreneurial failure—both of which make a positive contribution to entrepreneurial resilience. Furthermore, social needs can also push entrepreneurial motivation, action, and resilience—especially when social entrepreneurial endeavors aim to have an impact on society (Zahra et al., 2009). Nonetheless, social entrepreneurs also face multidimensional challenges throughout the life-cycle of their ventures and are thus also, and possibly to a greater extent, dependent on entrepreneurial resilience.

According to Lee and Wang (2017), literature on culture in relation to entrepreneurial resilience mainly refers to tolerance, to failure, and prejudice. In a failure-tolerant culture entrepreneurs are more motivated to try again after they have failed and even re-start a business or found another company (Cardon et al., 2011; Cope et al., 2004). Compared with societies where business success is a trigger for jealousy or business failure is evaluated harshly due to a bias against failure, societies with a tolerance toward both entrepreneurial success and business failure encourage entrepreneurs. Failure-tolerance, however, is influenced by societal norms, which manifest in a number of societies in varying degrees of failure stigmatization. For example, stigmatization and thus fear of failure is much higher in Japan and Europe than in the USA and may explain relatively low levels of entrepreneurial dynamism (Acs, 2010; Vaillant & Lafuente, 2007). Social norms thus impact entrepreneurial activities and entrepreneurial resilience differently in different societies.

Prejudice can influence entrepreneurial resilience both positively and negatively. People might have a favorable prejudiced view of sustainability entrepreneurs demonstrating "pro-social"-behavior and, thus, are less likely to be stigmatized by failure (Shepherd & Patzelt, 2015). Underlining that sustainability entrepreneurship primarily focusses on social and ecological instead of economic impact (Dees, 1998; Halberstadt & Hölzner, 2018) may also support this argument, since economic failure might be more acceptable when it is expected; or in contrast, if a focus on societal issues rather than financial is not taken as seriously as commercial entrepreneurial activity and is deemed less ambitious and/or less risky, this might make it even worse when entrepreneurs do not succeed. The risk of failure, however, could also be rated as higher for businesses focusing on two or more goals, both economic and societal, with both customers and beneficiaries as target groups. In addition, entrepreneurs' activities and own norms and values, which have been shown to influence their resilience, are also influenced by societal norms and values (Korber & McNaughton, 2018; O'Neill Jr et al., 2009; Rehman & Roomi, 2012; Thornton et al., 2011).

Social views and values can also have effects on particular groups of entrepreneurs, e.g., women. Cultural biases mean that female entrepreneurs are shown as having difficulties with managing both family and businesses and as being dependent on the support of their family or spouse (Goyal & Yadav, 2014; Mordi et al., 2010; Mustapha & Punitha, 2016). Research also shows that women entrepreneurs experience greater difficulty in securing financial support and building professional/social networks (Carter et al., 2003; Marlow & Patton, 2005; Orser et al., 2006). Cultural factors, however, can also positively influence women's entrepreneurial activity, resulting in increasing total entrepreneurial activity (TEA) rates for certain countries (Elam et al., 2019). Studies also underline that women specifics, such as stronger ties within smaller networks, lead to advantages in the field of sustainability entrepreneurship (Spiegler & Halberstadt, 2018). Differences in social needs and cultural factors may additionally explain that in contrast to commercial entrepreneurship, females' social entrepreneurial activity is almost equal to that of men.

A sound educational environment is shown to have a positive influence on personal development as well as entrepreneurial activity and entrepreneurial success (Robinson & Sexton, 1994; Simpson et al., 2004; Solomon et al., 2008). In addition, entrepreneurship education that focuses directly on entrepreneurial competences may enhance entrepreneurs' resilience, for example, by fostering general self-confidence as well as entrepreneurial self-efficacy. This seems to hold specifically true for practice-based teaching and learning (Dimov, 2015; Maritz & Brown, 2013). Training and mentoring programs can also directly address entrepreneurs' resilience by building crisis management skills or entrepreneurs' business acumen (Ghosh & Rajaram, 2015; St-Jean & Audet, 2012). Entrepreneurs who have little knowledge, prior job, or entrepreneurship experience and few skills are said to experience greater challenges in setting up and running business ventures and may also take a negative attitude toward failure rather than perceiving it as a source of learning (González-López et al., 2019; Lee & Wang, 2017; Politis, 2008). The quality of the educational environment can thus have a positive influence on entrepreneurial resilience in a variety of ways.

In sum, social and cultural differences between countries or regions are shown to have a significant influence on entrepreneurial resilience—both directly and by impacting on desirable personal characteristics and entrepreneurial settings in the entrepreneurial ecosystem.

4 Introducing a Research Model for Entrepreneurial Resilience

4.1 Overview and Interconnections

Entrepreneurial resilience is an area that is growing in relevance for research and practice. The current pandemic may even strengthen the need for (research on) resilient entrepreneurs and ventures. In order to effectively identify research questions and conduct studies on entrepreneurial resilience, we need to be clear about the type of entrepreneurial resilience under consideration as well as the setting and factors influencing the process of resilience development. As we have shown, entrepreneurial resilience can be seen, respectively, as the resilience of the entrepreneur, the entrepreneurial team, the entrepreneurial venture, or the entrepreneurial ecosystem. When focusing on resilience of the entrepreneur, literature has so far mainly concentrated on overall or general personal resilience. This is why most studies use CDRS as the tool for measuring entrepreneurs' resilience. Here, we call for future research to determine whether a differentiated scale, complemented by aspects of entrepreneurial resilience that are not based purely on general personal resilience, is needed. Individuals' general and entrepreneurial resilience, however, can be influenced by their traits, skills, and experiences.

An entrepreneurs' personal resilience is shown to have a positive influence on venture resilience, this often is a precondition for entrepreneurial success—it is specifically relevant in turbulent and unforeseen circumstances. Other factors affecting ventures' resilience and success include the characteristics of the venture in question, e.g., its age, size and type, and the sector in which it operates. In addition, some entrepreneurs' characteristics, such as industry knowledge and management skills, may also directly influence entrepreneurial success. The venture's success, in turn, can have a positive impact on the entrepreneur's resilience (it may, for example, contribute directly to self-esteem or indirectly by increasing knowledge)

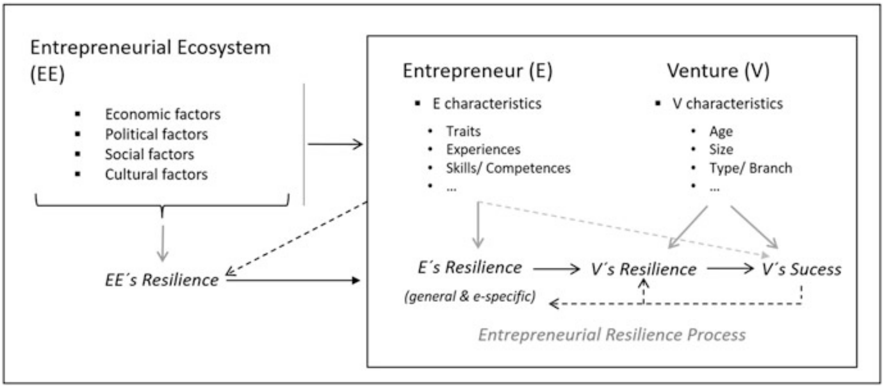

Fig. 1 Key constructs of entrepreneurial resilience

and on venture resilience (as long-term success can, e.g., lead to increased resources and a more stable financial basis).

Entrepreneurial resilience based on entrepreneurs' personal characteristics and the nature of ventures is always embedded in an entrepreneurial ecosystem. We thus underline the relevance of considering the context factors when undertaking research on entrepreneurial resilience. The economic and political environment is shown to impact negatively and positively on the entrepreneurial resilience of entrepreneurs and/or ventures, in both direct and indirect ways. Social and cultural factors are also shown to play an increasing role, directly and indirectly, influencing the development and sustainable manifestation of entrepreneurial resilience. In summary, these factors can form the basis for a construct named entrepreneurial ecosystem's (EE) resilience. It has an overall effect on entrepreneurial resilience—and possible interrelationships with entrepreneurs and ventures as they, in turn, influence the ecosystem, for instance, by contributing to economic growth or impacting on social and cultural settings. Figure 1 illustrates the key constructs and interconnections.

4.2 Selected Research Questions

Within the interplay shown above, it is possible to identify a range of research fields. On the basis of our work, we have carved out some research questions in the YEEES[1] project and implemented research sub-groups that are collaborating in

[1] Yields of Evocative Entrepreneurial approaches on Environment and Society; more information at www.yeees-project.org

the YEEES Research Center. A very brief introduction to these areas is provided below.

Measuring Entrepreneurial Resilience

As shown in the introduction, the term entrepreneurial resilience covers a range of phenomena. While underlining a strong need for clear definitions of entrepreneurial resilience for theoretical work, we also confirmed the need for empirical study. Based on the model presented above, taking entrepreneurial resilience as an umbrella term and differentiating sub-types of entrepreneurial resilience, this research group is working on defining and recording the forms of resilience that play a central role in entrepreneurship research and practice. Specific focus is placed on entrepreneurs' personal resilience because it comprises two forms of resilience: individuals' general resilience and entrepreneurship-specific resilience (resilience with regard to entrepreneurial endeavors).

Religion/Spirituality and Entrepreneurial Resilience

Academic discussion, in particular empirical work on how entrepreneurs can build and sustain resilience, remains scarce. Some studies, such as the work of Lee and Wang (2017) identify enablers and inhibitors and/or explore the effects of selected factors on personal entrepreneurial resilience. One of the intrapersonal factors, namely spirituality, which is defined as "[. . .] an inner awareness of something beyond the individual self" (Singh et al., 2016, p. 26), can play a central role. We have therefore initiated another research group focusing on the role of spirituality in entrepreneurial resilience and specifically on the entrepreneurs' resilience. Although work has been undertaken that includes spirituality as one aspect of resilience (Smith et al., 2012), we are identifying why and how different aspects of spirituality may influence a persons' resilience. Spirituality is closely connected to values and beliefs (Singh, Corner & Pavlovich 2016; Pio, 2010) and is shown to have an impact on pro-social and entrepreneurial intention as well as on shared values through increased awareness (Pavlovich & Corner, 2014). Reflecting on negative experiences and viewing events leading to failure as being part of a bigger plan of God can encourage struggling entrepreneurs to overcome the negative emotions of grief, remorse, and self-stigmatization; it may also lead to greater acceptance of failure and develop the ability to turn negative consequences into something positive—which can even lead to entrepreneurial action (Norlyk Herriott et al., 2009; Singh et al., 2015, 2016).

Although scholars are beginning to acknowledge the role of spirituality in entrepreneurship and there is a growing body of literature on religion, spirituality, and entrepreneurship (Nwankwo et al., 2012; Pavlovich & Corner, 2014), the work conducted by this research group is so far the first to empirically analyze the relationship between spirituality, personal resilience, and venture success.

Impact of Coronavirus on Entrepreneurial Resilience

The current coronavirus pandemic has not only had a severe impact on day-to-day life and even led to deaths, it also affects business in a number of ways (Kraus et al., 2020). The worldwide pandemic is linked with a number of particular challenges for entrepreneurs—both for start-ups and new businesses and for entrepreneurial activities within existing organizations and companies. Some initial academic work has already been undertaken on entrepreneurship in the context of the COVID-19 virus (Bacq & Lumpkin, 2021; Kraus et al., 2020; Kuckertz et al., 2020; Park & Kang, 2020; Ratten, 2020; Shepherd, 2020; Zahra, 2020). We have also found articles focusing on entrepreneurial resilience and the pandemic. Castro and Zermeño (2020), for example, have taken the coronavirus crisis as a prompt to undertake a literature review identifying resilience factors for the fostering of entrepreneurial skills. A study presented by Honerkamp (2020) analyzes the relationship between the development of entrepreneurial resilience in the tourism sector and business performance in the context of the coronavirus pandemic.

However, current work is either theoretical or consists of general empirical studies on the adaptation of entrepreneurial resilience to the corona crises. The few empirical studies analyzing entrepreneurial activity and/or resilience development in the context of the coronavirus are only able to cover the first couple of months of the pandemic, since responses to the crisis began less than a year ago. In addition, the current work on entrepreneurial resilience in times of crisis mainly deals with the pre-crisis period and on how to build up competencies or resources to withstand critical events (Bullough et al., 2014; Doern et al., 2019; Korber & McNaughton, 2018). It is only now that we are getting the chance to follow entrepreneurs and entrepreneurial ventures and analyze their (re)actions in a time of crises. One aim would be to provide insight into the way entrepreneurs with different levels of resilience deal with problems caused by the pandemic itself, associated changes to rules and laws and changing customer needs and behavior. Another focus could be the generation of entrepreneurial resilience in challenging times, since studies show that dealing with problems and even failure may lead to increased personal and venture resilience. Kuckertz et al. (2020), for example, highlight that innovation gives rise to resilience, since innovative businesses tend to better anticipate and adjust to different types of crisis (Hamel & Valikangas, 2004; Linnenluecke, 2017). However, resilience may also give rise to innovation—and this may be of particular relevance in times of crisis. Thus, it may also be productive to focus on the impact of resilience on creativity and the generation of innovative solutions and business models as a reaction to the challenges of COVID-19. As we already have formed YEEES research groups on entrepreneurial resilience, we will also take the opportunity to include the coronavirus situation in our ongoing work and to empirically capture the relevance of resilience in the current environment as well as the impact of resilience development.

5 Conclusion

Entrepreneurial resilience has been shown to be very important for entrepreneurship research and practice due to its impact on entrepreneurial success. As we have demonstrated, entrepreneurial resilience is used as an umbrella term for the resilience of ventures, entrepreneurial ecosystems, entrepreneurs, and/or entrepreneurial teams. Focusing on the personal resilience of entrepreneurs, we identified factors influencing entrepreneurial resilience, drawing together a number of personal and venture-specific factors with different effects on entrepreneurs' resilience. However, entrepreneurs' resilience is also dependent on context. Here, we found that primarily economic, political, social, and cultural factors were underlined as relevant for resilience development. Based on these findings derived from literature, we have developed a research model mapping the main effects certain factors may have on entrepreneurial resilience, centering the entrepreneur and the entrepreneurial venture in an entrepreneurial ecosystem. The specifics—including the resilience—of the entrepreneur, the venture, the ecosystem, and specific contextual factors have a range of reciprocal influences on each other and thus impact entrepreneurial success.

The model can be used as a framework for classifying and structuring future research on entrepreneurial resilience. It should also help with the identification of research fields and questions, and we have included examples from our recent research groups in the YEEES project to illustrate this. In addition, our work underlines the importance of entrepreneurial resilience. Our aim here is to draw attention to an issue that is key to entrepreneurial success but has thus far been underrated, especially in the challenging times we are all currently facing in the context of the coronavirus crisis. Further academic work will thus shed light on important practical implications for the long-term health and stability of entrepreneurs and entrepreneurial activities. This will not only contribute to improvements in conditions for current entrepreneurs and ventures, but will also encourage future entrepreneurs to contribute to economic, environmental, and social change. We therefore hope to deliver a research basis that others may draw on to pursue extended work in this field.

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Toward a Framework for University-Based Entrepreneurial Ecosystems and Human Capital Development in Sub-Saharan Africa

The Unisave Entrepreneurship HUB @ Universidade Save, Mozambique

Johann Bronstein and Shaun Bissett

1 Introduction

The institutional role of universities in society is no longer limited to conventional research and education but is increasingly that of serving as an innovation-promoting knowledge hub for regional development and entrepreneurial activity. The study of entrepreneurialism in underdeveloped regions and the role that universities play in enabling entrepreneurial activity is a subject of interest for scholars, practitioners, and policy makers alike. Nowadays, it becomes imperative for universities to establish structures, systems, and practices which fully incorporate entrepreneurship initiatives that are aligned with the surrounding innovation ecosystems, together with all actors involved.

The aim of this article is to provide a unique view of university-based entrepreneurial ecosystems in the Sub-Saharan African context based on a dynamic model of the process leading up to the emergence of the entrepreneurial ecosystem, from that of a local incipient stage to an expanded mature phase. Our study aims to both conceptually and practically shed light on the inner workings of university-based entrepreneurial ecosystems in the Sub-Saharan region and more specifically, to serve as theoretical basis for the action-based operation of a university entrepreneurship HUB in Mozambique that can contribute to the local

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entrepreneurial ecology, particularly by fostering human capital development where there is a lack of it.

Throughout our theory sections we will review relevant literature on university-based entrepreneurial ecosystems, human capital, and the intricate relationship between these subjects, in order to construct a conceptual framework that would stand as a blueprint for the implementation of a university-based entrepreneurship HUB located in Maxixe, Mozambique. The proposed framework is composed of a dynamic model that assumes an inexistent or very rudimentary ecosystem (as in the case of Mozambique). The purpose is to provide a design mechanism for the implementation and development of the ecosystems in developing countries. The dynamic model consists of three evolutionary stages: Incipient (embryonic), Development (growth), Mature (accomplished). Based on Isenberg (2010) we include four main ecosystem actors (University, Human Capital, Business, Government). The ecosystem's interactions take place under the influence of six domains: Markets, Business, Culture, Finance, Policy, and Support Infrastructure.

Our focus will then shift to the present-day entrepreneurial environment found in the Sub-Saharan African region, specifically that of Mozambique. Here we review an economic system still reeling from anti-free market post-colonial economic policies which resulted in decades of stagnant entrepreneurial activity. It is only in recent years that the minimal conditions have been created for an entrepreneur to engage the market freely and safely. We assess how this novice and still uncertain market environment has contributed to the domination of informal entrepreneurship over formal entrepreneurship as well as the large percentage of entrepreneurs characterized as "necessity" entrepreneurs as opposed to "opportunity" entrepreneurs. It is in this environment where initiatives such as the entrepreneurship HUB and the emergence of an entrepreneurial ecosystem will look to promote a more dynamic and resilient approach to entrepreneurship capable of contributing to real economic growth.

Subsequently, we will describe the actual implementation of this conceptual model in our case study, which shows on a practical level how a nascent entrepreneurial HUB has enabled the development of human capital in the city, thereby serving as a catalyst for a nascent entrepreneurial ecosystem in the region. Our empirical data has been obtained using the action research approach that has allowed one of the authors to produce unique contextual insights into the inner operations of the nascent entrepreneurial ecosystem that are not available to outsiders (Coghlan & Brannick, 2005). The author's insider status derives from his direct involvement in the planning, design, and execution of the Unisave Entrepreneurship HUB in Mozambique. Based on our proposed dynamic framework for the development of university-based entrepreneurial ecosystems, we will describe in a systematic manner throughout the case study how the incipient entrepreneurial initiatives have evolved from simple entrepreneurial trainings and collaborations within the university into the implementation of a development plan that has laid the foundations for the transition into the expansion phase of the ecosystem.

Concluding with our discussion section we should have been able to shed light on our reader about the fundamental importance of university entrepreneurial structures and how these shape the emergence of an incipient ecosystem by enabling the development of human capital at the local level, especially in countries and regions where such structures are undeveloped such as in Mozambique. Additionally, our research and case study can serve as conceptual and practical reference for experts, researchers, and policy makers in the higher education, public and private sectors; thereby providing a heuristic framework for the strategic design, structure, and implementation of University Entrepreneurship HUBs in Sub-Saharan Africa and other developing countries.

2 Universities as an Enabling Factor for Entrepreneurship

Since its modern emergence as an academic discipline, the field of entrepreneurship as well as the term "entrepreneurial" has been characterized by a lack of agreement on precise definitions and key terms. Currently, among the most widely accepted definitions of the term entrepreneur is that of Austrian economist Joseph Schumpeter (1936), which emphasized its innovative nature, defining an entrepreneur as a person who carries out new combinations, causing discontinuity in the market and thereby creating and adding value to it.

We share that view and understand entrepreneurship's conventional essence as that of generating and arranging innovative combinations of "factors of production" and "methods of accomplishing a goal" (Bygrave & Hofer, 1992). Likewise, it involves exploitation of opportunities beyond means that are currently available. These chances to exploit future goods and services are not simply taken, but created (Venkataraman, 1997; Reihlen et al., 2009) through innovation, novel businesses models, and social interactions (Vygotsky, 1978). In this context, the role of modern universities regarding entrepreneurial activity is to enable actual and potential entrepreneurs to innovate or exploit these opportunities by establishing structures and systems that facilitate the entrepreneurial process (Jennings & Hindle, 2004).

Most research on the entrepreneurial dimension in universities focus on specific elements of organizational designs that facilitate the commercialization and transfer of knowledge. These studies mainly look separately at structures, systems, practices, and contingency factors fostering entrepreneurialism in higher education institutions, but oversee the interactions among these factors at the organizational level as well as the interdependence with the macro-environment (Rothaermel et al., 2007). Reviews of the literature (Yusof & Jain, 2008; Guerrero-Cano, Urbano & Kirby 2006) display an emphasis on strategic context (where) and content (what), thereby neglecting the core of the entrepreneurial process itself, that is the entrepreneur as business creator and innovator. Namely, an important question that has not yet been addressed is that of how entrepreneurs as the human capital factor are enabled and supported by internal university structures when the entrepreneurial ecosystem is embryonic or inexistent, such as in underdeveloped countries as in Sub-Saharan Africa.

3 The Fundamental Role of Universities within the Entrepreneurship Ecosystem

Higher education scholars are increasingly interested in understanding how universities use their organizational capacity to initiate change in its local environment, as well as in the internal factors that strengthen the entrepreneurial capacity to respond to environmental changes (Fumasoli & Lepori, 2011; Jarzabkowski, 2005; Shattock, 2000). Academic studies on higher education have tried to address some of these questions by looking at the macro-environment fostering entrepreneurial change. Other studies have centered their efforts at the meso-level, namely by trying to understand the emergent entrepreneurial structures, systems and practices that have led to novel organizational configurations such as the entrepreneurial university (Clark, 1998; Etzkowitz, 2003; Kirby, 2005); adaptive universities (Sporn, 2001); the third generation university (Wissema, 2009); the triple-Helix model (Etzkowitz & Ranga, 2010); and University-based Entrepreneurial Ecosystems (Mason & Brown, 2014; Stam & Spiegel, 2017).

There is a wide variation in the capacity of local and regional actors to support entrepreneurial activity. These variations are not only confined to location but also to historical conditions as the established patterns of behavior and structures tend to reinforce themselves over time due to inertia and cultural drag (Alvedalen & Boschma, 2017). The important role universities play in shaping the social, economic, and cultural environment at the local and regional levels, highlights its characteristic as a fundamental part of the Entrepreneurial Ecosystem.

Using concepts from biology and ecology in social science, economics, and entrepreneurship studies to describe various phenomenon in these disciplines is not new. In the same manner as an ecosystem in a natural environment can be described as a balanced, interdependent, homeostatic community of organism sharing a common space; so is the concept of entrepreneurial ecosystems underpinned by the systemic interaction among entrepreneurial actors, tangible and intangible factors of production (i.e. Capital, Innovation Capacity, Creativity), and socio-economic structures within a geo-political boundary, all of which are conducive to entrepreneurial activity, new firm creation and innovation (Stam, 2015). This “ecosystem” can also be described as a network of social interactions, communication, physical infrastructure, and entrepreneurial attitudes and behaviors of different communities (Isenberg, 2010).

According to Isenberg (2011) entrepreneurship ecosystems are intrinsically self-sustaining and consist of six domains, which regardless of the overall common framework portray unique characteristics and remain independent regardless of the degree of interdependence within the ecosystem. These six domains are Policy: government, leadership and policy makers; Support: infrastructure, public and private institutions and support professions; Human Capital: entrepreneurs, labor and educational institutions; Markets: early and potential customers, networks; Finance: financial capital; and Culture: success stories and societal norms.

Each domain influences actors in their degree of entrepreneurial activity, propensity, and contribution to the system, adding layers of complexity and an emergent uniqueness to the particular ecosystem that relate to the contextual conditions and socio demographic circumstances.

Our conceptual framework is based on the aforementioned basic principles by considering contextual element associated to infrastructure, human capital, culture, business, and markets; while specially focusing on universities as seminal actors in enabling human capital when regional entrepreneurial ecosystems are deficient or inexistent; such as in Sub-Saharan Africa and more specifically in the case of Mozambique.

4 University-Based Entrepreneurial Ecosystem and Human Capital

University-based entrepreneurship plays a central role in enabling the healthy development of an entrepreneurial ecosystem. Higher education institutions can stimulate enterprise creation by more than merely teaching and research activities. For instance, by providing praxis-based teaching techniques using best practices to learn from failure (Naia et al., 2014) and offering specialized training in opportunity identification and business model adaptation to cultural contexts (Blenker et al., 2012). Likewise, university-led HUBs, incubators, networks, co-working spaces, and camps among others are considered catalysts for the development of sustainable entrepreneurial ecosystems (Dahms & Kingkaew, 2016).

A university-based entrepreneurial ecosystem can be understood as one that bestows the central role of enablers and primary drivers of entrepreneurship activity in the higher education sector. Neck et al. (2014) define it as "university-led activities that support entrepreneurship development through a variety of multidimensional initiatives related to teaching, research, transfer and outreach." This conceptualization places the university as the primordial actor being an interconnecting hub among all the stakeholders in the ecosystem. In this view, the dynamism of the university system supports the entrepreneurial processes, empowers human capital, and fosters innovation by developing the knowledge base of the region (Fauzi et al., 2019).

This research paper aims to construct a conceptually grounded basis for the development of a university-based entrepreneurship ecosystem in a poorly developed area in Mozambique, thus providing a significant theoretical contribution with practical implications. The proposed framework is composed of a dynamic model that assumes an inexistent or very rudimentary ecosystem (as in the case of Mozambique). The purpose is to provide a design mechanism for the implementation and development of the ecosystems in developing countries.

The dynamic model (see Fig. 1) consists of three stages: Incipient (embryonic), Development (growth), Mature (accomplished). There are four Main Actors

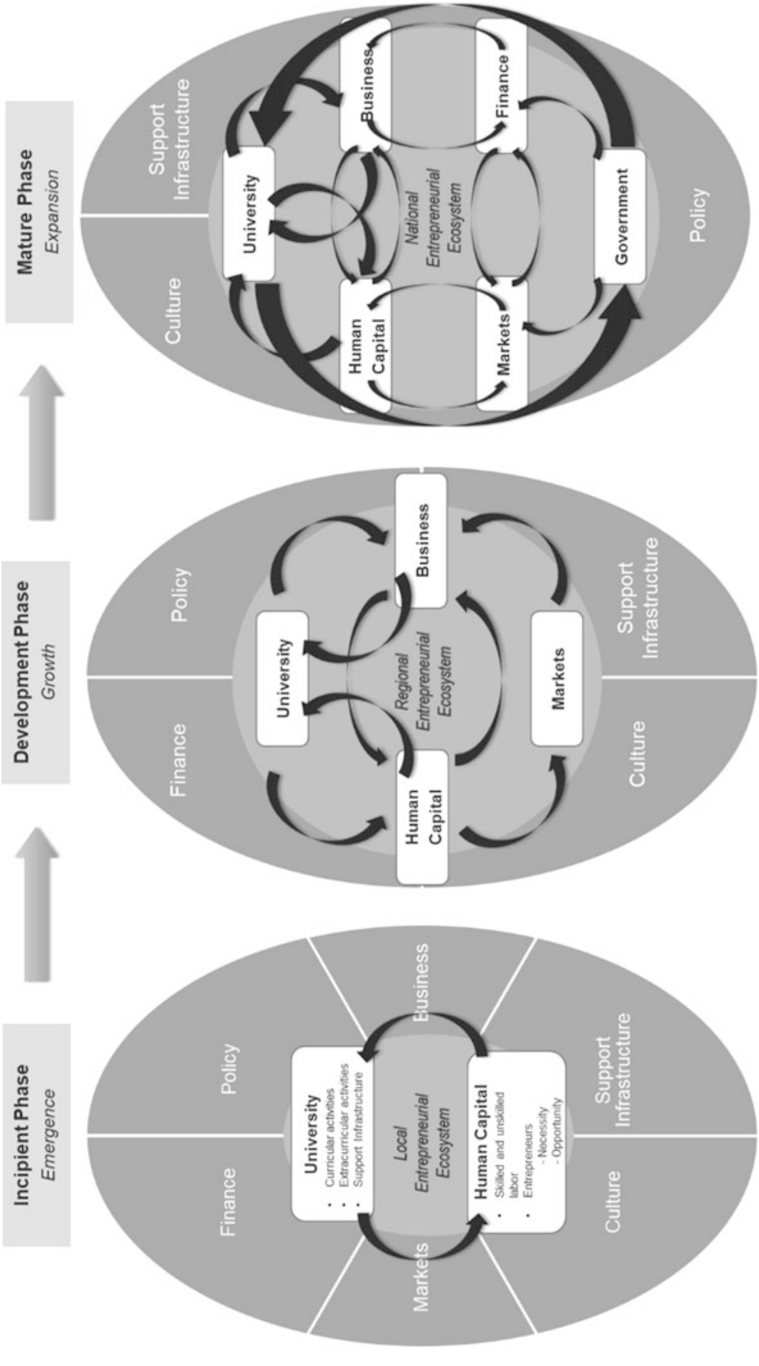

Fig. 1 Dynamic Framework for University-based Entrepreneurial Ecosystems

(University, Human Capital, Business, Government). The ecosystem's interactions take place under the influence of six domains (based on Isenberg model): Market, Culture, Finance, Policy, and Support. The three stages unfold as follows:

1. Incipient: we start with two actors only and mainly two domains that interact within the emergent ecosystem (Markets and Business)

   (a) University

   - Curricular Activities.
   - Extra-Curricular Activities (training, camps, etc.)
   - Infrastructure (Incubators, HUBs, Co-Working Spaces, Office Space)

   (b) Human Capital

   - Entrepreneurs

     Necessity
     Opportunity

   - Students
   - Skilled and Unskilled Labor

2. Development: business and markets become main actors of the growing regional ecosystem.

   (c) University
   (d) Human Capital

– Business: Start-ups, Small and Medium Sized Enterprises, Established Firms
– Markets: new and established markets are reached at a local and regional level

- Mature: a fully-fleshed self-sustaining entrepreneurial ecosystem emerges with four actors and five domains (Policy and Support become part of the ecosystem)

– University
– Human Capital
– Business (in addition to the former three elements, Large Firms and Corporations are attracted to and participate in the ecosystem)
– Markets: new and mature markets are reached at a regional, national, and international level
– Government: Policy, Physical Infrastructure
– Finance (government programs, tax-incentives, Private and Business Investors, etc.).

5 University HUBs as Enablers of Human Capital for Entrepreneurship

There can be no entrepreneurship without entrepreneurs. Thus, when considering the ecosystem at the micro-level the central role sine qua non is at the hands of the entrepreneur. Therefore, in most entrepreneurial ecosystem's frameworks the entrepreneur and labor, both as human capital, play a central role as either catalyst for action and creator of new ventures or as skilled labor to empower and support the start-ups (Isenberg, 2010; Stam & Spigel, 2017).

Human capital theory describes knowledge development, innovation, and opportunity recognition as a function of human capital. We can define human capital as the stock and level of education, experience, skills, and intelligence of an individual or a group of individuals which is available to be employed for a determinate socio-economic endeavor (Østergaard & Marinova, 2018). Becker (1993) suggests that education and skills gained through experiential training form the bases of human capital development. This conceptual understanding, technical skills, social and practical knowledge for new ventures can be learned and enhanced in universities through entrepreneurship education.

Besides the role of the entrepreneur as a central player in the ecosystem, other individual actors that can be classified within the human capital domain also play an important role: mentors, advisors, investors, and role models among others (Isenberg & Onyemah, 2016; Stam & Spigel, 2017). These actors play a resource allocation and supporting role which is generally considered routine and such, act as crucial gatekeepers and enablers of certain types of entrepreneurial activities (Blake, 2006).

We can argue that the key domain in entrepreneurship ecosystems is essentially related to human capital, making it the key underlying factor that drives entrepreneurial activity and performance in a region (Chatterji et al., 2014). Moreover, the local supply of individuals with entrepreneurial inclinations and skilled workforce to support new business creation is associated with the general level of training and education of the human capital available to a specific region (Nicotra et al., 2018; Stam, 2015).

The availability of skilled labor with entrepreneurial potential is a structural precondition for the development of university-based entrepreneurial systems (Bresnahan et al., 2001). Thus, entrepreneurial clusters are more likely to arise wherever universities provide a talent pool of skilled human capital and wherever entrepreneurial education clusters with support infrastructure are located. Also, opportunity-driven entrepreneurial activity is strongly related to local income levels (Radosevic & Yoruk, 2013), which relates to the level of education and capabilities of the human capital in a region. This in turn positively affects the purchase power and quality of life of the population in a region, strengthening the potential market for new firms and increasing the success likelihood of entrepreneurial endeavors (Florida & Mellander, 2014).

The human capital domain of an entrepreneurial ecosystem is influenced by a range of contingent elements that can be broadly characterized as social, cultural, and material (Spigel, 2017). Social elements refer to the role of social networks within the ecosystem and to the extent and quality of its connectedness and interaction with others entrepreneurial ecosystems. Cultural elements can be associated with the attitudes towards entrepreneurship which can encourage or discourage entrepreneurial activity; for instance, risk adversity, role models such as successful entrepreneurs and cultural support mechanism in case of failure. Among these lines, we can notice that the level to which an entrepreneurial culture flourishes within the ecosystem will depend on the degree to which actors in and around the university behave in accordance with entrepreneurial values and beliefs (Greenwood & Hinings, 1993). In other words, these entrepreneurial attributes will be determined at the most basic level by socio-cultural factors and wider cultural belief attitudes toward entrepreneurship in a region (Bronstein & Reihlen, 2014). Finally, material elements concern place-specific physical support infrastructure as well as regional organizations and private or public institutions that provide support to the ecosystem either through financial means or government sponsored programs and public policies conducive to facilitating entrepreneurial activity.

In this paper we advocate for the relevance of human capital to entrepreneurial success and performance, as well as the fundamental role that universities play within the entrepreneurship ecosystems in enabling, empowering, and supporting the human capital dimension and the individual entrepreneurs, especially during the incipient and developmental stages of an ecosystem life cycle in developing countries, where other actors do not usually actively participate or engage in the promotion and support of entrepreneurial activity. Subsequently we describe how we engage in implementing our conceptually-based framework to a real-life case in the city of Maxixe in Mozambique, where one of the authors is actively engaged in applying our theoretical learnings by developing a university-based entrepreneurial ecosystem together with a local university called the Unisave Entrepreneurship HUB.

6 Entrepreneurship in Sub-Saharan Africa: The Context

A walk through the downtown market of any Sub-Saharan African city will unveil the creativity and industriousness that lies at the heart of African entrepreneurship. It is here in the urban markets of places such as Harare, Accra, Maputo, and Nairobi where innovation and ingenuity are practiced as a means to survival and the pursuit of opportunity results in entrepreneurial initiatives as distinctive as anywhere in the world. With the International Labor organization estimating that 66% of the Sub-Saharan African population draws its livelihood from the informal entrepreneurial sector and a recent African Development Bank by stating that up to 22% of the working age population is setting up formal businesses (Herrington & Kelley, 2012), it goes without saying that entrepreneurship will have a tremendously important role to play in fostering economic growth and wealth creation (Beugré, 2016) as well as the development of a modern and open economy in the Sub-Saharan African region (Wennekers & Thurik, 1999; Garavan & Barra, 1994).

7 Historical Development

Any discussion of the current Entrepreneurial situation in Sub-Saharan Africa requires an understanding of that which came before it. With increased interest in Entrepreneurship from the academic community, there is growing attention to the research of entrepreneurial (historical) development (Audretsch et al., 2006; Lee & Peterson, 2000). Research in entrepreneurial development has expanded our understanding of the way in which entrepreneurship has developed historically in different context (Barringer & Ireland, 2016). Despite this increased awareness of entrepreneurial development from researchers, our understanding of the historical context and entrepreneurial development of the developing world, including Sub-Saharan Africa remains limited (Amankwah-Amoah et al., 2018). Given that the 46 countries of the Sub-Saharan region are anything but identical in their history, culture, and socio-economic status, it is always unwise to make any generalizations about the region. With that being said, we have found that many of the countries have indeed followed a similar trajectory in terms of their market evolution. For this reason, we will generalize the Sub-Saharan African post-colonial entrepreneurial evolution by the following three periods:

1. Immediate post-colonization dominated by nationalization and creation of state business limiting access by private actors.
2. Destabilization and chaos dominated by civil armed conflicts and absence of property rights and other business protections required to inspire entrepreneurial confidence.
3. Adoption of free markets, contemporary reform and globalization creating fertile ground for a new generation of entrepreneurs.

8 Necessity Vs Opportunity Entrepreneur

Our discussion begins in the third phase of the development of Africa Entrepreneurship, the adoption of an open market where entrepreneurs can act freely. It is here, amidst the adoption of a free market where we find the emergence of two types of entrepreneurs, namely the "necessity" entrepreneur vs the opportunity entrepreneur. The distinctive contrast between these two types of entrepreneurs being that the necessity entrepreneur is forced into entrepreneurship due to the lack of other income generating options in the market while an opportunity entrepreneur engages the market through the recognition of business opportunity (Fairlie & Fossen, 2017).

While opportunity entrepreneurs are most likely to be employed or at least financially stable, a necessity entrepreneur has limited or even no job options and therefore turns to the market to survive. As to be expected, in Sub-Saharan Africa one finds that the proportion of necessity entrepreneurs far outweighs that of opportunity entrepreneurs. Kayizzi-Mugerwa et al. (2016) claims that for there to be any significant rise of opportunity entrepreneurs in the African context that there would require a medium per capita income of $7300. While the accuracy of this figure is entirely contextual, given the fact that the average medium per capita income in Sub-Saharan Africa is less than 2000$, it goes without saying that if the status quo remains, that it will be generations before we find a sufficient number of opportunity entrepreneurs to result in any meaningful economic growth. Hence, it is imperative that concerted efforts are put forth towards empowering entrepreneurs and creating functioning entrepreneurial ecosystems that are capable of supporting and facilitating the entrepreneurial process.

9 University-Based Entrepreneurial Education in the Region

Before making our case for the creation of locally based Entrepreneurial Ecosystems that are founded and cultivated by local university-based Entrepreneurial Hubs, we will briefly consider the common approach of university-based entrepreneurial education initiatives seen across Sub-Saharan Africa. Despite sporadic efforts across the region, entrepreneurship education in institutes of higher learning is still lagging (Beugré, 2016). Efforts towards Entrepreneurship education at the university is primarily based on the idea that the region must work towards instilling a mindset among its graduates as job creators as opposed to job seekers (Adom et al., 2017).

It is with this underlying sense of urgency to produce graduates that can become self-employed that is at the root of so many of the university-based entrepreneurial initiatives. Such initiatives are varied and could take the form of requiring all students to take an entrepreneurship class regardless of their area of study as seen in *The Eduardo Mondlane University* in Mozambique or could extend to a university wide approach that integrates entrepreneurial concepts into all university programs such as found at *The Kenyatta University* in Kenya (Robb et al., 2014). And while entrepreneurial education becomes increasingly commonplace in the university setting, critics have begun to ask questions regarding the outcome of such efforts and investment. The fundamental question being asked is, are these students going on to become entrepreneurs? With such little follow-up by universities regarding student employment status post-graduation, it is exceedingly difficult to accurately determine the final outcomes of these university-led initiatives.

10 The Rise of Entrepreneurial Hubs in the Region

Beyond the classroom based entrepreneurial education and training, another entrepreneurial initiative of universities worldwide, including Sub-Saharan Africa, is the creation of Entrepreneurial Hubs. In getting to the core of what constitutes a HUB we look to Toivonen & Friederici in their article, It's Time to Define What a Hub Really Is (Stanford Social Innovation Review, Apr 7, 2015). It is here where the four "core features" of a HUB are put forth as:

– It builds collaborative communities with entrepreneurial individuals at the center.
– Attracts diverse members with heterogeneous knowledge.
– Facilitates creativity and collaboration in physical and digital space.
– Localizes global entrepreneurial culture.

Hubs which began to embrace these values became more prominent in the SSA landscape starting around 2010 (Toivonen & Friederici, 2015). These HUB's tapped into the worldwide excitement regarding grassroots entrepreneurship and technological and social innovation (Jiménez & Zheng, 2017) as well as the increased availability, speed and availability of the internet along with the sense of possibility that the digital world has provided (Hopkins, 2016). With Nigeria and South Africa both with over 100 Hubs operating in the innovation and tech space followed by Kenya and Ghana which are approaching 50 Hubs, it is obvious that the spirit of entrepreneurism and innovation is vibrant particularly among young, globally minded, cosmopolitan Africans. Significant funding, particularly for initiatives that are tech focused, has provided financial support as well as clear partnerships with like-minded foreign organizations which has contributed to the success shown by many of these hubs.

11 Entrepreneurship Evolution in Mozambican Recent History

Within 2 years of gaining its independence from Portugal in 1975 following 475 years of colonization, Mozambique descended into a 15-year civil war which was responsible for taking the lives of a million Mozambicans and saw upwards of five million people displaced. Under the pos-colonial governance of a socialist single party regime, Mozambique spent the better part of three decades as one of the poorest countries in the world. In 1994 Mozambique had its first democratic elections and soon after began its shift from a socialist government to one adhering to free market principles. Consequently, it is only towards the final years of the 90s that Mozambique took its first steps as a peaceful nation and fledgling free market system looking to participate in the globalized economy. To this day, arguably, the greatest challenge faced by Mozambican society is how to break the cycle of poverty, continuously made more complex by rapid and significant population growth. With a steadily growing population of 32 million and a medium age of 17, employment and economic growth are fundamental determinants of the future of this Sub-Saharan African nation.

With this history in mind, it is understandable that Mozambique is lagging when it comes to private sector development. At present the Mozambican economy is dominated by a few large firms, a massive informal business sector and an extremely limited SME sector. Due to the lack of meaningful economic growth amidst a weak SME sector, both governmental and non-governmental organizations are constantly implementing initiatives in attempts to stimulate and assist the drivers of the SME sector, entrepreneurs. Countless efforts by both governmental and non-governmental actors aimed at facilitating and building the capacity and skills of Mozambican entrepreneurs have been implemented over the years, all yielding mixed results. Such initiatives as lines of low interest credit, grants, mentorship, and training are all theoretically available to the Mozambican entrepreneur. How inclusive these initiatives are for all population groups, and the real measurable impact resulting from such efforts is a topic of much debate.

12 Case Study: Emergence, Development and Expansion of the Unisave Entrepreneurship HUB

12.1 Incipient Stage

In 2014, one of the authors of this paper, Shaun Bissett, began to integrate concepts of entrepreneurship into the English Communication Techniques class he taught at the Universidade Save in Maxixe, Mozambique. This class was taught to a group of students majoring in English Language Teaching. Shaun, who besides teaching is also the founder of three businesses, believed that with the right encouragement many of his students could also go on to become successful entrepreneurs. With the wealth of both written and audio-visual material regarding entrepreneurship at their disposal, the students enjoyed the dual learning experience of English language learning while simultaneously exploring the basic principles of entrepreneurship. It was during this experience that Shaun began to notice an excitement towards learning in his students that he had never seen before which would eventually lead to Shaun's recognition of both the need and potential of entrepreneurship education for university students in Maxixe.

A serial entrepreneur, one of Shaun's businesses is a private primary school whose model is based on the concept of high-quality bilingual education at a price that the working class can afford. At present, the school has almost 350 students in grades 1–6. Seeing the opportunity to incorporate Entrepreneurial mindset teaching into the curriculum, Shaun began to create teaching modules that would aim to sow the seeds of the entrepreneurial mindset with the children. Within the context of a Mozambican educational system that is based on a traditional approach of rote learning with very little regard to the development of soft skills such as self-efficacy, perseverance, and teamwork, the entrepreneurial mindset training gave the students an opportunity to explore a part of themselves that was always ignored within the school context. For Shaun personally, this experience continued to solidify the impact that entrepreneurship education could have among Mozambican students.

12.2 Developmental Stage

While pleased with what he had been able to accomplish regarding entrepreneurship teaching, Shaun knew that finding like-minded collaborators would be critical if he wished to bring entrepreneurship education to a larger audience. Shortly after Shaun began his search for such a partnership he came across the YEEES project, a German DAAD funded university project looking to create a network of German and African universities under the umbrella of promoting sustainable entrepreneurship and the development of solutions to urban challenges through innovation. YEEES (Yields of Evocative Entrepreneurial Approaches on Environment and Society) created a network of Entrepreneurial minded scholars and students from The University of Vechta in German, Nelson Mandela University in South Africa, The University of Namibia, and The Universidade Pedagogica in Mozambique (now known as the Universidade Save). Inspired by the opportunity to engage like-minded entrepreneurs from international universities, Shaun immediately took a proactive approach to the collaborative efforts of the YEEES project which soon earned him the position of Coordinator of the Africa Entrepreneurship Training Center, a role which allowed him to further delve into the field of Entrepreneurship education in the African context.

Participation in the YEEES project further solidified Shaun's belief that Entrepreneurship teaching had the potential to become a tremendously impactful endeavor in Maxixe. The arrival of the YEEES project in Maxixe was exciting for all those involved as the university community had never previously been exposed to a project centered on entrepreneurship. To be able to engage with an international group of foreign students and faculty on entrepreneurial initiatives rooted in innovation and sustainability was an incredibly motivating and transformational experience for all the participating Mozambican students. Students who participated in the YEEES project would later describe their experience as a feeling of becoming "unleashed," where they now possessed a "sky's the limit" mentality where they too could go on and be creators of change. During the 4 years of the YEEES project there were two Entrepreneurship training initiatives, the Entrepreneurship Camp and the STEP Program, both of which would serve as tremendously influential to creation of the Entrepreneurship HUB.

Entrepreneurship Camps Based on the concept of the SCHUB Camp held at Leuphana University in Germany, the YEEES project offered students of its partner universities the opportunity to participate in an Entrepreneurship Camp during each of its 4 years of the project duration. The first camp was held in Germany in 2017, followed by Mozambique in 2018, South Africa in 2019 and Namibia in 2020. Six students from each partner university would participate in the 3-week camp. Students' applications to the camp were based on their past entrepreneurial experience and their commitment to seeking out innovative approaches to achieve sustainable change in their respective fields. The Camp structure was based on the following model. An opening event where the participants would meet relevant local actors involved in sustainable entrepreneurship. A period dedicated to students further developing their ideas together with local experts and with the YEEES training team. A testing and implementation phase to see the viability of the idea in the local context. A final event where they would present their ideas to local stakeholders and potential partnering entrepreneurs.

The Maxixe Camp experience was extremely memorable for both the camp participants as well as the local community. As a small southern Mozambican city, Maxixe has a very small international community and the novelty of having foreign students created an exciting environment for everyone involved. The Camp participants divided themselves into three groups: one group created an entrepreneurial mindset program for primary school age children; one group created an easy to use accounting and bookkeeping scheme for the informal vegetable sellers; one group created a recycling and reuse program for those that make a living in trash related activity.

Student Training for Entrepreneurial Promotion (STEP) The STEP program is an innovative approach to Entrepreneurial training which was uniquely designed for university students who are enrolled in non-business-related courses (Frese et al., 2016). The STEP training program employs theory and scientific evidence as the basis for its learning program as well as the fundamental belief that "action" is the real driver of entrepreneurship and that action principles must be a fundamental component of the training (Melyoki et al., 2018). Based on the belief that effective Entrepreneurial training is based on both the development of soft skills such as persistence, networking, and creativity as well competency in hard skills such as business planning, accounting, managerial skills, the STEP program includes both skill areas in its action-based training program. Beyond the classroom learning, simultaneously, students establish micro-business activities where they confront the entrepreneurial experience in a real-life simulation (Melyoki et al., 2018). Through this "wise" and short term (Frese et al., 2016) training package of action and theory (Melyoki et al., 2018) STEP aims to contribute to the development of entrepreneurial mindsets with the initial basis of the soft and hard skills necessary to start a firm (Gielnik et al., 2016).

Two German Step Trainers arrived in Mozambique in mid-2019 as Maxixe had been chosen as the Mozambican university to host the STEP program. The STEP trainers began by conducting a 4-day intensive Train the Trainer course. 13 University professors, looking to capacitate themselves as Entrepreneurial trainers, participated and successfully graduated from the Train the Trainer course. Following the completion of the course, the trainers then went on to provide an entrepreneurial training course to 80 non-business major students. The training course lasted 2 months, each trainer taking on the responsibility of teaching one module of their choice (i.e. bookkeeping, marketing, etc.). During the months of the training course, the students formed startup groups were given 100$ startup capital, and asked to start up micro-business where they would implement the skills being learned simultaneously in the course. Upon receiving the money, students were told that the money must be returned following the completion of the course, while the profits may be kept. Through this coming together of classroom learning and action-based "real-life" experience students were exposed to an intensive entrepreneurial learning experience that would inspire and prepare them for future entrepreneurial endeavors.

13 Towards the Expansion Phase. The Introduction of the Entrepreneurship HUB

Inspired by the positive outcomes of the YEEES project and buoyed by its continuing collaboration with the contacts made during its realization, the University Save Entrepreneurship HUB is currently in the incipient stage of its creation. The initial interest that was created with the announcement of the nascent Entrepreneurship HUB project, an initiative dedicated to collaborating with aspiring as well as early to advanced stage entrepreneurs, was far more than anyone could have been expected. Following the posting of the initial university flyer soliciting student volunteers to participate in the creation of the HUB, the Hub was flooded with 340 student applications, about ten times more than their initial forecast. Such overwhelming interest shown by the university community demonstrates the high level of interest in entrepreneurship that had been engendered during the YEEES project, and the effect it had on the university community.

Committed to embracing the best practices developed by other university-based entrepreneurial initiatives both Mozambican and international, and considering the vast wealth of information that can be found in the area of entrepreneurship education, research, and outreach, the Unisave HUB finds itself in a privileged position from which to begin. Two essential factors, both common to underdeveloped societies, lead the HUB founders in their belief that "the university" is the most qualified candidate to house an effective and productive Entrepreneurial HUB in the context of Maxixe. The first is based on the high concentration of Human Capital potential present at the university in comparison to that found outside the university. With less than half the population having finished primary school and a 47% literacy rate, the university presents itself as having an incomparable wealth of human capital in relation to its surroundings. Perhaps because it is the sentiment of exclusivity brought on by this contrast that Unisave suffers from the "Ivory Tower" syndrome and therefore has an extremely limited approach to outreach type activities and therefore creates little impact in its region. The second is the university's unique position as the catalyst of a regional Entrepreneurial Ecosystem.

Considering the environment created by the convergence of Human Capital present, accommodating university infrastructures, reverence, and good standing of the university at a societal level, we see the university as the most well-equipped candidate to house an entrepreneurship Hub.

While the Unisave Entrepreneurship HUB's physical location is the university, it is extremely outward looking as it recognizes its potential to inspire economic growth in the larger Maxixe region. On top of this, as the self-proclaimed catalyst of a larger entrepreneurial ecosystem in the region, the HUB's ability to work with both internal (university) and external actors will be essential to its ability to its success. Therefore, it is necessary to identify these actors and analyze their roles within the HUB.

13.1 Internal (university) Actors

- *University Board:* positive relations and the full backing of the university board are essential to the Hub's success. It is essential that the HUB prioritizes clear communication with the board regarding the benefits and impact upon the university community due to the HUB's initiatives. The HUB aims to inspire the creation of an entrepreneurial culture at the university and the board's enthusiasm in such an ambitious effort is essential.
- *Professors:* academic and university personnel will be encouraged to implement entrepreneurial modules into their teaching. Curriculum development workshops and training sessions for professors will be held to this effect. Like the board, encouraging the professors to embrace the entrepreneurial culture that the HUB intends to promote is the challenge and goal of the HUB. University professors are a key element of the "Human Capital" element that the Hub hopes to be able to effectively leverage, and therefore the recruitment and the involvement of the professors in the HUB is crucial.
- *Students:* university students will serve as the motor of the HUB. Training sessions, workshops, incubation, and accelerator programs and research opportunities will all be available to them through the HUB's programs. Students who wish to take on more active roles in the HUB's activities will have opportunities to work directly with external actors in the wide-ranging HUB initiatives.

13.2 External Actors

- *Local Government:* arguably, no one is more invested in the favorable outcomes of the entrepreneurship HUB than local government. As one of the outcomes of the HUB's initiatives is regional economic growth, the government will certainly be hopeful that the entrepreneurial HUB is able to have a positive impact on the local entrepreneurial environment. Through the synergy created by the affinity between the objectives and goals of the HUB and local government, the HUB is counting on local government partnership.

– *Regional Business Associations:* regional business associations such as the Chamber of Commerce and Confederation of Trade Associations are critical partners to the Entrepreneurial Hub. Committed to entrepreneurship, these associations will have a vested interest in the outcomes of the HUB which will inspire collaboration through mutually beneficial joint projects.
– *NGO's:* national non-governmental organizations and non-profit institutions with projects committed to the economic growth and stability in Mozambique will be interested in the work of the HUB. As the HUB is committed to research in entrepreneurship and other issues affecting the local economy, these results will also prove relevant for NGO's. Initiatives such as entrepreneurship training in the community and accelerator and incubation programs will also be of interest to NGO's invested in the economic growth of the greater Maxixe region.
– *International Partners:* the HUB continues to count on international cooperation in its efforts. Partnerships forged during the period of collaboration with YEEES have secured a strong foundation of partners both on the African Continent as well as abroad. Continuing with these partnerships, and the opportunities they bring, will be critical towards the HUB's success.
– *Local Entrepreneurs:* the HUB aims to be a resource for all local entrepreneurs including those aspiring to enter the world of entrepreneurship. Numerous initiatives such as training courses and workshops, incubation and acceleration courses will all be designed with the local entrepreneur in mind.

13.3 The Unisave Entrepreneurship HUB Physical Space/Activities

– *Physical Infrastructure*: the HUB will have its own co-working space located at the main campus of the Unisave campus. The space is quite large (a former classroom) and at capacity could sit comfortably up to 40 people. The layout will be "open space" as several workstations facilitate the possibility of having multiple groups simultaneously working. For larger meetings, tables can be brought together. Motivational visuals on the walls will characterize the space as one belonging to entrepreneurs. The space will aim to create an environment that is comfortable and friendly and at the same conducive to focused work, result driven work. The space is only steps away from the university copy center where all printing may occur. It is also near the university café. Free University WIFI is available at the HUB to all visitors.
– *Activities*: the hub activities will be rolled out in phases to ensure excellence as well as ensure that the proper review process can be completed regarding one activity before starting with another. The HUB wants to be seen as an exciting, cutting edge, and innovative entity within the university context and

will constantly be rolling out new entrepreneurial based activities for both the university community as well as the Maxixe community at large. HUB activities will be divided up into activities that are (a) Curricular: initiatives that are meant to complement or add to existing university curriculum, (b) Extra-curricular those that will be available to students outside of their normal classes, and (c) Community Outreach: activities that are offered to the non-university community.
– *Curricular:* one of the aims of the HUB is to create university wide excitement regarding entrepreneurship and ultimately work towards a cultural shift in making all of those connected to the university more "entrepreneurial." One of the ways the HUB intends to accomplish this is by encouraging university professors to include concepts and principles of entrepreneurship in their teaching. Through a series of curriculum design workshops for professors and administrators, the HUB will orient non-business subject professors on techniques that will facilitate the integration of entrepreneurial concepts with the class' traditional curricular content. Another strategy to integrate entrepreneurship in non-business university classes is the inclusion of a separate entrepreneurship module, taught separately from the normal course content, where entrepreneurial principles are connected to the course content.

The challenge of convincing professors of the importance of integrating entrepreneurial concepts into their teaching, particularly in non-business subjects, will certainly be a challenge. The university board will be crucial at this junction as their commitment to making the university more entrepreneurial will go a long way toward influencing professors. It is upon the HUB to create an environment where professors will recognize the benefits of integrating entrepreneurial concepts into their teaching. Through a university wide campaign titled "Para uma universidade mais empreendedora" (Towards an Entrepreneurial University), the HUB hopes to inspire the creation of an all-encompassing entrepreneurial environment at the university where entrepreneurship is welcome in everything the university does both in and outside of the classroom.

– *Non-Curricular:* these activities will play a significant part in the HUB's output. Such activities can be divided into two categories, namely those activities promoting entrepreneurship such as entrepreneurial training workshops, incubation, acceleration, and idea creation sessions and the second category being geared to research and scientific production. Activities such as those indicated in category one will both contribute to the entrepreneurial environment of the university as well as offer opportunities to students who wish to engage with entrepreneurism. The HUB is committed to having a full line up of activities where students will constantly have opportunities to sharpen their entrepreneurial skills, further develop their ideas and take steps towards opening their own business.

Research and scientific production are also fundamental outputs of the HUB. Research areas of the HUB include the local entrepreneurial environment (i.e. access to capital, ease of doing business), outcomes of entrepreneurial curricular work at the university (i.e. mindset shift, action-based approach), as well as general research into local business and economy (market opportunities, economic growth). As part of an international network of entrepreneurial researchers, the HUB aims to contribute relevant, insightful research to the larger field of Entrepreneurship in Sub-Saharan Africa. The HUB intends to establish itself as a knowledge center of regional economic issues that is capable of contributing to both the discourse regarding economic issues and entrepreneurship at a local level as well as become a voice on the topic of African entrepreneurship at the university level.

13.4 Community Outreach

The HUB is committed to establishing itself as the catalyst for the creation of a larger, regional Entrepreneurial Ecosystem. Due to factors such as the preponderance of Human Capital at its disposable, the physical infrastructure at the university lending itself to events of all size and the "political freedom" the university holds in its ability to engage all groups and sections of society, we believe that the university is in a unique position to play the role of the catalyst of this regional ecosystem. The HUB will aim to connect all the internal and external actors through various initiatives aimed at improving the regional entrepreneurial environment. Some of the possible activities to be implemented by the HUB with the aim of fostering the entrepreneurial ecosystem are:

- Organized meeting bringing together the public and private sector.
- Guest lecturers by business minded experts.
- Networking events aimed at inspiring future collaborations.
- Trimestral newsletter highlighting the collaborative efforts of various stakeholders.
- Coordinating collaborative initiatives among the actors.

The HUB will also focus considerably on working with local entrepreneurs, engaging them through training sessions and other related activities. The aim of the HUB is to serve as a resource for aspiring, initial stage, and even experienced entrepreneurs. Through accelerations and incubation type events the HUB will generate excitement in the entrepreneurial community and provide much needed assistance to those projects with the potential to succeed. Through training sessions, workshops, and courses, the HUB will provide a foundation for future and acting entrepreneurs who dream of pursuing an idea but perhaps lack some of the basic skills needed to succeed. Through a collaborative effort of university/community the HUB aims to serve as a catalyst for the local entrepreneurs in the creation of a productive and supportive community.

14 Discussion: University as Enabler of Human Capital for Entrepreneurial Endeavors and Catalyst for the Development of Entrepreneurial Ecosystems in Sub-Saharan Africa

Throughout our previous sections we have followed a line of argument that is based on two essential maxims: first, the fundamental role that universities play in establishing the bases for the development of entrepreneurial ecosystem, especially in Sub-Saharan Africa where there is little to non-interaction among the actors and insufficient planned mechanism in place that would drive the ecosystem; and second the enabling factor of human capital through all stages of evolution of the entrepreneurial ecosystem. But more importantly at the embryonic phase in which the empowering feedback loop between the university and the human factor becomes the seeding mechanism of a nascent entrepreneurial ecosystem in regions where structures are not in place, such as in the case of Universidade Save in Maxixe, Mozambique. Moreover, we have shown in our case study that in practice the nascent entrepreneurship hub truly provides a starting point to empower and support actual and potential entrepreneurs and their employees, while at the same time serving as director and orchestrator of a wider university-based entrepreneurial ecosystem encompassing various actors and domains.

Entrepreneurship involves human agency which in turn is provided by the human capital factor. Individuals or groups of individuals start businesses, they are not started by market characteristics, presence of opportunities, legal frameworks, macroeconomic conditions or local geographic attributes. Even though these factors are influential, the entrepreneurial activity will only be started because people are motivated and prepared to act; and more importantly trained and educated to develop, initiate, and implement a new enterprise (Beugré, 2016).

We can deduct from our literature review that the concept of human capital has a strong relation to the skills, level of education, trained abilities, and knowledge of an individual (Fairlie and Robb, 2009). Also, practical experiences, exposure to networks and embeddedness in a productive environment are important factors that influence and enhance human capital and entrepreneurial disposition. Consequently, an important number of entrepreneurship researchers has been interested in the relationship between human capital and entrepreneurial behavior and success (Marimuthu et al., 2009) For instance, Ployhart and Moliterno (2011) have shown that the level of education, previous business endeavors as well as training, skill development, and exposure are key factors that enable and contribute to entrepreneurial activity and success. In the other hand, there are also studies that argue in favor of the thesis that entrepreneurs are not made but born, such as Adom and Williams (2012) who argue that innate ability and individual traits are most crucial to entrepreneurial behavior and that they are the “differentiators” which separate successful from unsuccessful entrepreneurs. Nonetheless, we base our view on several studies that contend with the view that formal education and training (besides environmental and contingency elements) are crucial factors that determine success or failure of entrepreneurial endeavors (Wanigasekara & Surangi, 2010).

Even though most entrepreneurs in Mozambique and Sub-Saharan Africa engage in necessity-based entrepreneurship, recent efforts tend to indicate that young people in Sub-Saharan Africa are likely to embrace entrepreneurship as a viable career option. Recently, there has been an increase in entrepreneurial education offered at universities, as well as workshops, fellowships, and seminars organized in that focus on youth entrepreneurship (Beugré, 2016). In this regard, our study presents empirical evidence supporting the role of university-based entrepreneurship education in enabling human capital for entrepreneurial activity and at the same time, facilitating the emergence and guiding the development of entrepreneurial ecosystems in an undeveloped region where there is no existing formal support for potential entrepreneurs and entrepreneurial activities, such as in the case of Maxixe in Mozambique.

It is only through innovation and entrepreneurship that underdeveloped cities and regions in Sub-Saharan Africa can develop its human capital and leverage its vast natural resources in order to become more sustainable and resilient (Beugré, 2016). In this article, we have argued for the fundamental role that universities play in enabling the development of entrepreneurial ecosystems in Sub-Saharan Africa. This is essentially achieved by nurturing the human capital available that will engage in entrepreneurial activity, and by serving from conception until fruition as lead orchestrator and main hub during the evolution of the ecosystem. We acknowledge that although each ecosystem depends on the environment in which it is embedded, the conceptual framework we develop and its empirical implementation in our case study provide with general guidelines and serve as heuristic tools that that could pave the way for each country and region in Sub-Saharan Africa to implement its own university-based entrepreneurial ecosystem.

15 Conclusion

This research paper provides a unique perspective of university-based entrepreneurial ecosystems in the Sub-Saharan African context based on a dynamic model of the process leading up to the emergence of the entrepreneurial ecosystem, from a local incipient stage to an expanded mature stage. The actual implementation of this conceptual framework during the creation of the Entrepreneurial HUB in Maxixe has allowed us to inform our research and refine our understanding, allowing us to provide the readers of this article with a novel conceptualization of the primordial role of universities as enablers of human capital for entrepreneurship.

In our previous sections we have researched relevant literature on university-based entrepreneurial ecosystems, human capital, and the intricate relation between these subjects, in order to construct and propose a conceptual framework that would serve as a blueprint for the implementation of an entrepreneurship HUB in a university in Maxixe, Mozambique. Along these lines, we have described in our case study how a nascent entrepreneurial HUB has enabled the development of human capital in the city, which in turn has served as catalyst for a nascent entrepreneurial ecosystem in the region. We have described how this ecosystem has passed through the first two stages of our dynamic framework and we have laid the implementation plans for the transition into the mature stage of the ecosystem, in which Shaun and his collaborators are already working in a fully-fledged manner. We are confident that in follow-up research articles a developed entrepreneurial ecosystem will be fully operational, contributing to establish Maxixe as a more resilient city with sustainable long-term competitive advantage derived from vibrant entrepreneurial endeavors and innovation.

More than just another research article, the inspiration for the writing of this article was to serve both as a reflection of how the Unisave Hub came to be and as a blueprint of where it intends to go moving forward. The article serves as both a conceptual foundation to the existence of the Unisave Hub as well as a practical guide for its future development. It is through the discussions and conclusions found in this article that the HUB will characterize itself as it strives towards meeting its lofty ambitions. Similar to the HUB itself, this article brings together the theoretical and the practical, believing that optimal practical action is that which is rooted in theoretical analysis and that theoretical research is most valuable when it is used to solve a practical need. It is through this praxis-theory union that the HUB defines and employs itself as a guiding principle in everything that it does.

We conclude by acknowledging the necessity for more widespread support to this type of initiatives in Sub-Saharan Africa from other actors such as governments, private businesses, consortia, NGOs, and other relevant stakeholders at the local, regional, and national levels. We also call upon researchers and academics to double-up the increasing interest in the region and to capitalize on the learning potential of the embryonic stage in which the development of entrepreneurial ecosystems finds itself. As Nelson Mandela once said: “Vision without action is just a dream, action without vision just passes the time, and vision with action can change the world.” Our vision is a vibrant range of entrepreneurial ecosystems spread all throughout Sub-Saharan Africa, each contributing to the development of untapped human capital potential within its own region, driven by action of entrepreneurial actors embedded in an ecosystem that paves the way to more resilient cities and sustainable regions across the continent.

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Innovative Digitalisation Initiatives for Smart Communities and Smart Cities in a Developing Country

Anthea van der Hoogen, Brenda Scholtz, and André P. Calitz

1 Introduction

Digitisation is increasingly becoming part of our lives, especially during a time of the COVID-19 pandemic, lockdown and economic distress. Digitisation is defined by Brennen and Kreiss (2014) as "*the material process of converting individual analogue streams of information into digital bits*". Gartner's (2020) Information Technology Glossary provides a perspective from a research-advisory view on what these terms mean and describes digitisation as "*..the process of changing from analog to digital form, also known as digital enablement. Said another way, digitisation takes an analog process and changes it to a digital form without any different-in-kind changes to the process itself*".

Digitalisation is broader and deeper than digitisation and is defined by Brennen and Kreiss (2014) as "*the way in which many domains of social life are restructured around digital communication and media infrastructures*". The Gartner glossary describes digitalisation as "*the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business*". It is clear from the above that digitisation is taking the physical form of an item and converting it into a digital form. Both views indicate that once something has become digital, the action involves the modification of a process to an improved process.

Digital disruption seems to be a driver for initiatives in Smart Communities and Smart Cities where innovative technologies are used to help solve problems (Ernst & Young, 2017; Mehmood et al., 2017; Silva et al., 2018; Yaqoob et al., 2017).

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Lindskog (2004) indicated that the first time the term, Smart Community, was used in 1993 in Silicon Valley, California, during a recession where the community, business leaders, educators and others came together to help the region.

As the Smart Community concept grew, so did the definitions. An example shared by Lindskog (2004: p 2) is part of the Californian Smart Communities Guide book. It states that a Smart Community is "*a community in which government, business and residents understand the potential of information technology and make a conscious decision to use that technology to transform life and work in their region in significant and positive ways*". These communities became part of city-wide identities and therefore, the Smart City concept. However, finding one definition that is comprehensive and encapsulates the essence of every city is difficult since there are many definitions and views about what a Smart City is. The definition adopted in this chapter is the one from Caragliu et al. (2011): p 50), which defines a Smart City as "*a city is smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance*". It is clear from this definition that technology, organisations (including people) and the environment are core components of a Smart City.

Globally, cities are being mandated to create sustainable initiatives to manage the demands of education, healthcare, housing, sanitation, transportation and water. One of the main factors for these initiatives is the global urban population growth, which is predicted to grow by 63% between 2014 and 2050. The fastest growth will be in countries from Asia and Africa (Estevez et al., 2016). Cities and communities are therefore seeking opportunities to improve the management of their resources while creating initiatives to guide their solutions (Estevez et al., 2016; Hämäläinen & Tyrväinen, 2018; Khatoun & Zeadally, 2016).

Smart City solutions propose infrastructure that is mainly technology driven and involve infrastructures such as Information Communication Technology (ICT), Internet of Things (IoT) and Cloud-based technologies (Lu et al., 2019; Malik et al., 2019; Yaqoob et al., 2017). While the evidence for these solutions is mainly provided from examples in developed countries, the relevance of such technologies for initiatives in developing countries such as South Africa is still being tested (Silva et al., 2018; Tshivhasa & Mbanga, 2018). South Africa is faced with many challenges, such as corruption, apartheid-embedded inequality and poverty. These challenges add to the economic burden in South Africa, which includes high unemployment rates and technologically unskilled citizens (Bennett, 2018; Mawela et al., 2017; Musakwa & Mokoena, 2017; Tshivhasa & Mbanga, 2018).

The shortage of technologically skilled employees in South Africa is addressed to a degree by the growth of Small and Medium Enterprises (SMEs), which are vital in a city's economy (Du Plessis & Marnewick, 2017; Estevez et al., 2016). SMEs are seen as critical contributors to the economy in South Africa, but they are faced with many obstacles. Some of these were identified in the study of Du Plessis and Marnewick (2017), which was conducted in the city of Johannesburg. They investigated what impact Smart City services could have on the challenges and obstacles faced by SMEs. Their findings revealed that one of the main obstacles was the lack of governmental and entrepreneurial support. In addition, the SME owners reported that educational materials, support portals and e-Government systems were the three most valuable Smart City services.

Smart City research is growing due to an increasing need to address real-world problems. However, there is still limited empirical research in developing countries on Smart City initiatives, particularly those relating to Smart Communities and innovative technologies used. The purpose of this chapter is to highlight existing gaps in Smart City research and to report on global Smart City initiatives with the focus on developing countries. Special attention is given to the Eastern Cape province of South Africa with an investigation into five Smart Community initiatives. Internet searches and interviews with key stakeholders of these initiatives were conducted in order to determine the type and extent of technologies used as well as the value and impact thereof. This chapter contributes to Smart Community research in developing countries. Although the interviews were conducted with stakeholders of initiatives in the Eastern Cape, the lessons learned can be valuable to other Smart City and Smart Community initiatives and research in developing countries.

The chapter is structured as follows: the section that follows reports on the literature review. Section 3 presents the research design and the participants' profiles and explains the Technology, Organisation, Environment (TOE) theory used in this study. Section 4 presents an analysis of the findings. The discussions and conclusions are then provided in Sect. 5.

2 Literature Review

Some of the developments in the Information Technology (IT) industry over the last decade have resulted in new Smart City initiatives and solutions that are aimed at achieving the goals of sustainability and resilience (Lu et al., 2019). One of the fundamental factors of a Smart City is IT infrastructure, which includes connectivity. Connectivity is fundamental for Smart Cities to enable the citizens to be connected through smartphones and IT infrastructure, specifically using the IoT (Mehmood et al., 2017). The IoT is the growing trend in which large numbers of networking sensors are embedded into various devices, enabling information-gathering and a control function.

2.1 Digital Economy and Digitalised Economy

The term Digital Economy was first described around mid-1990. Before this, it was referred to by the United Nations as the Information Economy (UNCTAD, 2019). The definitions are still evolving three decades later. In this chapter, the following definition proposed by Bukht and Heeks (2018) is adopted to describe the context of a digital economy: "*that part of economic output derived solely or primarily from digital technologies with a business model based on digital goods or services*".

This definition is flexible enough to incorporate the context of innovative business models. Their model classifies the digital economy according to the following three sectors:

- Core (IT/ICT);
- Narrow scope (digital economy); and
- Broad scope (digitalised economy).

The first sector is the Core IT/ICT Sector, consists of hardware manufacturers, software vendors and IT consulting companies and Information Services and Telecommunication companies. The narrow scope sector is the digital economy, including digital services, platform economy, sharing economy and the Gig economy. A Gig economy comprises freelancers and consultants and is defined by Duszynski (2020) as "*a free market system where organisations and independent workers engage in short-term work arrangements*". The third sector is the broad scope of the digitalised economy and includes e-Business, e-Commerce, Industry 4.0, precision agriculture, algorithmic economy, all overlapping with the sharing economy and the Gig economy.

From the definition and scoping aspects described by Bukht and Heeks (2018), it is clear that the digital economy is what governments, businesses and cities should consider for the future (Ismoilova et al., 2019). One of the reasons to consider a digital economy is that digital economy enterprises grew faster than traditional enterprises between the years 2010 and 2016 (Kozhevnikov & Korolev, 2018). However, the descriptions of digital economy do not include some of the considerations that Smart Communities and Smart Cities include in their descriptions. For example, Smart Communities focus on the fact that people should understand the potential of ICT to transform their lives positively (Lindskog, 2004). In Smart Cities, the investment in human and social capital is as important as the investments in ICT, to contribute to a sustainable economy, life and natural resources (Caragliu et al., 2011).

2.2 Global Smart City Initiatives and Innovative Digital Activities

Marinakis et al. (2018) argue that IT and ICT offer greater potential to Smart Cities. The authors indicate that having innovative smart platforms and systems is critical for empowering the understanding and the behaviour of people. Their study presents a conceptual framework based on data from a Mediterranean community in Greece, where digitising energy savings contributes to sustainable Smart Cities. Users are given ownership to moderate their energy consumption and are motivated through an innovative incentive scheme, such as the virtual monetary entity for economic transactions using an energy-currency.

Denmark is a country with a well-developed digital infrastructure where all public organisations were mandated to go paperless in 2014 and to communicate only digitally with residents in the respective communities (Snow et al., 2016). This digital infrastructure has made Denmark an ideal country for testing and implementing smart solutions.

In London, the Transport for London, Open Data and Big Data, Smart City initiative was established (Hoogen et al., 2020a, 2020b). The initiative aimed to give developers from smaller businesses a chance to leverage data from larger organisations, to create innovative solutions for the city.

Patil et al. (2017) study in India, proposed an innovative surveillance system using IoT devices, web services and Google drive. They illustrate that their proposed system is more cost-effective than traditional surveillance and offers the benefit of having surveillance connected through cloud services, making storing and accessing of data effective and efficient. Surveillance in communities has also been reported as an important aspect of monitoring crime and promoting safety in cities (Lu et al., 2019; Mehmood et al., 2017).

In Russia, a National Technological Initiative was driven by the basic needs of people to create a digital economy (Vorobieva et al., 2019). The Russian government predicted that the markets of a digital economy could grow to $100 billion in the next fifteen years. The initiative stemmed from the fact that they have many technology-based entrepreneurs in the country and that these companies could grow and become leading companies in a digital market place.

In West Africa, the country of Burkina Faso has an economy that is reliant on agriculture and fishing (Zougmore et al., 2018). At one of the country's universities, the Nazi Boni University, an Aquaculture and Aquatic Biodiversity Research Unit deployed a sensor-based network to monitor and manage the water environment of a fish species, and measure the soil moisture of banana and papaya fields. The data are uploaded and shared via a cloud platform using a 3G modem. This research unit is regarded as part of the overall Smart City objective to supply the data that are collected to the farmers for decision making.

In South Africa, SMEs are leading several innovative digitisation and digitalisation initiatives for Smart Cities (Backhouse, 2015; Ernst & Young, 2017; Mora, Bolici & Deakin, 2017; Musakwa & Mokoena, 2017; Tshiani & Tanner, 2018). The City of Cape Town, in collaboration with local private businesses, is working towards a Smart City initiative to streamline the city's public transport system. The public transport management system was created to encourage local citizens and tourists to use streamlined public transport (Ernst & Young, 2017).

Nelson Mandela Bay (NMB) in South Africa started the Project NMB, which included Smart City initiatives such as the Safe City initiative, the Clean City initiative, the Smart City iGEMS initiative and the Connected City initiative (Project NMB, 2018). The project was started in 2017 as a vision for the city. Different stakeholders were identified and some factors for each initiative were identified. However, none of these initiatives has been reported on since 2018.

The 5 year (2017–2022) Nelson Mandela Bay Municipality (NMBM) Integrated Development Plan (IDP) specifies plans to address the city's problems through the implementation of Smart City concepts (NMBM, 2017). One specific action planned is the "*Integration of data collection projects and systems to more efficient data collection*" (NMBM, 2017: p. 166). The IDP for the city also includes the vision of the integration of digital technologies to create innovative solutions to address the city's challenges, which include water management, education and transportation services. Small, Medium and Micro Enterprises (SMMEs) were mentioned amongst the key role players, to help the city reach its vision, that is "*an iconic, friendly ocean City driven by innovation, service excellence and economic development—a destination of choice*" (NMBM, 2017: p. 4).

2.3 Connectivity in Smart Cities and Smart Communities

Patil et al. (2017) describe digitisation and smart devices as the requirements for innovative technologies where the use of IoT is integral in our daily lives. Smart Communities within a digital economy require connectivity to smart devices, through sensors and other technologies. All of these digital components need to be connected to the Internet to work seamlessly. The issue of digital trust is a concern noted by Kozhevnikov and Korolev (2018). These authors refer to digital trust as the relationship between the person having to make a decision and the autonomous intellectual agent. The agent, also known as an Artificial Intelligence (AI) agent, exists in the digital environment. The user places trust in this agent who acts on his/her behalf, for example, to make transactional decisions. Other issues relate to data security and the sharing of information via technologies such as cloud and web services (Kozhevnikov & Korolev, 2018).

The IoT has revolutionised how communication takes place within communities by means of innovative frameworks where digital devices connect invisibly to the Internet (Mehmood et al., 2017). Mehmood et al. (2017) explain how communication protocols, such as short-range (e.g. Wi-Fi) and long-range (e.g. LTE) wireless technologies, have become mandatory in Smart Communities. These communities use smart services to reduce costs and achieve higher quality services. For interoperability to take place amongst multi-vendors within Smart Communities, the IoT open source technologies and platforms are essential especially for sharing information, for risk management and for making sustainable decisions (Alam & Porras, 2018; Mehmood et al., 2017). One way of gaining value from the digital economy is through sharing information. UNCTAD (2019) highlights that this is a challenge in developing countries, especially for SMEs, where the owners lack digital skills to leverage the benefits from digital business operations.

2.4 The Role of Stakeholders and SMEs in a Smart Community within a Smart City

Governments are encouraged to collaborate with private sectors and large corporations which can provide training for SMEs on how to use digital platforms and leverage the benefits provided in a digital economy (UNCTAD, 2019). The 2030 agenda of the Sustainability Development Goals (SDGs) includes goals and targets for small scale and other enterprises (United Nations, 2015). Goal 9 is to "*Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation*" and target 9.3 of this goal is to: "*Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets*". However, SMEs in developing countries such as South Africa are faced with challenges of accessing resources such as finance, skills and infrastructure (Du Plessis & Marnewick, 2017; Ernst & Young, 2017; Estevez et al., 2016; Tshivhasa & Mbanga, 2018).

A Smart City is a collaborative community. It has been argued that SMEs should be part of a larger community where these enterprises can contribute to collaborative, innovative solution development in cities (Snow et al., 2016). Business leaders and educators who have resources and the research data of successful technology-driven infrastructure should be part of the main stakeholders of Smart Communities in cities (Snow et al., 2016). In order to overcome the challenges in South Africa and other developing countries, SMEs could be used to play a leadership role in Smart Community initiatives.

One example of this is the Transport for London, Open Data and Big Data, Smart City initiative, where a smaller developer community has access to an Open Data Store in London, which is provided by the larger organisations. They are able to create innovative services for the citizens without having to incur investment and extra costs (Van Den Bergh et al., 2018). If SMEs in South Africa can access the technology infrastructure of large organisations through Open Data portals, there is potential that these opportunities will encourage a shared community of innovative digitalisation, for all citizens and stakeholders. Therefore, not only do SMEs form part of the stakeholders in a Smart Community, but they can use the data provided within the different value chains to lead specific digitalisation initiatives. While achieving their business objectives, SMEs can thus promote Smart Communities, by aligning their products and services with the goals that the city is trying to achieve.

3 Research Design

In this chapter, the following two research questions are addressed:

- RQ1: What technologies are being used in innovative digitalisation initiatives for Smart Communities in the Eastern Cape province in South Africa? and
- RQ2: How do these initiatives impact and add value to the stakeholders?

In a previous publication linked to this research, one of the main drivers of Smart City initiatives identified was technological innovation (Hoogen et al., 2020a, 2020b). Dewi et al. (2018) and Hoogen et al. (2020a, 2020b) in their Smart City readiness studies show that the Technology, Organisation and Environment (TOE) theory was successfully used to analyse and report on innovative technological adoption. The TOE theory consists of three contexts; the Technology, Organisation and Environment contexts that characterise the adoption process of innovative technologies (DePietro et al., 1990). Relevant organisations that used or will be using technology equipment and processes (internal and external) are represented by the technological context (Baker, 2012; DePietro et al., 1990). The organisational context represents all the resources of organisations, which include the employees, any slack resources, the size of the organisation and the communication processes involved (DePietro et al., 1990). The environmental context represents an industry. The industry is represented according to its structures, size, competitors, macroeconomic context and its regulatory aspects (Baker, 2012; DePietro et al., 1990). The TOE theory can, therefore, be considered as suitable for categorising the aspects studied in this chapter.

The research reported on in this chapter used an interpretive research philosophy and an inductive approach to answer the research questions posed relating to the technologies and digital activities of Smart City initiatives and their impact on the city's economy, natural environment, and the daily lives of citizens. The findings are classified according to the TOE theory with the focus on the digitalisation of information from these initiatives.

The case study and a survey strategy were used to answer the research questions. This qualitative study was conducted over three phases. In the first phase, a literature review determined the scope of studies in the field of Smart Cities. Phase 2 consisted of Internet-based searches that were used to identify Smart City initiatives in the Eastern Cape Province. Nine Smart City initiatives and their project managers were identified. The interview survey instrument was validated in a pilot study as well as by an expert review (Creswell, 2014). Eight experts, some of whom had specific, expertise in Smart Cities were used in the expert review to validate the theoretical model. Each expert had more than 5 years of research experience in the field of Information Systems (IS). In the third and last phase, key stakeholders of Smart City initiatives in two cities in the Eastern Cape were interviewed. The two cities were Nelson Mandela Bay (NMB) and Buffalo City in South Africa. The collected qualitative data were transcribed and loaded into Atlas.ti and analysed using thematic analysis, which creates themes and sub-themes, as recommended by

Creswell (2014) and Bengtsson (2016). The validity of the themes and sub-themes was checked by using three different, independent persons to review the allocation of the data to the selected codes and themes.

Six participants of the original nine, from five Smart City initiatives, were able to take part in the interviews, based on their availability. Two Smart City initiatives were addressed from Nelson Mandela Bay, and the other three were addressed from Buffalo City. The five initiatives and their related goals were:

- Initiative 1—The IS department from the NMBM had a goal, where they started the initiative of a Smart Community. The initiative was driven to improve the technological skills of the employees. The areas of focus were that the employees should have a better understanding of the services that they are required to provide from an ICT perspective. They are required to provide services to citizens in NMB and to SMEs in the city.
- Initiative 2—An automotive manufacturing company sets out to use innovative technologies from smart automotive manufacturing industries. Their initiative required the use of data science techniques with IoT technologies to collect data for innovative decision making and solution development.
- Initiative 3—The initiative had two main goals; the first was the IDZ in Buffalo City wanted to form a smart park project as part of the city's Smart City strategy. The strategy is part of the development of a solution to address the water, energy and environmental challenges of the city and to align their strategy with the agenda of the Industry Revolution 4.0 (IR4.0) a. The second goal was to improve the use of existing resources and infrastructure to save costs for businesses in the IDZ while contributing to organisational sustainability.
- Initiative 4—The goal here was to focus on improving the processes of data management by using smart data and ICT infrastructure solutions that will lead to better decision making and transparency for citizens.
- Initiative 5—The goal was represented from a research and design viewpoint where location-based solutions for a smart campus were tested and implemented at Nelson Mandela University in NMB.

Table 1 shows a summary of the profiles of the six participants (P1 to P6) who represented the five Smart City initiatives. Each participant was interviewed individually, whilst P2 and P3 were interviewed together. These interviews were conducted over 1 week during 2019. At the time of the interviews, the participants were all males. P1 is the custodian and promotor of Smart City/Community initiatives from the ICT perspective, at the municipality in NMB. P2 was responsible for data science tasks at an automotive manufacturing company, while P3 was responsible for quality assurance from the data science perspective. P4 was one of the managers for the Smart Parks and Smart IDZ development initiatives in Buffalo City. P5 was a Managing Director for a company creating intelligent business solutions. P6 was involved with creating location-based services and products for the Smart Campus initiative at the Nelson Mandela University.

Table 1 Participant profile

Initiative	City	Participant Role ($n = 6$)
1. Smart community from the ICT perspective	NMB	P1: Custodian and promotor
2. Innovation and Technology in Smart Automotive Manufacturing	Buffalo City	P2: Projects and innovation-information technology-data science
		P3: Projects and innovation-information technology-quality assurance
3. Smart parks and smart IDZs		P4: Renewable energy and ICT sector manager
4. Smart data and ICT infrastructure		P5: Managing director-data science
5. Smart campus (map buddy–Nelson Mandela university)	NMB	P6: Director and research and design

4 Analysis of Findings

The analysis of the data collected from eight of the interview questions is reported on in this chapter, in order to address the two main research questions specified in Sect. 3. A thematic analysis (Bengtsson, 2016) was conducted to analyse the data and Atlas.ti was the tool used. The three TOE contexts of Technology, Organisation and Environment were used as a priori, first-level themes. The interview questions were used as the second-level themes. The third-level sub-themes were then identified from the interview transcripts. Table 2 shows the 44 sub-themes that are categorised according to the three TOE theory constructs together with the frequency (f) of statements in each sub-theme and the participant number of the participant making the statement.

The first question of the interview was "*What are the main goals of the initiative? (is it a for profit, or social entrepreneurship or non-profit; education, etc.)*". The sub-themes found were categorised into the Organisation theme since they related to the strategies and goals of the organisation/initiative. Seven main sub-themes for these goals ($f = 7$) were identified as follows:

- Accessibility/Infrastructure;
- Proximity;
- Cost Reduction;
- Innovation;
- Industry 4.0;
- Accurate and Complete Data; and.
- Data Discovery.

One of the participants (P4) stated that "*...basically we have been picking up trends in the industry, on everything moving towards "Industry 4.0", ...We've got a lot of the tier 2 and 3 suppliers that are based here in the IDZ and they supply components to (...). So, it's very important that we link up and integrate quite well with it. Not to mention that our then minister of Science and Technology, ...*

Table 2 Toe theory thematic classification

THEME	SUB-THEME ($f = 44$)
ORGANISATION -goals ($f = 7$)	Accessibility/infrastructure (P1)
	Proximity (P1)
	Cost reduction (P1, P2)
	Innovation (P3)
	Industry 4.0 (P4)
	Accurate and complete data (P5)
	Data discovery (P6)
TECHNOLOGY -types ($f = 6$)	Fibre (P1)
	AI and big data (P2, P6)
	Open source technology (P3)
	Cloud solutions (P2, P5)
	IoT (P6)
	Data loggers/data recorder (P4)
TECHNOLOGY -value of technologies ($f = 7$)	Integration/open standard (P1)
	Location-based data (P6)
	Open source technology (security, trust, cost-saving) (P3)
	Sustainability and automated reporting (P4)
	Efficiency/improvements (P1, P2)
	Business development objective (P4)
	Improved human behaviour (P5)
TECHNOLOGY -digital activities ($f = 6$)	Scoot system (traffic signals) (P1)
	Surveillance system (state/city) (P1)
	Building a secure data pipeline (P2)
	Eliminate data silos (P4)
	Data analyses (identify missing information) (P5)
	Digitalisation (human activity recognition) (P6)
ENVIRONMENT -stakeholders ($f = 4$)	University, IDZ, foreign investors (P1)
	All departments (P2); Non-IT-role players, policymakers, asset managers (P5)
	The industrial park, city, government (collaboration) (P4)
	Multi-vendor (P6)
ENVIRONMENT -economy ($f = 5$)	Attract foreign investors (P1)
	Lower connectivity cost (P1)
	Job creation and skills development (P2, P4)
	Transparency for citizens about municipal expenses (P5)
	Navigation and mobility (P6)
ENVIRONMENT -natural environment ($f = 4$)	Environmental monitoring (water quality, dam levels) (P1)
	Renewable energy project, green spaces (P4)
	Uncertain -employment (P2)
	Reduced traffic, less carbon dioxide (P6)
ENVIRONMENT -social lives ($f = 5$)	Proximity-improved mobility (P1)
	ICT education (P4)
	Efficiency (less paperwork, improved processes) (P5)
	Problem-solving skills (data-driven) (P2)
	Optimisation (space management) (P6)

said ... "Industry 4.0", all the IDZ's must get into this "Industry 4.0" and they must be ready for the impact and the disruption expected by the fourth Industrial Revolution". This data evidence was therefore classified into the Industry 4.0 sub-theme.

Accessibility and Infrastructure was a sub-theme from the data evidence stated by P1, saying *"But because we had no infrastructure at that time, (...) was not interested in putting infrastructure there because it just didn't make business sense for them. So, for us as a public entity it was our duty to put the connectivity or infrastructure there so that the people could enjoy the benefits"*.

Accurate and Complete Data was the goal stated by P5, who said that *".. the main goal here was obviously to come up with an accurate representation of the register that this department had digitally so that it could be tested for the auditor to make an assessment of. So that was the main goal. Firstly, it is to get an accurate and complete measure of the register information"*.

The second question related to the types and extent of technologies used in the initiatives and the sub-themes found ($f = 6$) were therefore categorised under the Technology theme. The six main technologies identified are provided together with the evidence from the interviews. These are:

- ***Fibre:*** P1 stated that ".. *you have to go across the city and that cuts across all different communities. So, we use the wireless to expand on the connectivity side, and we use fibre as a medium to provide the high-end applications and the demands from the communities*"
- ***AI and Big Data***: Two participants reported the use and need for AI and Big Data. P2 stated that—*"... using artificial intelligence of course. We leverage in this new field of IA and big data to try and improve quality on the production line*". In I5P6, P6 stated that "*The user interface is (...). We use artificial intelligence, especially long-term and short-term memory and (...) As I said it's a combination of all sensory technologies and IA mostly*"
- **Open Source technology**: P3 indicated that—*"We leverage in open source technology"* At the fourth interview P5 said *"... we first had to assess the problem statement which was that we've got an environment that has very little controls, it has very poor bandwidth in terms of infrastructure and also it has a very small budget so what we came up with was basically we developed a solution which centred around using cloud technologies as a central repository .... We then developed a customised web-based solution which would run on a mobile scanning unit"*.
- **Cloud solutions**: P2 stated that *"... We've got a very strict policy around data in general, specifically speaking to the customer so we are currently working on our own customer cloud solution"*.
- **IoT:** IoT was indicated by P6 as being used "*...for navigating sensor-based technologies, GPS, (...) gyroscope, camera tracking and we do some image processing, we do tracking people in buildings, we have added recently for new year"*.

- **Data loggers/Data recorders:** P4 stated that *" ... We're just testing and seeing what works, we also opened up our water system the other day and saw that we actually have data loggers and didn't know. So a service provider had been downloading it and telling us we don't have water leaks every month and now we are saying but now we need this platform similar to ... 'data lake', that's what we need to create now".*

The question regarding the value of technologies used revealed several sub-themes categorised as part of the Technology theme. These sub-themes are summarised in Table 3, together with samples and extracts from the data evidence relating to what each participant said during the interviews.

The six main digital activities identified were classified as sub-themes of the Technology theme with the data evidence from the participants, as follows:

- *Scoot system (traffic signals):* P1 said,

> We use a "scoot" system that regulates the flow of traffic and that runs on our network. So we had an application that... sensors put on the actual traffic signals that would sensor the flow of traffic during your peak hours.

- *Surveillance system (state/city):* P1 stated,

> To become a "Smart City" one of the concepts is also to have a "safe city". And that was one of the benefits I would say, by having that technology already there from 2006/7 onwards it allowed us to put the surveillance in the city that would assist our traffic department, the metro police as well as our South African police they could get footage from the network that we built.

- *Building a secure, standardised data pipeline:* P2 said,

> .. we've sort of standardised each layer of data acquisition. Firstly, from getting the data from the system itself, we speak directly to the suppliers. The interior standards really help us in determining what type of data we get from our suppliers and ensuring we get the correct amount and right set of data. We've got this internal tool that we've developed, in collaboration with the Germans, known as the manufacturing service bus, which is essentially the data pipeline. We store it in its unstructured format for a predefined amount of time. We are working together with Microsoft for security reasons, ... to actually encrypt our data so that Microsoft themselves cannot actually get our data.

- *Eliminate data silos*: P4 stated,

> ..., for now we operate like a municipality so we sell water and electricity to our tenants so, water, electricity, CCTV, access control, we've got a SCADA system, so we've got a control room that's drawing all this data and utilising it but it's all siloed technologies, so at the moment it's really a clean slate. We've got sensors and devices out there that we're not doing anything with or using in anyway in a "smart" sense.

- *Data analyses (identify missing information):* P5 said,

> *So we had to process reams of data because when we got in there we were given data to say this is what everything looks like. Now we had to take this 40 000 row spreadsheet basically and analyse it to say well not quite because we put this through the machine and the machine told us that 80% of the data is missing information so you have a much bigger problem than you think you have.*

Table 3 Technology: value

Sub-theme	Data evidence	Data evidence/Sample quotes
Integration/open standard	I1P1	*" . . . it allows us to integrate into open standard, I would say, business applications"*
Location-based data	I5P6	*"As I said, it can go to everywhere. It's a new thing and we can fit location-based data to any problem solving, I think, in any type of industry, schools, anything, education. They are everywhere, it's locations, it's our universe"*
Open source technology (security, trust, cost-saving)	I2P3	*"So the obvious benefit is that you don't have to pay to develop the software initially. You can use it and with open source technology you get an added layer of security because there are thousands of eyes looking at the code all the time and you are using code that is trusted by thousands and millions of people as well"*
Sustainability and automated reporting	I3P4	*" . . . So, there is a big push now for South Africa, especially state-owned entities, which we are, to have compulsory air quality reporting and carbon emission reporting so we can, if that's all automated and reporting it will be very easy to draw that data and then we put it in our annual report'* *"Also with very environmentally sensitive consumers that want to know that they are driving a vehicle made from renewable energy, so that's something we have to always respond to"*
Efficiency/ Improvements	I2P2	*"Because of our CICD pipelines, which would have traditionally taken longer and because the IT department is so close to the production line itself the bottleneck is no longer how we get this model that for example ... has built on ... laptop for the production line, it's more how we fast track the process of testing these models and giving feedback"*
	I3P1	*"Which is what it looks like, they are trying to push to South African legislation, corporates to do. So we can use that but it also creates efficiencies, we do the same thing municipalities do in the middle of the day you turn all your street lights on and someone drives around and looks that they're all on instead of just the light telling you that it's not working anymore, so there should be a way to turn everything around"*
Business development objective	I3P4	*"..we are trying to attract international companies, setting-up here. And if you can offer a compelling reason for them to come here" ".. So, we need to be unique and offer something very different to remain competitive and we believe that "smart industrial park" is something attractive but especially for high niche, high-end "sort of companies wanting to locate here"*
	I1P1	*" . . . immediately we saw the benefits of it by us providing those facilities out into the community and especially in the disadvantaged areas, we touched on a very forgotten part of the community and that was the small business community. Immediately we saw that from a small business a lot of the people came to our, we call them the "economic development hub . . . " We got them onto our network and then we started providing internet facilities. As soon as we provided the community with internet facilities, the small business came in there and then they started using the internet facilities to market their products"*
Improved human behaviour	I4P5	*".. we saw improvements in the actual behaviour of the users within the environment. When they determined that there was technology being used to assess the goods within their environment, they starting behaving differently. So there were improvements that were not technology based, that were more improvements in behaviour which emanated from that"*

- *Digitalisation (human activity recognition)*: P6 stated,

> we've digitised everything and our maps. Digitalisation would be like connecting the (...), we can track people with the movement. We can't track people inside the buildings so our solution is that we use the human activity recognition to see are they going upstairs, are they going downstairs and we use their activity to detect them but it is still experimental at this stage, it is not fully implemented.

The external stakeholder sub-themes were identified from the responses to the question *"How are other external stakeholders involved in the initiative?"* The five main types of stakeholders identified were:

- Universities;
- Foreign Investors;
- All departments (including non-IT-role players, auditors, asset managers);
- Industrial park, IDZ, City, Government, Policy makers; and.
- Multi-vendor.

The question that related to the economic impact was *"How does the initiative relate to or impact the city's economy?"* The sub-themes and excerpts from the participants for this question are listed in Table 4. Some of the participants said that their initiatives have an impact on attracting foreign investors, creating jobs in the city and developing skills of employees.

The question *"How does the initiative relate to or impact the city's natural environment?"* revealed four sub-themes, which were classified under the Environment theme, namely:

- Providing job creation and increasing employment;
- Environmental monitoring (water quality and dam levels);
- Introduction of renewable energy projects; and
- Traffic reduction and improved mobility.

The last question of the interviews was *"How does the initiative impact the daily lives of citizens, i.e. the social lives?"* Each of the participants indicated how their initiatives impact the lives of the citizens in their respective cities. A summary of the findings is provided in Table 5. Specific mention was made of how they improved mobility, increased ICT skills and data awareness and improved processes and efficiencies in businesses.

5 Discussion and Conclusions

The evidence obtained provided insight into what cities such as NMB and Buffalo City, in South Africa are doing in terms of their "Smart Community in a Smart City" initiatives. The findings show the initiatives identified in this chapter are from different perspectives and goals that are taking place across these cities. Many of the sub-themes that were identified help to provide more detail to these initiatives. The

Table 4 Environment: impact on the economy

Sub-theme	Data Evidence	Data Evidence/Sample quotes
Attract foreign investors	I1P1	*...” Because of that integrated approach of how we provide the telco services there, that’s why today (...) has got so many foreign investors”.*
Reduced costs (connectivity)	I1P1	*“At IDZ and it’s mainly you have a lot of the car manufacturing, you have a lot more of the Asian countries that is investing in there, you have a lot of different business sectors that’s coming in. And why? Because of the telco costs that has come down now”.*
Employment and skills development	I3P4	*“Currently we are sitting on 4.6 and with the new investors that are coming into the automotive industry we are expecting to get to about 7000/7.2 in terms of jobs created and not just any jobs but people with qualifications”.*
	I2P2	*“We employ a lot more people due to this initiative. I mean you could say that our innovation internal initiative was one of the driving factors that actually created this hub in the first place, and now it’s employing a lot more people and those people live in East London, they spend money in East London”.*
	I3P4	*“The (. . .) academy that they have, that they use to train the pipeline of workers, also helps as well“.*
Transparency for citizens about municipal expenses	I4P5	*...” Has an impact on the people serving a purpose so it’s very difficult for me to say yes, it had an impact but I do know that it did because if they purchase one less vehicle in the next financial year, that’s already an impact on our tax money so absolutely, by creating controls and putting structure around it you are going to have an impact, direct or indirect”.*
Navigation and mobility	I5P6	*“..What is the best and most optimised way to do it, control their energy so there is a lot of things, even like if you put this lecture here or there, it makes a lot of difference for the number of plugs that are on here, do we really need this much or we can change this”.*

municipality of NMB focused on wanting to provide citizens and SMEs in the city with better services by using ICT as a way to bridge the digital divide. Initiatives from NMBM were linked to the University in the city. One participant indicated that the University was its main stakeholder for data resources. This is in line with the study conducted in Burkina Faso, where it was found that the city relies on its universities to provide data for decision making about their fish population, which is a significant contributor to the economy of the country (Zougmore et al., 2018). The findings from the IDZ in Buffalo City highlighted the importance of setting goals that align with the strategy and agenda of the city.

Table 5 Environment: impact on the citizens' social lives

Sub-theme	Data Evidence	Data Evidence/Sample Quotes
Proximity - improved mobility	I1P1	*" what we've done is try to minimise the people, the communities of travelling into the cities, by us providing these type of services out there which are now becoming digital . . . that had an impact on their pocket, where previously they had to take buses and taxis, now they can, in their own communities get the same type of services as previously they would look up to coming into the cities".*
ICT education	I3P4	*... "you know what about 50MB for free if you answer a quick online survey or watch a little video clip about coding or about robotics, so we are trying to influence the youngsters and start getting them more . . . "*
Improved processes internally	I4P5	*" it was much easier for them with new technology and less paperwork and less manual approaches, it's a lot easier for them to do their jobs and therein roles the value down to the citizen level but also just simple things, like for example, the fleet manager could instantly see which vehicles needed to be serviced soonest so that made the operating model a lot easier"*
Data awareness	I2P2	*".. introduces new concepts to people that live and work there so it forces people to see the problems around them in a different way. Maybe they can now realise we don't have to use intuition to solve this problem, we can actually find data which can point us in the right direction objectively"*
Optimisation (space and time management)	I5P6	*" we can do space management, space utilisation.." " they can dynamically change it and make the best, most optimised way." Optimisation, again, has a different definition, energy-based, time-based"*

Furthermore, RQ1 is answered as the findings show the technologies used for the initiatives from the interviews are in line with technologies identified in the literature, such as IoT, Cloud Solutions, AI and Big Data (Alam & Porras, 2018; Kozhevnikov & Korolev, 2018; Mehmood et al., 2017; Patil et al., 2017). Sect. 4, in Table 3, where all the participants indicated the value of using these technologies. By using the technologies, the participants indicated some innovative digital activities for their initiatives. The Scoot system was used to regulate the traffic in Port Elizabeth but also provided an opportunity to monitor safety in the city as part of the Surveillance system for officials. P2 said that they could build a secure data pipeline by collaborating with a large organisation such as Microsoft, this ensured they protect their Intellectual Property while focusing on innovative solutions through access to the correct data when needed. Overcoming data silos was important for P4 as they needed to integrate their technologies and data to achieve a broader view of what was happening in their organisation. P5 said that using their technology to analyse the data of their clients helped them to make informed decisions and to save time with their investigation. Digitalisation processes helped the company of P6 to track human activity that enabled them to improve the solutions provided in their environment.

RQ2 is answered to indicate how do these initiatives impact and add value to the stakeholders. In Table 4, the impact on the economy is shown. Thereafter, the impact on the environment is stated by the different participants, and in Table 5, the impact on the citizens' lives are shown. The impacts listed from the IDZ in Buffalo City related to ICT education of the scholars in the community and job creation for citizens who have the necessary qualifications. P1 reported that one of the main impacts achieved in Port Elizabeth through their innovative digitalisation initiatives was Proximity through improved mobility in smarter ways amongst different communities. Citizens and residents could access services via their smartphones instead of having to travel to service providers.

The digital initiatives found in literature, mainly from developed countries (Sect. 2.2), indicated resources and infrastructure that contribute to achieving these initiatives. A country such as Denmark which has leading ICT infrastructure could mandate all public organisations to go paperless and have all communication streamed digitally to residents (Snow et al., 2016). In London, one of the initiatives was to focus on having small businesses focus on creating ICT-related transport solutions by using the data provided by larger organisations (Van Den Bergh et al., 2018). However, Patil et al. (2017) proposed a cost-effective idea to implement surveillance which is regarded as relevant since SMEs in South Africa are struggling with access to funding and cost-effective infrastructures. Therefore using cost-effective examples primarily related to cloud services as an idea here could highlight alternatives to SMEs in developing countries.

This chapter proposes that SMEs in South Africa should drive the initiatives in Smart Communities to achieve the agendas of overall Smart Cities. SMEs are part of city agendas and SDGs that address global challenges, which need to be overcome in the next ten years. Specific SDGs indicate that small-scale enterprises, especially in developing countries, should gain increased access to financial support (United Nations, 2015). These enterprises should integrate into value chains and markets. SMEs in South Africa are faced with many other challenges in addition to those relating to access to value chains and markets. If SMEs can lead Smart Community initiatives such as providing ICT support for residents, creating and delivering products and services at affordable rates to smaller, less developed communities, it will ease economic burdens in many cities. The main challenge is access to resources and data for these SMEs. Evidence that this can be achieved is seen in the findings of the interviews since these initiatives were shown to provide "Job creation and skills development" (P2 and P4), as well as "Accessibility of infrastructure" to SMEs and citizens (P1).

One proposed solution based on evidence from literature and the interviews is that SMEs should be aligned with larger organisations in their value and market chains. This will allow these SMEs access to data provided in these markets and implement the lessons learnt to improve the services to their target markets (Snow et al., 2016; Van Den Bergh et al., 2018, Participant 1). Having this chain of command and service delivery can increase the turnaround time and contribute to Smart City goals being achieved much faster. This ultimately can help to improved living conditions of citizens and all residents, while increasing the economic value of the cities.

In conclusion, one of the contributions of this chapter is the identification of 44 sub-themes relating to Smart City initiatives in the Eastern Cape province of South Africa. These were classified with the context of the TOE theory. This classification can be used by academics, city managers and other stakeholders and can also contribute to future research to designing a Smart City framework for a Smart Community. Another contribution of this chapter is the real-world evidence of the economic, environmental and social impact and value of these initiatives for the respective stakeholders. Data evidence from two cities in a developing country tackling digitalisation initiatives is provided. The types and extent of technologies used in these initiatives were investigated, as well as the impact of these and the value provided to the citizens and other stakeholders. The interview findings revealed that the value to the citizens of these initiatives was that they now have access to resources such as Internet facilities and "*economic development hubs*" (P1). These opportunities are available due to the provision of infrastructure and resources where citizens and smaller business communities can develop their skills through online courses or by expanding their small businesses through better advertising opportunities (P2, P4). Another finding was that people were changing their behaviour positively due to having better processes as a result of technology (P5, P6). Since citizen value is investigated, the study contributes to the research field of Smart Communities.

The limitation of this chapter is the small sample size. Therefore, future research should be expanded in terms of what other cities in South Africa and other developing countries are doing to achieve digitalisation in Smart Communities through Smart City Initiatives.

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An Exploratory Study of the Development Practices Used by Software Entrepreneurs in Namibia

Johanna Nelulu and Tulimevava K. Mufeti

1 Introduction

National policies of the Namibian Government have long recognized the role that Small and Medium Enterprises (SMEs) and startups play in contributing to the economic development of the country (National Planning Commission, 2004). Namibia's fifth National Development Plan (NDP5), for example, acknowledges that SME and startups can enable the unemployed to participate in the mainstream economy. In addition, Namibia's industrial policy and its Growth at Home strategy also highlight the role of SMEs in socio-economic development, and called for improved institutional environment to ensure sustained growth of SMEs. At the same time, the NDP5 also called for the adoption of e-services and innovation in all sectors, to guarantee the transformation of Namibia into a knowledge-based economy (National Planning Commission, 2017). More specifically, the NDP5 identified e-business, e-learning, e-health, and e-governance, as the priority sectors for ICT integration.

Worldwide, countries are investing in the creation of software startups (Unterkalmsteiner et al., 2016) to respond to the higher demand for software solutions in the public sectors. A similar trend is also observed in the Namibian industry (Iyawa, Herselman, & Coleman, 2016; Nehemia-Maletzky & Iyamu, 2018). Software industries in developing countries have a great potential to contribute to growing the economy of their respective countries (Cunningham, 2015; Mushashu & Mtebe, 2019). While the software industry is "not immune to a failing economy" (Capers, 2010), it is generally believed to be comparably resilient

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to macroeconomic conditions than other industries (Vlahovic, Glavan, & Frankovic, 2016).

Although software startups are widely reported in the literature, there seems to be no commonly accepted definition of this term in the literature. Giardino, Unterkalmsteiner, Paternoster, Gorschek, and Abrahamsson (2014) defined software startup as "newly created companies with little or no history of facing high volatility in technologies and markets". Paternoster et al. characterized startups as companies with no operating history, operating under severe lack of resources, but aiming to produce cutting-edge technologies under uncertain conditions. They further stressed that the lack of a common definition makes it difficult to identify an appropriate body of knowledge on software startups, and suggested that every researcher explicitly defines the features of the startup in their local context. In the context of this research, therefore, a software startup is defined in terms of the size of the company (i.e., less than 20 employees) as well as its period of existence (i.e., younger than 10 years). A software entrepreneur, on the other hand, is defined as an individual that is involved in a startup.

While the benefits of startups are well documented in the literature (Farvin, Mohamed, Baharom, & Deraman, 2013; Garousi, Coşkunçay, Betin-Can, & Demirors, 2014), examples of software startups that did not survive for a long time abound. Giardino et al. (2014), for example, reported that about 60% of startups do not make it beyond the first 5 years. More recently, Berg et al. quoted that 90% of startups fail, citing self-destruction rather than competition, as the main reason for failure. In the Namibian context, lack of entrepreneurial experience, lack of startup capital, and cumbersome registration processes are listed as some of the hindrances to successful startups in the country (April, 2015). Worldwide, the lack of experience, combined with a highly volatile environment, is reported to cause software startups to fail with a short period. Challenges and complications in software development processes can lead to poor quality software products developed. In addition to insufficient financial and human resources, however, a high number of software failures in Namibia were also attributed to dysfunctional user-developer communication (Iyawa et al., 2016; Winschiers & Paterson, 2004), which in turn indicate as lack of understanding of the context of software use.

The Namibia software development industry has, for a long time been and still is, reliant on offshore outsourcing or importation of expatriate workers from other countries. Although the benefits of software outsourcing in developing countries abound in literature, Shaanika and Nehemia-Maletzky (2018) argued that offshore outsourcing is not beneficial to Namibia, because outsourcing partners do not develop local skills or transfer the skills-set required to manage the developed software. Similar studies have also shown that costs associated with expatriate skills are prohibitive and do not contribute much to the local economy (Gurtua, Searcyb, & Jaberb, 2016). Calls for more local ICT-driven entrepreneurial activities, therefore, abound, as these are perceived to ameliorate the unemployment rate as well as the lack of job opportunities among the youth.

There seems to be consensus on the need to grow local software industries in developing countries. Ifeanyi and Udunwa (2016) argued that local software industries face challenges of patronage and growth, and governments should make a concerted effort to encourage sustained industry growth. Winschiers and Paterson (2004), on the other hand, argued that sustainable software development in developing countries can be achieved through the “acculturation of the software development process.” In this process, software developers must adopt user-centered approaches that are tailored to local contexts. They further observed that in the Namibian context, the success of software products did not necessarily correspond to the ability of a software to solve users’ problems. They, therefore, stressed that software development methods and solutions that may be considered universally acceptable are not always appropriate for the local context. This calls for adaptable software development processes and practices, that cater to the needs of local contexts.

This exploratory study is thus an attempt to understand the practices used by software development entrepreneurs in Namibia. The primary objectives of the study were to (1) identify the state-of-the-practice tools and techniques currently used by software entrepreneurs worldwide; (2) provide empirical evidence of software engineering activities in software startups in Namibia; and (3) determine the challenges experienced by software startups in the Namibian context. The practical value of the outcomes of this research is the provision of guidance to aspiring software entrepreneurs on what currently works in the Namibian industry. The results of this study can also provide insight to current entrepreneurs into state-of-art practices that are widely used in the business environment in which they operate.

The rest of this chapter is structured as follows: Sect. 2 presents similar work from previous research that is related to this work. Section 3 introduces the conceptual framework used in this study, presenting the main knowledge areas that are widely accepted as characterizing the practice of software engineering worldwide. In Sect. 4, the methods used for data collection are explained. Section 5 presents the results and discussion of findings, and Sect. 6 presents the research conclusions.

2 Related Work

Several systematic mapping studies that attempted to understand software engineering practices are reported in the literature. Paternoster, Giardino, Unterkalmsteiner, Gorschek, and Abrahamsson (2014) carried out a systematic mapping study on 43 primary studies published between 2004 and 2013. Their study identified 213 different engineering practices that were applied to software development projects in startups. The identified work practices fell into four main categories: software development, managerial/organizational, process management, and tools and technologies. While concluding that flexible and reactive development approaches seem to be the preferred orientation of startups, they also found that startups seem to apply development practices opportunistically rather than methodically, tailoring approaches to specific operating contexts of the startup. Kirk and Tempera (2012) however warned that claiming the use of agile practices should be considered with caution, since the term “agile” is vague, and it could also “practically mean anything.”

Klotins, Unterkalmsteiner, and Gorschek (2019) also carried out a systematic mapping study aimed at identifying software engineering practices in startups. They found no evidence of the application of software engineering in any phase of the lifecycle of the startups, leading to the conclusion that many software startups undoubtedly fail due to poor software engineering practices. Empirical research carried out in Tanzania which surveyed a mix of both small, medium, and large firms found that the Tanzanian software development industry tends to use traditional development methods instead of agile and iterative methods. Based on these findings, Mushashu and Mtebe (2019) were able to suggest useful recommendations to both the practitioners and academia, in an attempt to bridge the gap in providing appropriate training for the Software industry in Tanzania.

Berg, Birkeland, Nguyen-Duc, Pappas, and Jaccheri (2018) conducted an exploratory study on current practices of software development in the Malaysian software industry. Similar to Mushashu and Mtebe (2019), they also reported that traditional software development approaches are commonly used in Malaysia. A major finding of this study, however, was the lack of adherence to software development standards amongst the surveyed organizations. As a result, many organizations experienced problems with the quality of their products, late delivery, exceeding the project budgets, etc. They also reported that many software products that were released to customers needed further improvement or modifications. These challenges could be overcome by adhering to established software development standards.

Garousi et al. (2014) carried out a similar study aimed at identifying software development practices used in the Canadian and Turkish contexts. Results showed that researchers and software professionals had an interest in the latest trends in the software engineering industry. The study reported the dominance of incremental, agile, and/or lean development models and minimum usage of the Waterfall model in software sectors in Turkey. They also found that a significant number of participants did not take into consideration software size measurement methods and software testing. For those who use the Waterfall model, it was reported that they mostly experience challenges with the requirements phase of the model (Garousi et al., 2014).

Iyawa et al. (2016) compared software development methodologies deployed in Namibian Software Firms, focusing on Customer Interaction and their implications on the chosen model. Their research involved three purposefully selected software firms in the Khomas region of Namibia, but did not state the actual size of the firms. The study reported a wide adoption of both traditional (the waterfall model) and the iterative model, agile methods (Scrum and XP), and Rapid Application Development in the Namibian context. It also concluded that there is in-depth customer interaction in software development practices in Namibian software firms. However, the study also highlighted that customer interaction remained a challenge in many software practices. The study thus recommended the need for continuous improvement in software development processes and customer involvement, to ensure successful completion of software projects.

As can be seen in the various studies reported in literature, therefore, there is no consensus on which software development practices are appropriate for startups. While earlier studies seem to emphasize agile, some recent studies reported no unique difference between practices used in startups and well-established companies. The varied findings seem to suggest that the preference and actual usage practices may be company- or context-specific. It could even be project-specific, in companies that seem to employ a combination of both traditional and agile methodologies. This, therefore, calls for more research on the adoption of established practices by startups, as advised by Klotins et al. (2019).

3 Conceptual Framework

This section presents an overview of the conceptual framework used to design the questionnaire in this study. This is especially important since different researchers have used varying frameworks in their quest to gain insight into software practices adopted in the industry. In identifying an appropriate framework, our interest is in practices that are specific to software engineering, rather than general business practices. Therefore, this study focused on software engineering knowledge areas defined in the Software Engineering Body of Knowledge (SWEBOK) (Bourque & Fairley, 2014). Although the SWEBOK is criticized for not being appropriate for startups, it is well recognized by the Software Engineering community, and defines themes that are recurrent even in the practices used by startups as reported in the literature. SWEBOK defines 14 knowledge areas of Software Engineering practice, but we focused only on the first eight as defined below:

- Requirements—Our research aimed to determine how software entrepreneurs systematically determine and gather the needs and constraints of required software products. We were interested in finding out the techniques used to elicit the requirements, and whether participants treated requirements engineering as a once-off process at the beginning of the project, or if it was an evolving process that is tightly coupled to other software development activities. We also wanted to know if they kept a requirements specifications document, and how they managed requirements during the life cycle of the software product.
- Design—The aim was to determine how software entrepreneurs articulate the architecture and system design of their products. We also wanted to know whether they use specific tools to represent the structural and behavioral aspects of the software solution.
- Construction—We were interested in determining the languages used to develop the software product. We wanted to know the programming paradigms (object-oriented, functional, etc.) commonly used in the industry, as well as the actual

programming languages adopted in the Namibian industry. We also wanted to know if entrepreneurs preferred to use a specific Integrated Development Environment or specific tools in their development activities.

- Testing—We wanted to determine practices and activities related to verifying that the software meets its original objective. We wanted to know how the entrepreneurs verified that the software is functioning and behaving as expected by the end-uses. Of importance also was information related to who does the testing, the mechanism used to conduct testing, and the testing tools and processes employed by the organization. We were also interested in activities related to assuring clients that the software product satisfies client needs under specified conditions.
- Maintenance—We wanted to know the activities performed after release of the software including bug fixing, expanding the software to accommodate new requirements.
- Configuration Management—We also wanted to know about practices related to the delivery of the software product to the end-user. Of importance also was to determine whether they had specific practices related to source code organization and documentation. We also wanted to determine whether entrepreneurs have specific practices related to software configuration management.
- Software Engineering Management—we wanted to know how startups apply management activities to ensure efficient and effective delivery of appropriate services to the clients.
- Software Engineering Process—we wanted to know how startups define software processes, and how they decompose work activities into tasks. We also wanted to know the software engineering process tools used by startups.

4 Methods

The primary objective of this study was to identify state-of-the-practice software development methodologies currently used by software entrepreneurs in Namibia. To achieve this objective, we designed a survey instrument based on the conceptual framework presented in the previous section. Data was then collected using printed and online questionnaires, and semi-structured interviews. We are aware of research that argued that using survey instruments that ask participants about development practices and methodologies is ineffective since users could claim to follow a development methodology or practice, while in reality, they only apply a component of it. In addition to a written questionnaire, we organized semi-structured interviews to discuss follow-up questions, and reviewed documentary evidence to support the claims made by the respondents. Follow-up discussions and reviews gave a better perspective in determining whether the methodologies and practices were strictly followed, or only components of it were applied.

The population of this study composed of information technology and computer science professionals from local software startup companies. Six startup companies in Windhoek that are known to the researchers were initially targeted to participate in the survey. Using a snowball sampling technique, the identified companies gave a referral to four other software startups, who subsequently also received the questionnaire. Of the 10 companies, only six responded to the questionnaires and agreed to participate in the semi-structured interviews, with 16 participants (10 males and 6 females). Examples of reviewed documentary evidence include the Requirement Specification Document, Software Project Management Report, and demonstration of software code.

5 Results and Discussions

The results and discussions in this section are presented based on the results of the questionnaire, as well as the main knowledge areas that characterizing the practice of Software Engineering worldwide, as presented in the conceptual framework in Sect. 3.

5.1 Requirements

This section aimed at determining the techniques used by software entrepreneurs to elicit software requirements. The techniques used by entrepreneurs differed significantly. Overall, participants reported using a combination of interviews, prototypes, and observations as the main techniques for gathering requirements. One client reported the following about their techniques:

> It depends on the project. For this project, I was working on developing a new management system for the client. In addition to interviews, I also had to observe how they use the current system to do what they want

Contrary to the findings of Iyawa, Herselman, and Coleman, most of the participating entrepreneurs (74%) indicated that they do not have a signed-off Systems Requirements specification document. Two of the participants interviewed were requested to submit a sample Systems Requirements Specification (SRS) for any of the software projects they had previously worked on. One of the provided SRS consisted of screenshots of the prototype initially presented to the user, with no supporting documentation such as user acceptance of the requirements. This poses a risk to the developer, as the requirements could have been misunderstood the client, or similarly, the requirements could change anytime.

5.2 Design

All participating entrepreneurs reported using some techniques to describe the structure and architecture of the system components. Seventy-two percent of the participating entrepreneurs worked on web-based applications, and their design phase included defining the web application hierarchy. Reviewed documentations included diagrams showing distinctions between client-side and server-side architectures, single-page applications and service-oriented architectures.

The following three types of software design techniques were noted: (1) the use of entity relationship diagrams to model the components of the database tables as well as the relationships between the entities; (2) use of UML class diagrams, using object-oriented concepts to describe the system components; (3) the use of data flow, use case, and sequence diagrams to model the flow of control within applications.

Respondents also reported the use of the following tools for design purposes: MySQL workbench, Umbrello, Visual Studio IDE, Wireframes, and Delphi Pascal IDE. Design documents include wireframes of user interfaces, demonstrating the appearance of web pages using different themes and colors, and different alignments of controls on the screen. None of the respondents provided evidence of conceptual design documents.

5.3 Construction

Most of the respondents (35%) listed Java as their used programming language, followed by Python (25%), C# (23%), and C/C++ (17%). Also, all entrepreneurs listed that they use PHP, HTML5, and JavaScript as their most frequently used scripting language. The results of the preferred language are shown in Fig. 1.

Respondents also listed the following Integrated Development Environments that they commonly used when working on software products: Visual Studio, Eclipse, NetBeans, and PHPStorm. Text editors include Sublime, Notepad ++. Collaboration tools include Slack, v5 code, GitHub, and Trello. Other commonly used software in the industry includes STS, My SQL workbench, and Oracle ACM & OUM. The following are some of the comments received on specific programming languages:

Javascript: "This is the language for the current and future web. Can run on both client and server. Has many client- and server-side frameworks. You can build hybrid applications for mobile and web."

PHP: "we use this for legacy projects or projects that require an SQL database."

VSCode: "it has support for multiple languages and plugins for autocomplete on most popular frameworks."

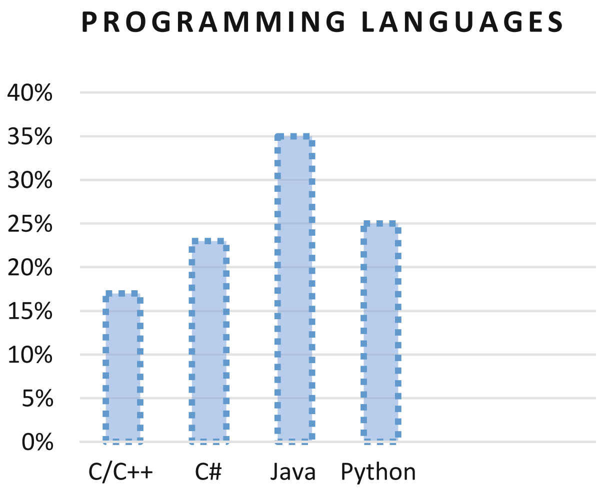

Fig. 1 Software development models used

5.4 Testing

Participants were asked to indicate the software testing methodologies, techniques, strategies, and/tools that they use during software development. Our research shows that 15 out of 16 entrepreneurs that participated in this study use manual rather than automated tools to test their applications. We also only observed one developer who uses built-in libraries:

> Javascript has unit testing libraries.

We also found that entrepreneurs conducted unit and integration testing themselves, while beta testing was performed by the intended application end-users just before the release of the product.

> Most testing is done by the team who are not involved in the project.
>
> The users test every component and give feedback on how it meets their needs.
>
> We task the users to test data from Excel files or other tools that they used in the past.

We also noted that when final testing is done, the end-users would have seen the final product and interacted with it numerous times before, making it easier for them to accept the final product. We, however, noted that in all cases, there were no release documents present, neither was there a proof of final acceptance testing by the users.

5.5 Maintenance

All 16 participants indicated that maintenance is a crucial part of the software development process for startups. Fifty-six percent indicated that they use corrective maintenance to correct errors that may be discovered after the release of the software. Eighty-one percent also indicated that although it is more than 2 years since they had worked on a project, they are still involved in the software products that they had helped create, either for further development or in resolving user issues with the software. As the end-user gets accustomed to the system, their operating environment expands, identifying further needs for the product to be improved. One respondent captured it as follows:

"It is in this process that I was able to at least recover the investments that I put in this software."

However, not all startups had the same experience. Although clients expect startups to maintain their software, signing Service Level Agreements has proved difficult in practice for some startups. One respondent related the difficulty in the maintenance process as follows:

> Customers are reluctant to pay a small maintenance fee for small adaptive maintenance.

5.6 Configuration Management

All respondents indicated that they use version control systems for software configuration. GIT and GitHub are the most commonly used Version control Systems by the respondents.

All respondents also indicated that they provided a hosting option for the user, especially in the earlier months of the release. Forty-four percent indicated that their clients already had the required hardware, and deployment involved the installation of the product in the context of use. Although this was indicated in the questionnaire survey, the observed examples included developed websites that are successfully hosted online. Apart from proof of payment for the work done on the project, none of the interviewed entrepreneurs had sign-off documents for the developed systems.

5.7 Software Engineering Management

Respondents were requested to explain how they identify potential clients in the Namibian market. All participants agreed that finding new clients is a challenge, as most organizations do not advertise or request for an expression of interest from software developers. Instead, entrepreneurs reported learning about new business opportunities from word-of-mouth ("referrals"), especially from existing clients. One entrepreneur also indicated that in all cases, he had to identify the need for the software himself, and approach the target organization with a prototype and negotiate for possible consideration:

> I realized that waiting for adverts will not work. I had to design a prototype and request an appointment with the CEO so that I can be afforded a chance to show them that I have a product that could assist the organization.

> We identify gaps in prospects' business operation and propose an efficient computerized system solution.

All entrepreneurs also indicated that in some cases, they have more than one software project from an existing client. It appears that it is easier for the clients to assign new projects to the same startup once they have established the technical capabilities and rapport of the startup. Figure 2 below shows the sources of software development projects as indicated by the participants.

We also wanted to know more about the client or target market for software. Although the entrepreneurs cater to both public, private companies, and individual customers, the main recipient or client for software products is the public sector. The distribution of projects among the different sectors is shown in Fig. 3.

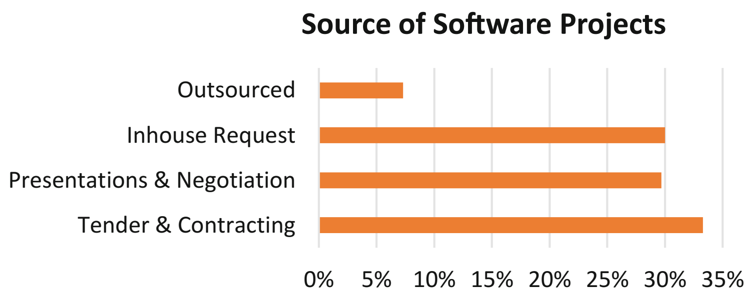

Fig. 2 Sources of software development projects

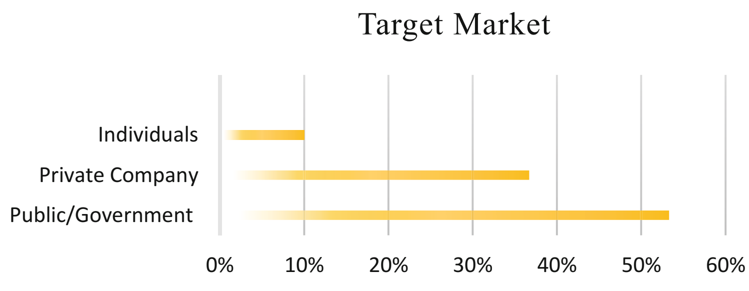

Fig. 3 Target market for Namibian software startups

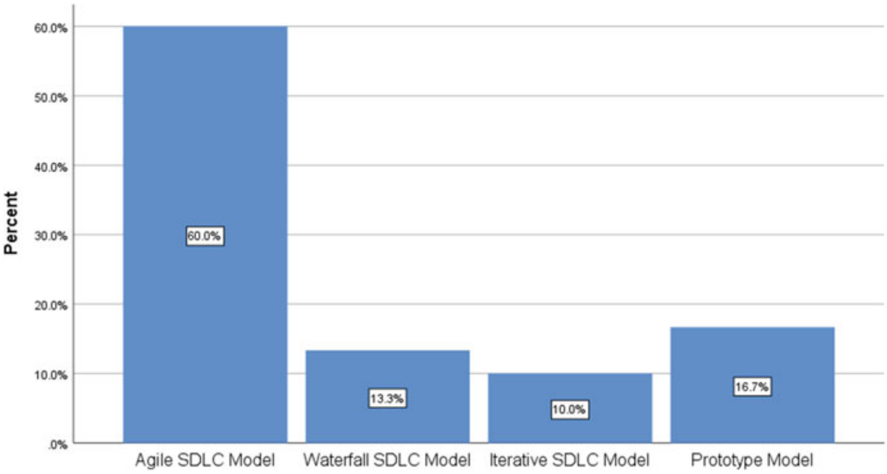

Fig. 4 Software development models used

5.8 Software Engineering Process

For the Software Engineering Process, respondents were requested to indicate how they define software processes, and how they decompose work activities into tasks. Sixty percent of the participants indicated that they use the agile processes although processes from well-known traditional process models such as the waterfall model, and iterative models were also listed. The percentage of users who reported using a specific development is shown in Fig. 4.

6 Discussions

The study found that startups used different practices in different software development projects. This is consistent with the results reported in the literature, where the employed methods are dependent on the project or problem to be solved. It is also consistent with the results of Tessler, Barr, and Hanna (2003), who argued that "one-size-fits-all" strategies are not realistic, as each country or project will have unique conditions which will need to be adapted to the specific context.

The study found that the methods used to elicit, analyze, specify, and validate requirements depend on the context of the project they are working on. For projects where the initial project idea was clear to the client, interviews are mostly used. This is possibly because developers did not know much about the requirements, and/or they needed to ensure that they understood the clients' point of view, as well as the expectations of the system. However, for development projects that were initiatives of the entrepreneurs themselves, developers had to "market" them to potential customers for consideration. In these types of projects, entrepreneurs would typically develop a prototype to try to convince the targeted clients of the expected benefit from the system. The clients could accept the proposal as is, suggest changes to the prototypes to fit the working context of the client, or see no value in the proposed software service.

The study also found that, although there are commonly used tools or programming languages within startups, during the different stages of software development, developers to not necessarily stick to these tools or languages in each project. The tools used again depend on the project, and is highly influenced by the clients preferences/experiences. We also found that the developers do not necessarily keep records of the required documentation for the projects, and they do not always follow the provided software engineering guidelines (e.g., requirements specification and design documents signed off by the clients). This not only poses a risk to the developer (i.e., low degree of user acceptance), and can also contribute to the low quality of final software products. It is, therefore, highly advisable for entrepreneurs to adhere to commonly accepted software engineering guidelines and standards.

Respondents indicated that they embrace agility in their development practices to reduce production time and increase the satisfaction of their clients and end-users. They also use iterative and incremental software development approaches, which they believe lead to better quality software and user acceptance. Although none of the respondents specifically alluded to using traditional development practices, some of the observed practices closely matched those of the traditional approaches to software development. We also observed that not all startups keep documentation to prove usage of the specific practices employed during the development process. Results of this study show that there is enough evidence of software development activities in Namibia, and the demand for software applications continues to increase. However, there is a general feeling amongst entrepreneurs (also confirmed in previous research), that the current efforts of the government are not sufficient to stimulate the development to local software industry in Namibia. Outsourcing of software development jobs or purchasing of off-the-shelf or cloud-based services inhibits the development of local software development industry. There is, therefore, a need for deliberate efforts to create conditions that will accelerate and shape the growth of software development in the country, by ensuring that the principles of the "Growth at Home" strategy and the objectives of the Industrialization Policy are implemented. Without this deliberate effort, software entrepreneurs will continue to find it challenging to identify and penetrate the software development industry in the country.

7 Conclusions

This study aimed to determine the practices of software development employed by Namibian software startups. Most software development opportunities in Namibia seem to result from individual initiatives of entrepreneurs. An understanding of the entrepreneurial ecosystem in Namibia is thus critical to enable software startups grow and sustain their operations. This study, therefore, recommends that further studies aimed at understanding the entrepreneurial ecosystem of software startups in Namibia are required to build a resilient software industry and foster sustainable software entrepreneurship in the country.

8 Limitations

This study was exploratory, due to limited literature on software development practices in Namibia. The sample size used in the study was very small, and participating companies were all from Windhoek, making it difficult to generalize the findings. Also, as indicated in the SWEBOK guidelines, following the software development theoretical framework adopted in this study poses an inherent risk of a waterfall-like development process, which is not always applicable to Small and Medium Enterprises.

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Part II
Resilience Through Learning and Teaching

TANKS: A Tangible Programming Tool to Introduce Children to Coding Through Fun Problem Solving Activities

Batteson Byron, Greyling Jean, Busch Kim, and Jacobs Desme

1 Background

Computer programming has a high financial barrier of entry and many South Africans do not even have access to a rudimentary computer. Therefore, it is unlikely that a child from a rural background would have encountered programming before entering a higher or tertiary educational institute, which offers programming. According to Duff (2014), only 2% of rural homes in South Africa have Internet access, which is in contrast to the fact that 17.9% of rural households go online using mobile devices. This lends to the assumption that more rural homes have access to mobile devices than computers.

Within the context of the Fourth Industrial Revolution, computer programming and robotics are becoming essential to the economy of the future. To establish and build an economy in such a way to support this, people are needed who are able to develop and work with the latest technologies (Singh, 2004). To get a population that is comfortable with technology, children need to be enabled to program and be comfortable with robotics. However, in South Africa there is a problem with this as the poorer and more disadvantaged communities lack access to computers. Due to their lack of exposure, they cannot be expected to have an interest in it and this implies that they will fall further behind in this economy. This is part of the problem known as the digital divide. The digital divide consists of 4 kinds of barriers to access (Deursen & Dijk, 2014).

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- Lack of elementary digital experience
- No possession of computers and network access
- Lack of digital skills caused by insufficient user-friendliness and inadequate education or social support
- Lack of significant usage opportunities

A further challenge for South Africa is that software development is seen as one of the scarcest skills. According to the latest CareerJunction Index Report for September 2019 (CareerJunction, 2019), Information Technology remains the top employment sector. Software developers remain the highest sought-after skills set locally, with an increase of 11% quarter-to-quarter. The CareerJunction Index analysis is based on comprehensive data gathered from the CareerJunction website—where around 3000 of the country's top Recruiters (both agencies and corporate companies) advertise their positions to millions of registered job seekers.

According to Oxbridge Academy (2018), the top three skills that South African employers are looking for are software development, network and information security, and web development.

This paper reports on a project conducted by a fourth-year computer science student (Batteson, 2017) at Nelson Mandela University, South Africa. The aim of the project was to investigate and develop an inexpensive educational tool (as a mobile app) for an introduction to computer programming, making use of the concept of tangible programming (Sect. 2). The objectives of the final tool were thus the following:

- Accessibility, regarding cost, as compared to its predecessors (Sect. 3);
- Introduce programming concepts such as sequential, conditional, and loop logic (Sect. 4); and
- A tool that learners can interact with and have fun while doing so (Sect. 5).

It must be emphasized that, within the South African context discussed, the focus of the project is not mainly to create an introductory programming tool, but rather to give them "a taste" of what programming is. Through this the authors aim to make learners aware of coding and to entice them regarding a career in software development.

Section 4 discusses the implementation of the mobile app, named TANKS, providing an overview on how it works. TANKS was rolled out at five design thinking workshops in the Cape Town area, which provided important insights regarding its potential (Sect. 5).

2 Tangible Programming in Education

Tangible Programming is a concept in childhood education that embraces the idea of learning by creating something with your hands. Children thus build code by physically putting blocks together. This happens before the child starts coding on a computer and as an introduction to coding, is much more effective (Manry, 2017).

David, Triona, and Williams (2006) stated that a *hands-on* approach to learning could inform cognitive development through its kinesthetic involvement by going from concrete to abstract. Rogers, Scaife, Gabrielli, Smith, and Harris (2002) suggested that allowing children to use mixed realities (virtual or physical tools) in the context of play and learning allowed for uncharacteristically extended interest and reflection. The extended interest would be key for an introduction to programming concepts.

Marshall (2007) stated that tangible programming may increase collaboration between children, as learning on a single desktop with a mouse and keyboard would result in one or two children taking control of the application while others may only observe. Horn, Solovey, Crouser, and Jacob (2009) compared educational tangible systems to graphical systems. The results were that both systems were equally easy to understand, but tangible systems tend to increase group participation. Children were also found to become more involved with tangible systems than adults.

TANKS is considered tangible game-based because it is a physical interaction mediator to a computer function. This opposed to the definition by Mokhtar et al. (2015) who defined tangible in their study as an augment of the physical elements and real environment without computer use. A tangible game has the advantages to develop learners' cognitive, social, and physical skills as well as the ability to stimulate the human mind (Mokhtar et al., 2015). The authors' research study and the current study are similar, that is, both have the propensity to use tangible game as a creative approach in introducing programming to school learners because of its easiness and an interesting interface that should influence learners' motivation in developing cognitive skill (Thornton & Yoong, 2011).

The concept of tangible programming as applied with TANKS would fall in a broader category known as "application and table-top hybrid games." Being a hybrid, they can make use of the advantages of both board games and mobile applications. Andersen, Kristensen, Nielsen, and Grønbæk (2004) state that it is possible to take advantage of the positives that both these genres bring by creating a hybrid app and table-top game. Mandryk, Maranan, and Inkpen (2002) stated the difference in interactions between players of computer/console games and players of board games. Board games are designed for interaction directly between players using the board game rules, such as asking a player to pay you rent in Monopoly; whereas in console games, players may be sitting side-by-side with fellow players, yet only looking at and interacting with the screen.

The main advantage that board games have over video games is the social interaction that comes with playing them. Xu, Barba, Radu, Gandy, and MacIntyre (2012) described these interactions, unique to board games, as being:

- Reacting to and reflecting on other players' strategic choices.
- Strategizing your own upcoming turns and uncovering the strategies of your opponents.
- Talking about subjects unrelated to the game in-between turns.
- Commenting on and discussing the game itself.

Mandryk et al. (2002) came up with a few other advantages of board games as they explored the "space between board games and video games." According to them, board games are:

- non-oriented, allowing multiple players to view it from different angles and simultaneously interact with it;
- portable; and
- flexible regarding altering the rules to suit the players.

Considering these points, it would suggest that either a virtual system (only on a phone, for example) or a tangible system would be successful for instruction. However, virtual systems normally include the use of a computer, which is costly. Another issue that arises is that sole interaction with a mobile phone for programming would discourage group participation.

3 Extant Systems in Tangible Programming

Three different extant systems were investigated: AlgoBlocks (Sect. 3.1), Tern (Sect. 3.2), and Sheets (Sect. 3.3).

3.1 AlgoBlocks

AlgoBlocks is an implementation of tangible programming (Suzuki & Kato, 1993). The blocks are large electrical components which connect to each other to create a set of logical steps for a program on the computer to run. AlgoBlocks have controls more closely related to typical programming languages including *if-then-else*, and *repeat ... until* blocks. It further has an additional debug mode which allows users to trace along the execution of a program by pressing buttons on each block. An important objective of the AlgoBlocks project was to create a more collaborative learning experience than its predecessors. However, AlgoBlocks—like its predecessors—is still expensive due to the use of electronic components, and the requirement of a computer to run the programs.

3.2 Tern

A newer form of tangible programming, named Tern, was introduced in 2007 (Horn, n.d.; Horn, 2007; Horn & Jacob, 2007). One of the objectives of Tern was to be inexpensive. Tern blocks contain no embedded electronics, and are simply composed of w3ood. The command blocks are connected to one another to form a program. An image is captured with a webcam from either a computer or a laptop, and the program is interpreted and executed in some virtual environment.

Tern achieved two things that align with the objective of this project. Firstly, the blocks not using embedded electronics make them cheaper than previous solutions. Secondly, the fact that electronics are not involved implies that the command blocks can be far more complex in nature without raising the cost of the project or the size of the command blocks themselves. However, Tern is a computer-based solution which requires a webcam.

3.3 Sheets

A unique and promising tangible programming system—with a prototype implementation called Sheets—was developed in 2015 by Tada and Tanaka (2015). This system utilizes printable paper-based command objects instead of the typical command blocks, and is thus a slightly more inexpensive successor to Tern. Sheets programs are interpreted by a computer by utilizing a webcam to capture an image of the paper command objects.

Tern and Sheets are an improvement on AlgoBlocks because electronic components as building blocks are not needed. An important aspect, however, of all three extant systems that were investigated, was that they are all computer-based solutions. There is thus the need for a tangible programming tool making use of mobile phones, and thus usable to children who do not have access to computers.

4 Implementation of the Application

The application (Batteson, 2017) is a complete Android application capable of working on most handheld Android devices with an APK level of 15 or higher and a device camera. It is known as TANKS, since it was drafted as a military tank objective-based game. The objective is provided on the mobile device, requesting the user to move a tank to a final destination, keeping in mind walls, as well as obstacles that can be removed by shooting (Fig. 1). There are 35 different objectives (referred to as levels), of increasing complexity. The user places the tangible command tokens such that they complete an objective. The mobile device then captures the placement of the command tokens using the built-in camera of the device. The sequence represented by the command tokens is then interpreted and executed, aiming to complete the objective.

Fig. 1 Example of objective provided to

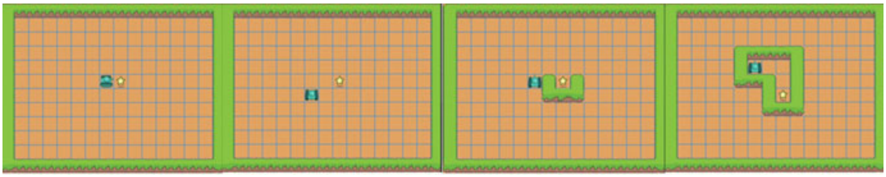


Fig. 2 Levels 1–4

4.1 Levels (Challenges)

The design of levels needed to encourage the use of more complex command tokens as the user progresses throughout the game. There are 35 levels, with each group of 5 levels introducing a new concept:

1. Levels 1–5: Basic sequences
2. Levels 6–10: Loops
3. Levels 11–15: Conditional logic
4. Levels 16–35: Complex combination of previous concepts

Figures 2 and 3 present the first four and the last four levels, highlighting the increased complexity of the objectives.

4.2 Tokens

Various programming tokens were designed representing essential actions, constant values as well as conditional and looping actions.

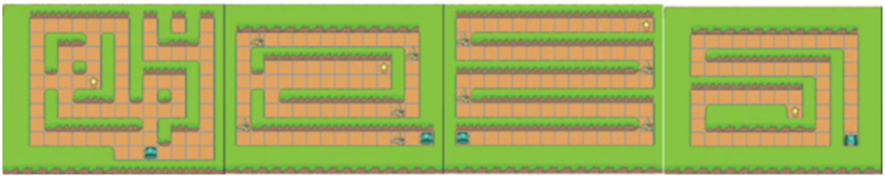


Fig. 3 Levels 32–35

Fig. 4 Start token

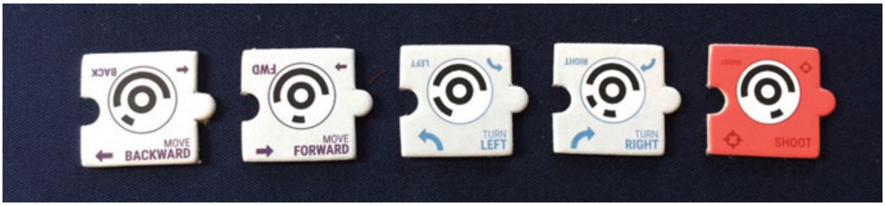


Fig. 5 Basic tokens

Fig. 6 Conditional token

The start token (Fig. 4) indicates the beginning of a sequence to be executed. The command tokens (Fig. 5) represent the essential actions, which can be performed by the military tank: the basic move and turn commands, as well as shooting.

The conditional token (Fig. 6) presents the concept of conditional logic. The tank evaluates whether something is in front of it and, in essence, blocking its path. This allows the user to follow two different sequences of flow based on the outcome of the evaluation.

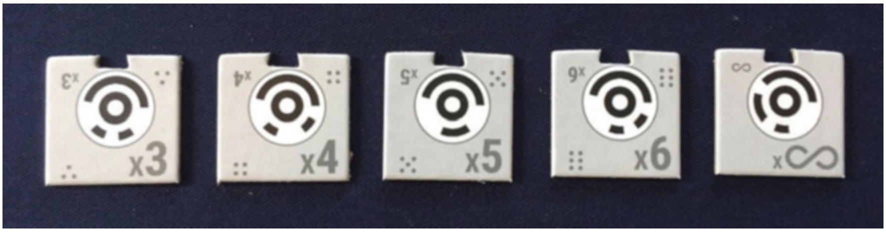


Fig. 7 Value tokens

Fig. 8 Repeat token

Fig. 9 Sequence extract of repeat loop

The value tokens (Fig. 7) present the concept of a constant or, more accurately, the equivalent of a constant argument in most programming languages. The last token represents infinity.

The repeat token (Fig. 8) presents the concept of looping. The repeat token accepts the previously mentioned value tokens as a parameter, placed below it. The trapezoidal shape below the token is another indication of the use of a value token parameter. The tokens above the repeat token are repeated as many times as indicated by the value parameter. An infinite token used in this context would indicate repeating continuously. Figure 9 presents a sequence extract of a repeat loop. In this example, the military tank is made to move forwards three times before the execution of the sequence continues.

The circles within the tokens are called TopCodes. The TopCode library is an image recognition library written by Horn (n.d.). There are a few specifications and restrictions on the design. Firstly, there are a limited number of possible TopCodes. The reason is that TopCodes have a unique identification code represented by 13 binary digit (bit) values. Of these 13 bits, exactly five are allowed to be a *one*, the rest have to be a *zero*. Each of the 13 bits is drawn as a slice of a full circular ring. If the current bit being drawn is a *one*, then a white slice is drawn, otherwise a black slice is drawn.

4.3 Example of Solving a Challenge

As stated, the aim of the tool is introducing coding to learners. True to the nature of coding, there are often different solutions to a problem. Figure 10 shows one of the more complex levels in the game. The simplest way of solving this challenge would be to use the sequential tokens. Figure 11 shows how cumbersome this solution is, specifically because of the 6 consecutive *move forwards* after the first *turn left*. At this stage a facilitator could encourage the player to find a more efficient solution by using a repeat token. This introduces players to the concept of looping, as shown in Fig. 12.

A further improvement to the solution would be to first identify another path to the destination (Fig. 13), where the tank continuously moves forward, except

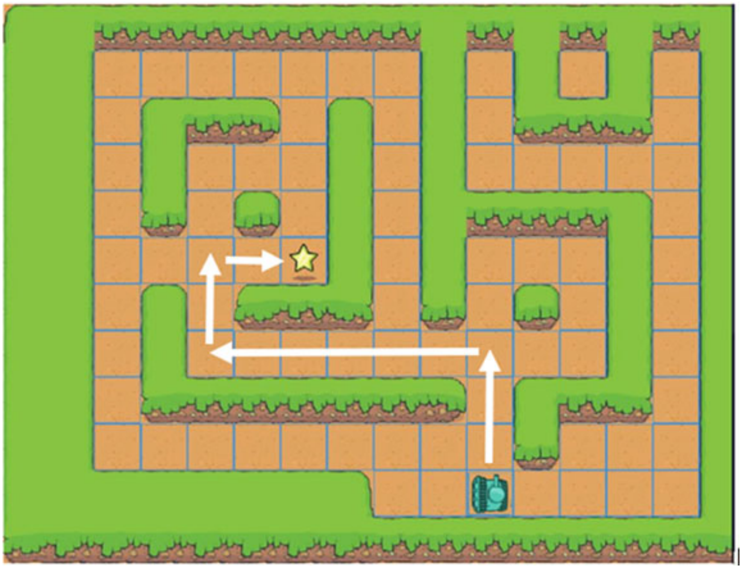


Fig. 10 Simplest route to destination

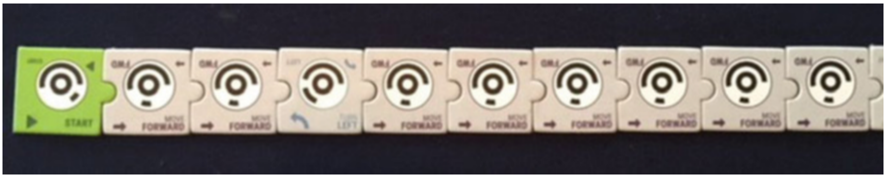


Fig. 11 Sequential solution

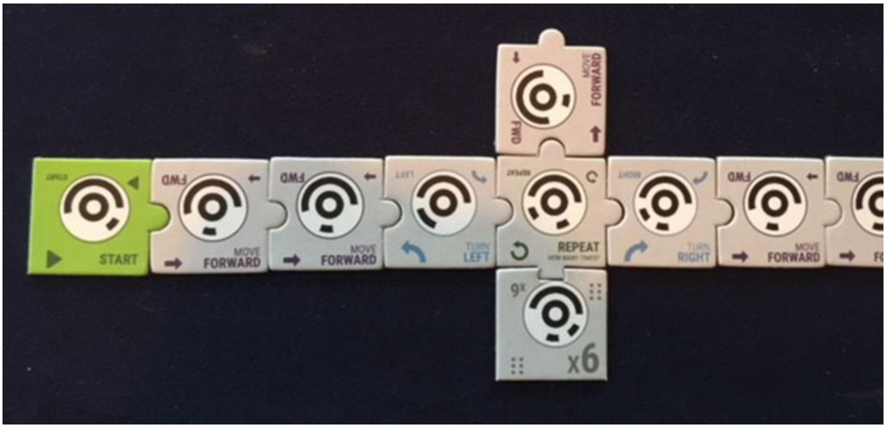


Fig. 12 Using the repeat token

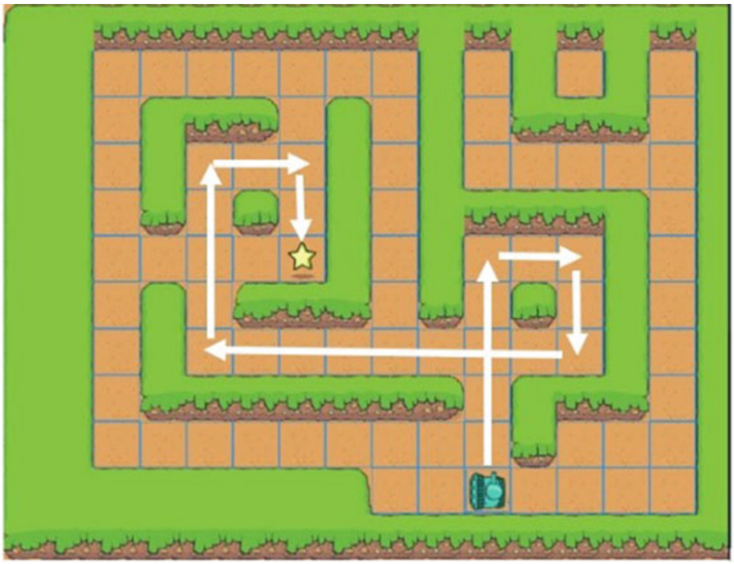


Fig. 13 An alternative repetitive solution

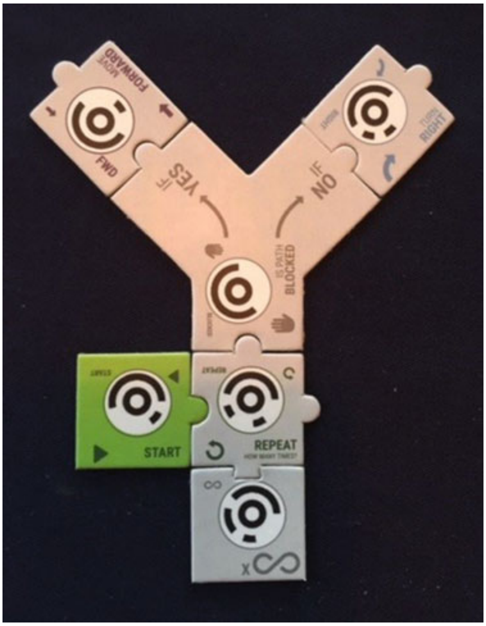


Fig. 14 Using the if token within a repeat

when blocked where it then turns right. This solution makes use of the *if token* within a *repeat*. It infinitely repeats until the destination is reached (Fig. 14). This solution relies on the feature of the game that the tank stops when it reaches its destination. Younger players will most probably not identify this solution on their own. Through guidance, once they have insight in how it works, it will illustrate the effect of advanced coding constructs in a very powerful way.

5 Rollout of the Application

The developers of the application collaborated with RLabs, based in Cape Town, to conduct an impact study. RLabs was founded in a marginalized community known as Bridgetown. Their passion is solely to create systems and environments where the lives of many can be impacted, where individuals may find empowerment and transformation can occur through hope, technology, innovation, training, and economic opportunities.

RLabs often presents Design Thinking workshops, and therefore the application was seen as a logical addition to their program. The purpose of these workshops is generally to identify problems, and then to think creatively and find solutions to solve complex problems.

The workshops were presented in the following suburbs around Bridgetown: Vangate, Retreat, Philippi, Mitchells Plain, and Strandfontein. 100 children aged

10–15 years participated. Coming from typically marginalized communities, the children mainly have very limited (if any) contact with computers at home and school. None of them would have ever had a previous experience in coding.

The workshops had three stages, namely a general introduction to problem solving through design thinking, playing a physical coding game, and then interacting with TANKS.

5.1 General Problem Solving Activity

The children were tasked to identify their dislikes regarding going to school. Figure 15 provides an overview of the dislikes identified across the five venues. After identifying their dislikes, they were tasked to demonstrate these dislikes in one of the following forms: dance, rap, singing, or beatbox.

During the final phase of this activity, the children had to build a solution for their dislikes using various art and crafts materials. They then had to present their finished product to the rest of the class. Through this exercise, the children learned about prototyping and communicating a solution to an audience.

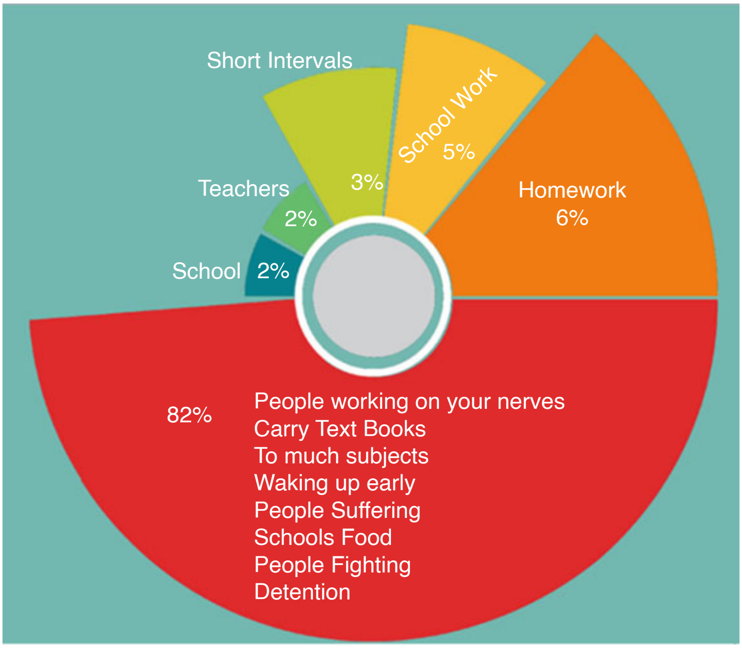
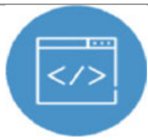


Fig. 15 Children's dislikes

Table 1 Function cards for physical game

	Wait one round before moving forward		Switch with your team member		Remember a number until the end of the game
	Spin around for 10 s		Perform some if statement		You and your team member must perform a dance

5.2 *Physical Coding Game*

Before starting with TANKS, the children had the opportunity to play a physical coding game that was created by the Innovation Lab Team from RLabs. This was created so that participants could understand how coding works before doing any coding, and is therefore an ideal preparation to playing with TANKS.

The purpose of the game is to introduce variables, if statements, and loops to the participants. The learners split into pairs of two. There are different function cards (Table 1), and the objective is to move forward, with the winner the one that moves 10 times first, thus reaching the final destination. The role players in the game are "program," the person giving the instruction, and "computer," the person performing the instruction. These roles aim at assisting children further in understanding the context of coding.

5.3 *Application of TANKS*

After the physical coding game, the children had the opportunity to interact with TANKS. They were told the previous day to bring a smartphone along to the workshop. The children played together in small groups, which were provided with sheets containing the different programming tokens (Fig. 16). Before starting the game, they had to push the tokens from the sheets. Each team could then progress through the levels at their own speed.

The facilitators from the different venues submitted reports afterwards, which gave good insight in the use of TANKS in such a setting.

The following are the aspects, which the facilitators identified as working well:

- The majority of the kids had cellphones, knew how to connect to the wifi and how to download the app. Having wifi assisted greatly, since most children did not have airtime.

Fig. 16 Sheets that were provided

Fig. 17 Working in groups

- Pushing out the tokens from the sheets at the start caused great excitement.
- Children could take the games home afterwards, which allowed them to continue with more complex levels at home. Some also introduced it to their friends.
- The children enjoyed playing with TANKS by working together in groups with their friends (Fig. 17).

The challenges that the facilitators identified, included the following:

- Initially children had problems really understanding how the different tokens of the game worked.

- Some children had initial difficulty with capturing the tokens through their phone's camera. A typical problem was waiting for the camera to focus and having the correct angle.
- Some groups progressed faster than other groups, which created a form of despondency amongst the children.
- One student could not download the app onto his phone, and had to play with someone else in his group.
- The more complex levels caused some frustration with the younger children.

5.4 Reflection on Workshops

The initial activities of the workshops did not involve coding. They were conducted in the context of design thinking and solving problems. This was followed by a physical coding game before interacting with TANKS. Within this context, the TANKS game took on a broader role than purely an introduction to coding. Intuitively children were focusing on problem solving, and this theme was carried over to the TANKS game in more than one way. Firstly, the actual challenges in the game had to be solved. There were also the other challenges that were mentioned in Sect. 5.3. Although they could be viewed as limitations of the game, the children who were confronted with them, had to try and find solutions.

Despite the difficulties, it was clear that most children were having great fun playing with TANKS. Without them realizing it, they were introduced to the world of coding, and many had a great sense of achievement afterwards (Fig. 18)

Fig. 18 Great sense of achievement

6 Conclusions

When TANKS is rolled out in disadvantaged areas, challenges that can be faced could include the lack of airtime to download the app, as well as the fact that children might not have compatible phones. This can be solved by having wifi in the venue, and having children play in groups where at least one phone is available.

From feedback at the workshop, the aspect of introducing the children to the basic tokens before letting them play needs attention. The researchers are currently investigating the development of a board game, which uses the same programming tokens. It will allow facilitators a better opportunity to prepare children before interacting with TANKS.

The main aim of the project is to introduce children at a young age to the joys of programming, in an inexpensive way, enticing them towards a future career in software development. The workshops where TANKS were rolled out showed that children enjoyed interacting with the game. It furthermore showed that the game has meaning in a wider context than pure programming, in the sense that it works very well in a general design thinking workshop.

A definite aspect that needs to be addressed is where learners could be directed to after playing the game—especially those who enjoy the concept of coding. Scratch (Resnick et al., 2009) would be an obvious next step, given that the learners have access to a computer. Existing mobile apps which allow participants to do conventional programming, combined with instructional videos, could also be considered.

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Use of Augmented Reality Mobile Devices to Support Farming Teaching and Learning

Manuel Constantino Zunguze and Lussane Hepuclen Machaca

1 Introduction

Computing has become part of the daily lives of people and organizations from different sectors, including the educational environments. According to Menezes, Nunes, and Livi (2018), knowledge in this area is very important for life in contemporary society. With this, new ways of learning and teaching concepts emerge at every moment to understand society in constant evolution. Thus, it is essential that all individuals have basic knowledge and can learn about and with computing.

Mobile computing technologies are currently undergoing rapid evolution and appear destined to become the new dominant computing paradigm (Myers & Beigl, 2003). The use of mobile devices in education has created a concept, called Mobile Learning or m-Learning. Its great potential lies in the use of mobile technology as part of an integrated learning model, characterized by the use of wireless communication devices, transparently and with a high degree of mobility (Ahonen, Joyce, Leino, & Turunen, 2003; Syvänen, Ahonen, Jäppinen, Pehkonen, & Vainio, 2003).

The provision of telecommunications services and mobile devices capable of providing mobility to different participants in educational projects presents several opportunities for the development of research in the field of mobile computing applied to education (Meirelles, Tarouco, & Alves, 2004). In support of learning, three-dimensional virtual environments, where the individual can move, listen,

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see, and manipulate objects, as in the real world and learn, represent interesting opportunities available to educators. The introduction of the so-called augmented reality systems (ARS) in education can significantly modify the role of these educators (Meirelles et al., 2004).

In this study, we propose to analyze the potential of the ILPF—livestock and forest integration system in mobile devices as a teaching and learning tool for agriculture, starting from the idea that continuous and open activities in education are necessary in educational, productive, and social organizations and that new technologies can contribute to student learning.

2 Methodologies

The methodological procedure that guided the research was divided into different stages, detailed below.

2.1 Methodological Approach

The research had a quanti-qualitative approach due to the nature of the collected data, which allowed to make quantitative and qualitative analyses. For Vieira (1996), qualitative research can be defined as that which is mainly based on qualitative analysis, characterized, in principle, by the non-use of statistical instruments in data analysis. On the other hand, according to Vieira (1996), quantitative research is characterized by the use of statistical instruments, both in the collection and treatment of data, and whose purpose is to measure relationships between variables. The research was also exploratory-descriptive.

2.2 Data Collection Procedures

Data collection during the research was carried out using two instruments, a questionnaire and an interview.

The questionnaires and interviews were directed to students and teachers of the third year of the Agricultural course at Licungo University, Extension of Beira, in the academic year of 2019.

We opted for the combination of a mixed research methodology, using several methods of data collection and analysis since it is "often useful, if not necessary, to use different techniques in the same research" (Lessard-Hébert, Goyette, & Boutin, 1990).

Sampling was done for convenience, using informal contacts, and asking students and course Teachers to participate. It was possible to work with a sample of 40 respondents among teachers and students, mostly students. The questionnaires were distributed and answered on paper.

Lists of validated indicators were used as a starting point for data collection. The questionnaire started with the search for requirements related to the course, from the classroom to the campus, after which the students were submitted to a pre-test. Then an explanatory text related to the contents (ILPF Networks) of the pre-test questionnaire was generated, which was provided to the same group of respondents to be aware of what was going to be addressed. Following the explanatory text, the participants had the possibility to install the application and interact with the ILPF cube in augmented reality.

After the students interacted with the application and cube ILPF about the programmed contents, they were submitted to a post-test. Following the post-test, students and teachers were invited to answer a satisfaction questionnaire about the functionalities of the ILPF cube application.

The interviews were conducted with teachers and students. They allowed to extract information related to the research objective, the level of satisfaction after the experiment with the ILPF cube application. The interviews enabled the enrichment of numerical data throughout the work.

2.3 The Experiment

This session presents the ILPF system and its augmented reality markers (AR-markers), the operation and visualization of objects (Fig. 1).

The virtual model is made up of different AR-markers, each of which is available for viewing different phenomena related to farming, livestock, forest and their integration. For visualization there is a need to install the ILPF cube application on a mobile device.

To install the application, you must access the mobile application store, for Android or iOS, and download the ILPF RA cube application. The application can be installed on a cell phone or tablet. After installing the application, access the website https://www.embrapa.br/documents/, download, and print the images. Cut out and assemble the cube. After the assembly, open the application and point the camera of the cell phone or tablet to each of the faces (Fig. 2).

On each face of the cube there are markers that visualize certain phenomena of the integration of farming, livestock, forest and some buttons that allow interaction with the application for the user.

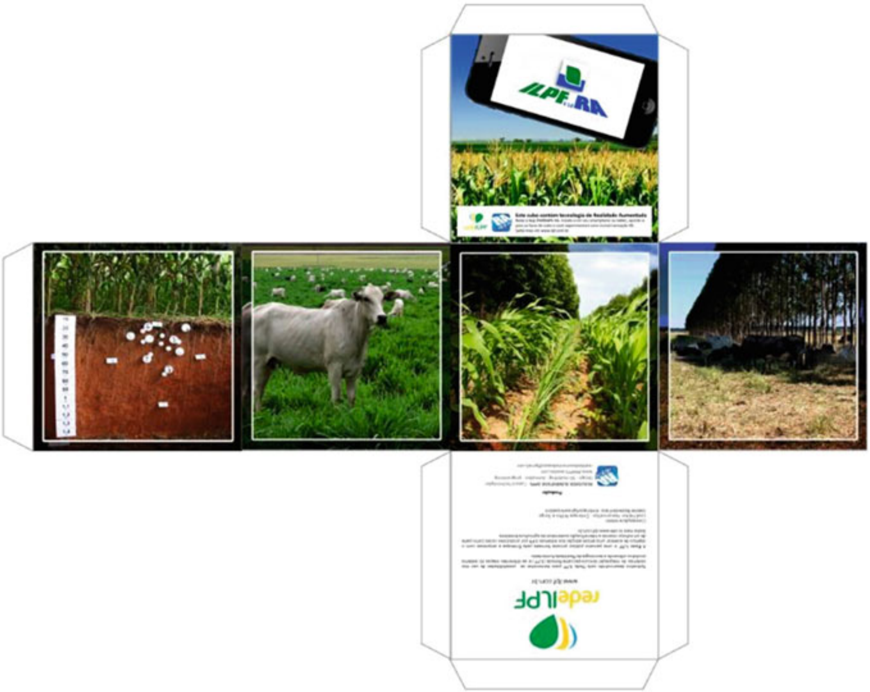


Fig. 1 Virtual model in augmented reality. Source: Embrapa (2019)

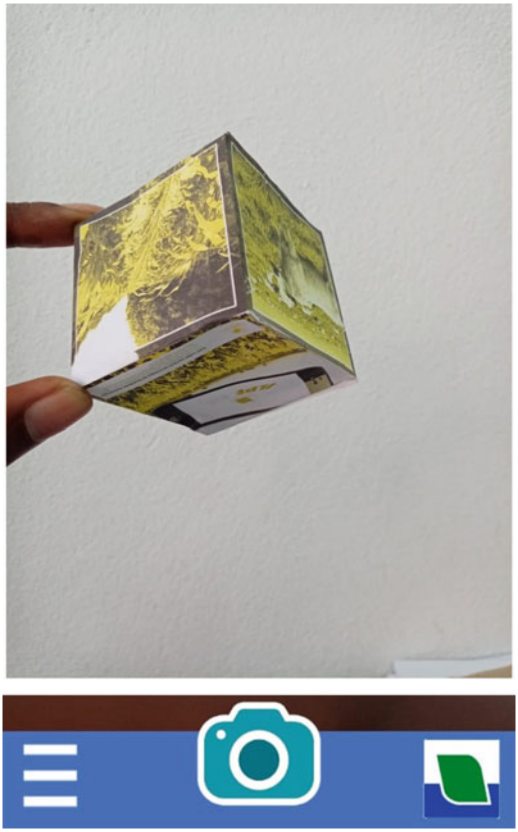
2.4 Visualization of Objects in Augmented Reality Available in Markers

One of the first activities was the demonstration of ILPF network as an aid to farmers and teaching and learning processes. Figure 3 show some activities offered by the ILPF network in augmented reality.

Figure 4 illustrates a system of soy and corn production planted in a straw in the same area where it can be seen that the growth of each crop does not disturb the growth of the other, thus verifying the beginning of integration.

Figures 5 and 6 illustrate the benefits of integrating cultures. In the figures it can be seen interaction buttons that allow to give the effect of whether or not there is straw. In Fig. 5, the cultivation of corn was done without straw, which does not benefit the soil, where it can be seen that the roots are unhealthy than in Fig. 6, where the cultivation was done with straw and it is noted that the roots have more nutrients.

Fig. 2 Assembled cube viewed from a mobile device



The interaction with the application allows to verify the effects that water causes in the cultivation areas such as soil degradation, erosion, and even the details of the culture (Figs. 7 and 8). It is also possible to see the profile of the soil, what is happening to the roots and nutrients. In Fig. 7, it can be seen that in rainy season there may be cases of erosion due to the lack of straw in the plantation, a different situation in Fig. 8 where the planting was done with straw.

Figure 9 illustrates the integration of livestock and forest where it is possible to see the benefits of one activity for the other and also the dynamics of carbon dioxide between the two activities.

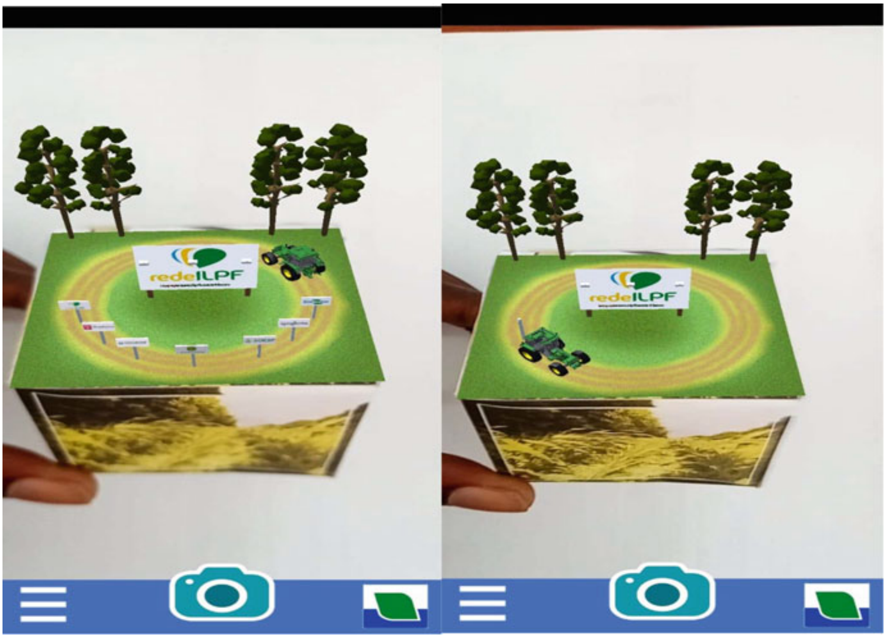


Fig. 3 Activities offered by the ILPF network in augmented reality

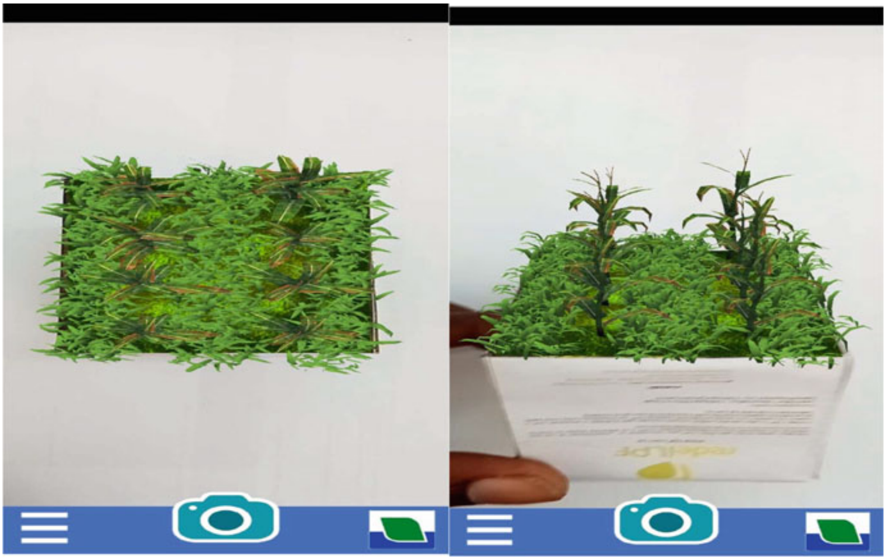


Fig. 4 Integration of soy and corn plantations in the same area

Fig. 5 Profile of the soil without straw

Fig. 6 Profile of the soil with straw

Fig. 7 Soil profile without straw and rain effect

Fig. 8 Soil profile with straw and rain effect

Fig. 9 Livestock and forest integration in augmented reality

3 Results

This section presents, in a clear and detailed way, the results achieved by the experiment performed, which in the previous section was made the description.

The data was collected from the 40 participants (including teachers and students of the third year agricultural course, from Licungo University—Extension of Beira) that will be analyzed, who were given the opportunity to test and use the ILPF Cube application in Augmented Reality. The collection and analysis of data was divided into four phases, shown below.

3.1 Requirements Survey Questionnaire

The first questionnaire applied aimed at evaluating the students' perception about the farming course, mobile devices for interacting with farming, livestock and forest environments, and augmented reality.

In the first question, the students were asked whether the farming course is more practical or theoretical. The answers are shown in Fig. 10.

More than half of the respondents (62%) said that the course has two aspects of teaching, being theoretical and practical. Twenty-five percent answered that the course is theoretical and thirteen percent that the course is practical. By the distribution of the students' answers, it can be concluded that the course has a theoretical and practical character witch is the genesis of a farming course.

In the following question, we tried to find out if there has been consolidation of theoretical and practical classes. The answers are shown in Fig. 11.

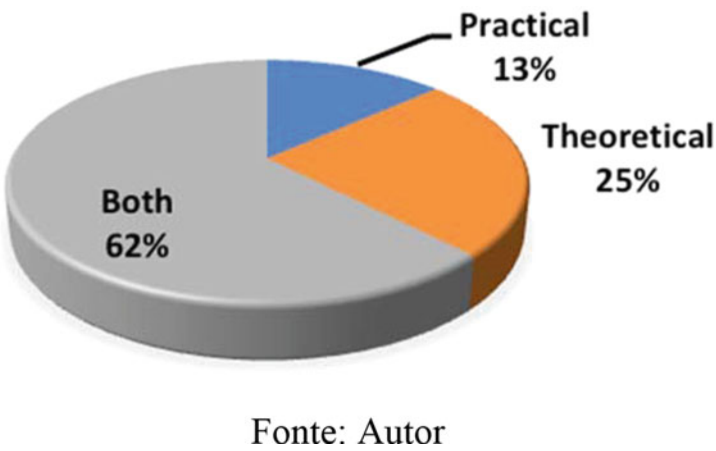


Fig. 10 Model of the farming course. Fonte: Autor

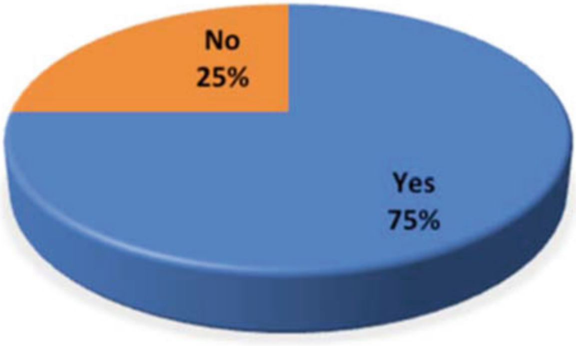


Fig. 11 Consolidation of theoretical and practical classes

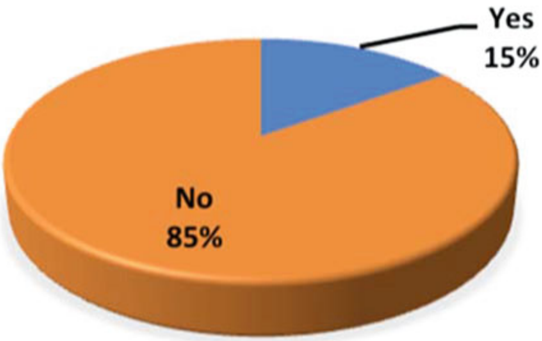


Fig. 12 Existence of spaces prepared for practical classes in the course

It was observed that the consolidation of theories and practices classes has taken place as shown in Fig. 11. However, due to the observations made, there are contents that are taught theoretically and that are not possible to be observed in practice due to the lack of adequate or appropriate equipment and fields of experimentation. It is for this reason that some of the respondents (25%) do not confirm the consolidation of practical and theoretical classes. This information is reinforced by the answers to the following question presented in Fig. 12.

It was observed that this question helps to answer the research question, where mobile devices and virtual models can help in consolidating or supporting the consolidation of theory in practice, since 85% of respondents say that there are no prepared spaces to consolidate those classes. With this data, it can be assumed that mobile devices with the appropriate applications can help students to suppress this non-existence of these spaces.

The students were asked if they knew any way of interaction with the farming, livestock, and forest environments through the computer or mobile devices. The answers are shown in Fig. 13.

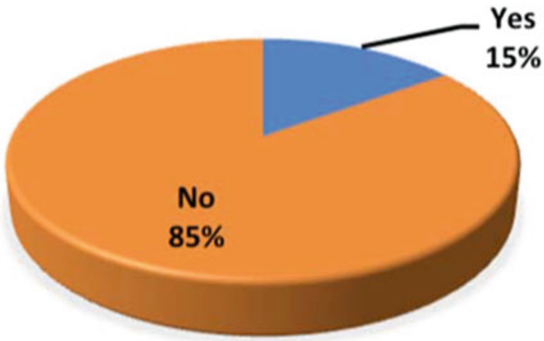


Fig. 13 Interaction with farming, livestock, and forest environments through computer or mobile devices

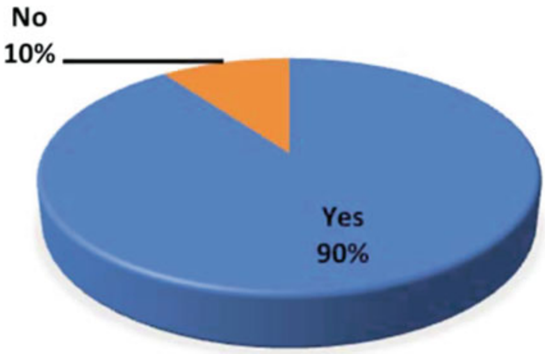


Fig. 14 Acceptance of 3D farming, livestock and forest integration model

It can be seen from the data in Fig. 14 that only 15% of respondents knew an environment of integration farming, livestock, and forest to support teaching and learning. For the vast majority, the Augmented Reality ILPF Cube was the first.

To view content in Augmented Reality, a virtual model is needed where it contains the contents in addition to a mobile device or computer. That is why students were asked if they would like to have a 3D model that makes it possible to check the content learned in the classroom, where they could have a greater sense of farming, livestock, and forest. The answers are presented below.

We can see that most of the respondents would like or want to have a 3D virtual model that will make it possible to observe the contents learned in the classroom in practice to consolidate the theoretical knowledge on the subject. The remaining 10% are not interested in having a model of this nature stating that the most important thing is to be aware of the integration.

We sought to know from the students about their interest in using technology through computers or mobile devices as a tool to support teaching and learning inside and outside the classroom.

In the question, respondents were given the possibility of choosing between several alternatives, it was a question with five alternatives, where by the nature of the question and the answers it shows that the technological tool proposed in the research and tested in it aroused interest in the use of technology by the respondents.

According to Fig. 15, it can be highlighted that 78% are very interested in using technology and this has made the research gain more impact on the course.

Finally, we tried to find out from the students if they had ever used an application in augmented reality. The answers are shown in the following Fig. 16.

Although the results show that 78% of students answered that they had never used applications in augmented reality, it was observed that there has been learning through mobile devices or computers, since some of the students participating in the experiment have mobile applications on their devices intended for learning.

This thinking is supported by the answer to the following question, where students were asked if they had ever used mobile devices for learning (Fig. 17).

The result showed a balance, where 53% of respondents did not use mobile devices to view educational content and the remaining 47% said they used it. It should be noted that 90% of those involved in the experiment have mobile devices.

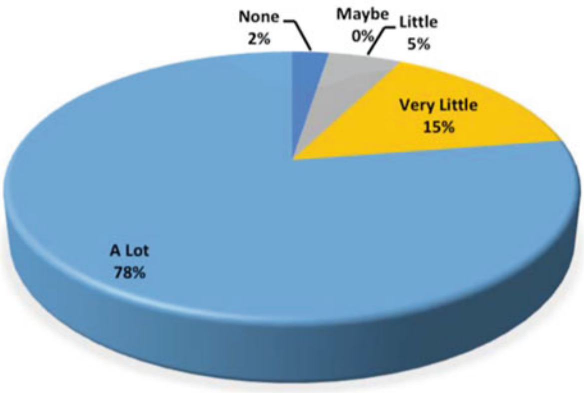


Fig. 15 Interest in the use of technology through the computer or mobile devices as a tool to support teaching and learning inside and outside the classroom

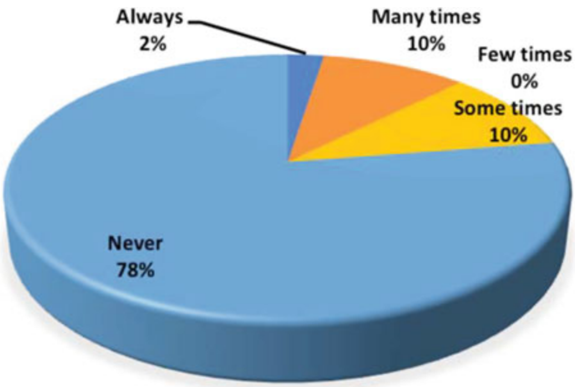


Fig. 16 Use of augmented reality applications

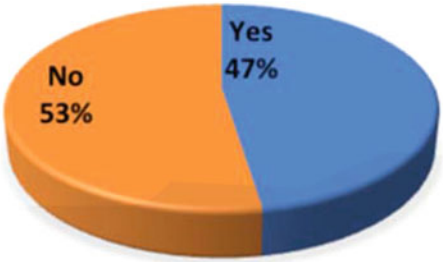


Fig. 17 Use mobile devices for learning

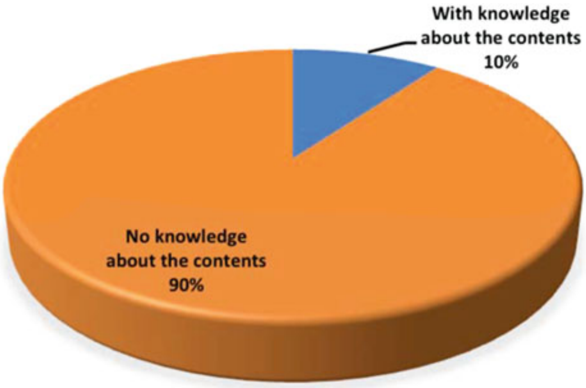


Fig. 18 Level of knowledge of students regarding the content covered in the research (pre-test)

Also, it should be noted that among the respondents, those who already had an understanding of augmented reality or had heard about augmented reality had this knowledge on television or in conversations with friends or colleagues.

3.2 Pre-test Questionnaire

Before carrying out the experiment, students were submitted to a questionnaire that aimed to assess the level of knowledge on the subject to be addressed in the research. The result of this questionnaire is shown in Fig. 18.

The results obtained from this questionnaire, which are shown in Fig. 18, showed that about 90% of the respondents did not know about the topic to be addressed in the research. Still, students were unaware of the usability of virtual models and mobile devices in supporting the teaching and learning processes for visualizing phenomena addressed in the classroom.

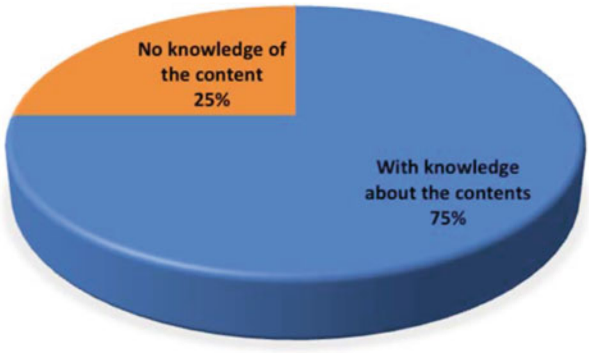


Fig. 19 Level of knowledge of respondents regarding the content covered in the research (post-test)

3.3 Post-test Questionnaire

The post-test was applied after the students had approached the programmed contents and used the ILPF application. The post-test questions addressed the same concepts as the pre-test (Fig. 19).

The results obtained from the post-test with the same questions as the pre-test showed an increase in the number of students who showed knowledge of the content.

3.4 Level of Satisfaction

After conducting the research, we sought to know from the participants (students and teachers) the level of satisfaction with the application, the usability and its integration in support of the teaching and learning process. For that, a questionnaire was applied to achieve the objective mentioned above. Figure 20 shows the results of the first three questions in the questionnaire.

The answers to the first three questions in the satisfaction questionnaire showed that approximately 100% of respondents rated the ILFP model positively. Qualitatively, responses ranged from 45% good to around 55% very good.

The next question sought to find out the opinion of the respondents regarding the usability of the ILPF system. Their responses are shown in Fig. 21.

It was observed that 70% of the respondents evaluated the ILPF model as being easy to very easy to use. The remaining 30% rated the model as having reasonable usability.

We also tried to find out from the respondents if, after carrying out the experiment, they would use the system to help the classes. The answers are shown in Fig. 22.

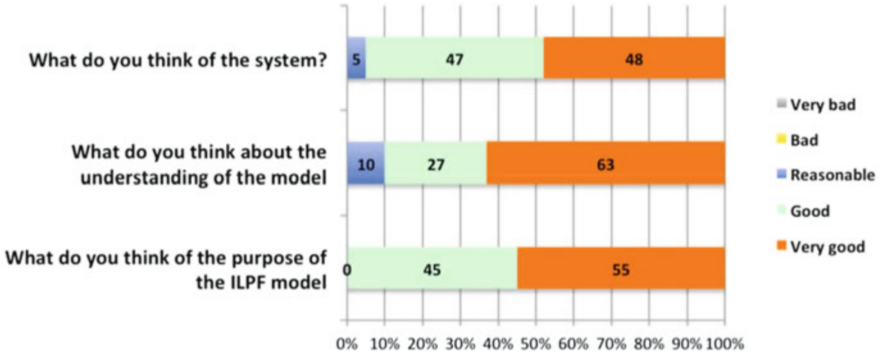


Fig. 20 Level of satisfaction with the application

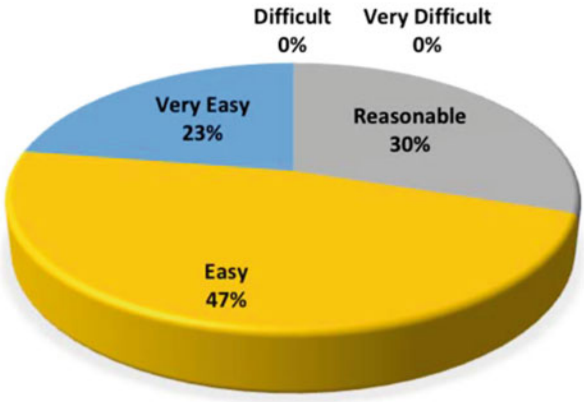


Fig. 21 Usability of the ILPF system

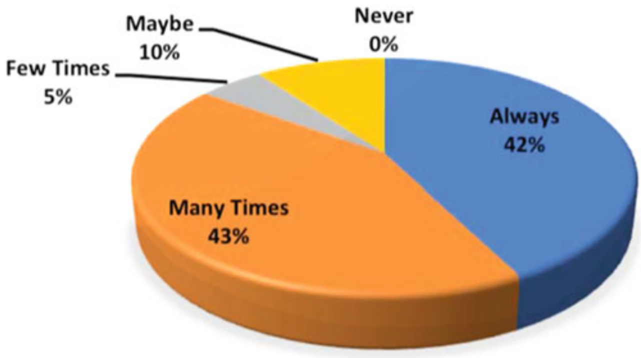


Fig. 22 Use of the system to help in class

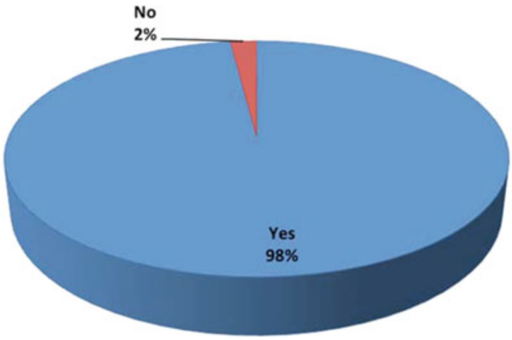


Fig. 23 Visualization of 3D objects

The question gave the respondents the choice between several alternatives. From the responses of the respondents, it can be concluded that the technological tool used in the survey aroused much interest on the side of the respondents.

As a last question about the usability of the ILPF model, we tried to find out from the respondents if they were able to visualize the 3D objects.

From the result shown in Fig. 23, it was possible to verify that from the mobile devices the respondents were able to observe the phenomena that occur in the farming activities proposed in the research.

This shows that the research has achieved the previously defined objectives and that the use of mobile devices with ILPF systems in aid to practical classes helps to consolidate theory in practice.

4 Conclusions

In this chapter, the conclusions arising from the present research are presented, where, according to the results obtained, we sought to achieve the previously defined objectives.

The work focused on making use of the ILPF system—Integration of Farming, Livestock, and Forestry in support of teaching and learning processes in agriculture in order to demonstrate the phenomena that occur covering the lack of integration between theory and practice and exploring the benefits that the system presents. This integration, in some way, improves the quality of teaching. Being a technical area, students have to graduate knowing how to consolidate theoretical classes to practices.

The research participants showed interest in using in a massive way the ILPF system—farming, livestock, and forest integration in augmented reality. This showed that the use of new technologies in teaching and learning is seen as an ally to traditional teaching and learning methods and that help in understanding certain thematic content.

Regarding the knowledge of the content covered in the research, it was possible to conclude from the results of the pre-test, that the respondents showed to have no knowledge of the research topic, about 90%.

After conducting the experiment with the ILPF system, the respondents were subjected to another test called post-test, with questions that addressed the same contents as the pre-test. The results of the post-test showed that 75% of the respondents had knowledge of the content in their responses.

After conducting the research, we sought to know from the participants (students and teachers) the level of satisfaction with the application, the usability and its integration in support of the teaching and learning process. The results showed that almost 100% of the participants were satisfied of using the system and were able to view the phenomena.

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VIEIRA. (1996). Marcelo Milano Falcão Vieira. A comparative study on quality management in the Brazilian and the Scottish prison service.

Developing an ERP Skills Programme to Build ICT Capacity for Disadvantaged South African Youths

Temitope O. Tokosi, Michael Twum-Darko, and Lorna B. Holtman

1 Introduction

South Africa (SA) is a country located at the southern tip of the African continent. It borders the countries of Namibia, Botswana, Zimbabwe, Mozambique and eSwatini. Lesotho is an enclave entirely surrounded by South African territory. With a land area of 1,214,470 km, it boasts of numerous natural resources ranging from gold, platinum, diamond to human resource. It attained its independence from UK on the May 31, 1910. Pretoria is its executive capital, Bloemfontein, the judicial and Cape Town its legislative capitals, respectively (CIA.gov, 2020).

The research goals are to develop an experiential learning framework structure to capacitate SA Black youths to be employable or entrepreneurs. The methodology is a case study qualitative approach to tackle the problem of unemployment of Black SA youths using this learning framework.

2 Problem Definition

Historically, racial discrimination dis-empowered non-Whites (Africans, Coloureds, Indians) from participating in the formal economy in SA. Apartheid was a system of government in SA, abolished in 1994, which systematically separated groups on the basis of race classification (Naidu, 2011, p. 1). It was designed to keep non-

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Whites unskilled, subjected to abject poverty and total dependency on the State for welfare (Gama & Willemse, 2015, p. 721). It also created inequality among all racial groups, making SA one of the most unequal country in the world, having the highest GINI coefficient of 0.65, a measurement of income inequality (McKeever, 2017, p. 114). With a shrinking economy, adequate skill in SA is demanded so acquiring ICT skills is adequate in meeting these demands. But also in redressing the racial skills imbalance, there is a need to skill Blacks and bring them to the level of their White counterparts without reverse discrimination.

There is a growing interest by Black youths in ICT-related disciplines according to Kirlidog et al. (2018, p. 16). In their study at one SA university department, results showed that Black students have a strong tendency to study ICT and they comprised 82.1% of all ICT students for a particular academic year. The problem arises when these Black youth (students) complete studies and enter the labour market. Employers demand work-related experience alongside a formal qualification. This results in capacity inadequacy.

The problem of capacity is borne of the fact that there is inadequate supply of skilled Black professionals in the ICT sector, specifically enterprise resource planning (ERP) skills. Generally, ERP skills are technical and analytical in nature and require manipulating computer application(s). This is not to say that other ICT areas (such as programming and networking) do not experience similar skill shortages. In SA, lack of appropriate work skills inhibits youth employment. Employers have the resource(s) to help skill youths. Training a youth at an employer's premise is a way to skill a youth. But training may not be conducted in many cases because employers are not willing to allow learner youths to use their resource due to software costs, risks of system damage, time and training constraints. Thus, an ICT skills programme is proposed in this study to skill Black youths to be better prepared for work or entrepreneurial activities.

With government's demand for transformation and racial inclusiveness (Andrews, 2017), there is a strong focus on Blacks being trained and skilled. The SA department of higher education and training (DHET) further highlights government's resolve through the national skills development strategy to prioritise and confront racial inequalities, with a particular focus on giving more opportunities to previously (and currently) disadvantaged South Africans. Continuing, this requires focused attention on skills provision for Blacks in general and Africans in particular (Department of Higher Education and Training (DHET), n.d.). Kingdon and Knight (2004, p. 21) argued that the historical characteristics of blacks had unfortunately put them at the back of the queue for employment especially among Black women (English & Hay, 2015, p. 149), so improving their characteristics may improve their place in the queue. These characteristics according to the authors include human capital (education) and employment experience. These problems led to the formulation of research questions to guide this study.

2.1 Unemployment in South Africa and ICT skills

Information and Communication Technology (ICT) skills are emerging as essential ingredients for job acquisition among the youth globally. Key skills such as problem solving, teamwork, communication, planning, numerical and IT skills are increasing in significance in many occupations (Felstead, Gallie, Green, & Zhou, 2007). In a study by the DHET and gazetted, the ICT sector was identified to show signal for increased labour demand as well as recover relatively quickly from the impact of COVID-19 (Department of Higher Education and Training (DHET), 2020, p. 17). South Africa (SA) as a republic has a total population of 59.62 million according to Statistics South Africa (SSA) mid-year estimates with youths accounting for 16.1%, that is, 9.59 million (Statistics South Africa [SSA], 2018, p. 8).

Unemployment, according to Kingdon and Knight (2004, p. 21), is inequitably distributed in SA and certain racial groups are highly likely to be unemployed and remain in it than others. These groups are typically non-Whites and young Africans in particular who live in homelands and remote areas. Unemployment remains a problem especially for the youth due to little or no work experience. Youths in this study are between ages 18 and 30 years.

The unemployment problem is more pronounced among Black youths who we classify in this study as disadvantaged. Blacks comprise African, Coloured and Indian people would be referred as such in this study. At 27.1 million in the October to December 2018 survey, the total unemployment was very high especially among Black youths who account for most of this total unemployed population (Table 1). Of the 6.1 million unemployed in the October to December 2018 quarter, 1.7% are graduates (Statistics South Africa [SSA], 2018, p. 7). Post-COVID-19, we anticipate that unemployment will increase because of the many businesses currently closing down or being liquidated and Black youths will be severely affected.

Table 1 shows that between the months of April to December 2018, unemployment slightly declined across all the various population groups (African is 0.1%, Coloured is 1.7% and White is 0.4%) except for Indians which recorded an increase of 2%. For 2020, statistics are not readily available but speculations are high that unemployment has increased exponentially, which is attributed to the national lockdown leading to some small and medium companies closing down permanently and employees losing jobs.

Within the South African ICT sector, the only available comprehensive IT race representation data to date is outdated (older than 10 years); it revealed that Blacks in general are under-represented (Fourie, van Rensburg, & Serfontein, 2005, p. 49).

Table 1 Unemployment rate by population group

	Black/African (%)	Coloured (%)	Indian (%)	White (%)
Apr–Jun 2018	30.5	23.3	10.4	8.0
Jul–Sep 2018	31.1	21.8	10.1	7.1
Oct–Dec 2018	30.4	21.6	12.4	7.6

Table 2 Total population estimates and IT race representation

Population groups	Technical area	%	Non-technical area	%	Total	Total population estimates 2005
African	40,394	30.5	20,701	29.8	61,094	37,205,700
Indian	13,907	10.5	8,641	12.5	22,548	1,153,900
Coloured	21,560	16.3	11,414	16.4	32,974	4,148,800
White	56,520	42.7	28,712	41.3	85,232	4,379,800
Total	13,2381	100	69,468	100	201,849	46,888,200

This under-representation is in-line with 2005 estimated population data (Ratele, 2008, p. 26) and IT race data comparison. This prompted the study report here which attempts to address this imbalance by proposing a skills programme (Tokosi, 2008). Table 2 by Fourie et al. (2005) indicated a gap in the racial disparity in IT skills as of 2005. A study by Schofield and Dwolatzky (2019, p. 11) on IT skills survey in SA within the MICT (Media and ICT) SETA indicated that 34% are white employees, 43% Black and the remainder almost equally split between Asians and coloured people. The need for a comprehensive new research study on IT race representation similar to Fourie et al. (2005) is imperative post-COVID-19 to assess the current situation as population and skill proportions have changed.

Table 2 is indicative of the proportion of each racial group in comparison to their representation within the ICT sector according to technical and non-technical areas in 2005. For example, Africans (Blacks) constitute 29.8% (61,094) of the total IT representation while they make-up 79.35% (37,205,700 million) of SA total population. Conversely, Whites constitute 41.3% (85,232) of total IT representation but make-up 9.34% (4,379,800 million) of SA total population. Skills and qualification standard is presented in the next section to highlight learners' competency requirement levels.

2.2 Skills and Qualification Standards in South Africa

While there is slow growth and improvement of participation by Black youths in the ICT sector, the SA government wants to accelerate the increase in the participation rate; however, financial resources to train these youths are limited. The Sector Education Training Authority (SETA) was established to address these problems where each SETA is tasked with undertaking training of all unskilled South Africans within its industry irrespective of race.

Since training is relevant to tackle challenges of growth, competitiveness and employment, there must be commitment from all stakeholders. These stakeholders partake in a tripartite agreement involving the learner, training provider and employer (public or private firms). The government is the facilitator of this agreement to ensure that all parties to this agreement abide by it. The involvement of social partners such as the SA government and SETA acts as a guarantee to the

Table 3 South African national qualification framework (NQF)

NQF level	NQF band	Qualification type		Learning routes to qualification
10	Higher education and training	Doctorate		Universities: Universities of Technology (formerly Technikons)
9		Master's degree		Universities: Universities of Technology
8		Post-graduate diploma Honours degree		Universities: Universities of Technology
7		Bachelor's degree Professional qualification		Universities: Universities of Technology
6		Diploma advanced certificate		Universities: Universities of Technology
5		Higher certificate		Universities: Public FET colleges: NGOs
4	Further education and training	Senior certificate Adult national senior Certificate Senior certificate (vocational)		Secondary schools
3		Occupationally directed qualifications		Secondary schools
2		Occupationally directed qualifications		Secondary schools
1	General education and training	Grades 7–9	ABET level 4	Primary and secondary schools
		Grades 4–6	ABET levels 2–3	Primary schools
		Grades 1–3	ABET level 1	Primary schools

maintenance and investment ploughed into ensuring that this training is successful. This training go beyond addressing short-term needs of participants but also tackling skills shortages of qualified Black ICT professionals especially in the ERP domain. An ERP system is an enterprise information system tool designed to integrate and optimise business processes and transactions in a corporation (Leon, 2014, p. 18).

SETA incentivises learners to partake in learning programme through the provision of stipends. Learners' participation increases the skills base for companies to choose from. Table 3 highlights the 10 levels in the South African National Qualification Framework (NQF). All qualifications in South Africa need to adhere to this framework.

The skills programme requires learners to have a minimum NQF level 4 qualification standard as presented in Table 3 above as each learner must have acquired the minimum competency of end-user computing, mathematical and communication skills. A review of the literature is undertaken in the next section to describe the model underpinning the study.

3 Theoretical Framing for Experiential Learning

A review of the literature is a synopsis of research undertaken on capacity building, empowerment, and different learning models. Capacity building builds independence especially for trained disadvantaged youth groups as they will be equipped with the necessary or relevant skills and experience. The drive for independence from government in areas like job provision is why a skills programme is important. While this explanation is satisfactory, it is not complete. Capacity building goes beyond skills development (Senge, 2014). Senge (2014) explains capacity building as, '*a means to improve efficiency of performance and productivity of either an individual or group*'. The individual or group in question will be brought up to a level of competence through skills development and knowledge acquisition to make informed decisions.

Capacity building should be targeted at the people or a group that have been disadvantaged, under-served or 'left behind' (Airhihenbuwa et al., 2011, p. 28); in this study they are Black South African youths. After building capacity, youths should be equipped with skills to work or create job. Although efficiency and productivity in SA are equated with creating opportunities, these are the primary objectives of a skills programme which is to create job opportunity for learners who undertake it.

The success of a skills programme should be conditional upon improving knowledge and changing people's behaviour and ways of thinking (Gackowski, 2003, p. 363) so that they can make informed decisions and choices. Behavioural change is not only a change in mind-set but adapting to new challenges as it occurs. It is also changing learner's way of thinking from total dependence on government to interdependence on networks and associations, thus quality education is important.

In-line with the United Nations Sustainable Development Goals (SDG) 4 (quality education) and 8 (decent work and economic growth), experiential learning through a skills programme has the potential to skill Black youths as education builds human capital which in turn promotes economic growth (Sachs et al., 2019, p. 806). Through the leave-no-one-behind principle, the SDG can be implemented with the aim at overcoming inequalities and discrimination by gender, race, social status or other qualifiers, which according to Sachs et al. (2019, p. 808) result from a range of factors including power dynamics, discrimination, poor system design and insufficient financing.

3.1 Experiential Learning (EL)

Experiential Learning (EL) is an action learning process and comes in various forms such as skills programmes, learnerships, apprenticeships, service learning, internships, job shadowing (Bindal & Goodyear, 2014, p. 528), work-based learning (WBL) (Cunningham & Dawes, 2016) and externships (Kuckes, 2014). Many of these forms of EL show overlap as they exhibit similar characteristics, this is to say that some of these forms are the same because they show the same characteristics, but are sometimes referred to by different names and implemented differently in different countries.

Rudman and Terblanche's (2012, p. 70) findings demonstrate that EL work experience (through vacation work) addresses skills and competencies of learners by enabling them to reflect on and apply their theoretical knowledge when applying this knowledge in a business scenario and vice versa. In addition, such skills and competencies are currently neither addressed in theoretical lectures, nor through other teaching aids. Sanahuja Vélez and Ribes Giner (2015, p. 128) in their study of internships in the travel and tourism industry concluded that well trained and supervised interns, especially those whose job performance skills match the needs of the agency are likely to stay employed at their respective agency or employer. Pool et al. (2016, p. 27) highlighted a research project that confirmed most workers' learning occurs at the workplace itself with formal learning contributing the most when it is both relevant and well-timed. Hannaway et al. (2018, p. 50) recommended a transition from theory to practice using a mentoring system. In addition, this system is better enhanced and optimised as the value of a mentor (or supervisor-teacher) focuses not only on developing appropriate competencies but should be implemented in accordance with the methods that are used by supervisors in their classroom practice.

Other examples of EL include job shadowing which is a work experience option where learners learn about a job by walking through the workday as a shadow to a competent worker. It is temporary unpaid work exposure to the workplace in an occupational area of interest to the learner (Bindal & Goodyear, 2014, p. 528). WBL is more focused on learning in the workplace, derived from work undertaken for or by an employer (i.e. in paid or unpaid work). It involves the attainment of competencies and knowledge in the workplace. An internship on the other hand is an opportunity to integrate career related experience into an undergraduate educational curriculum to enable learners to participate in planned, supervised work lasting 3–6 months. Learners learn the relevant skills and aptitudes that someone will need to progress during the early stages of their career (Sweitzer & King, 2013).

It is noteworthy that EL is not only learning in business practice and connecting to theory but include cognitive and practical learning (Ilonen & Heinonen, 2018, p. 399). In addition, it involves affective learning and learning for life where learners can transform their practical experience into business opportunity such as entrepreneurship. Affective learning relates to learner's interests, beliefs, motivations and attitudes and with the current job "blood-bath" in SA due to the coronavirus pandemic, affective learning can contribute to reducing unemployment through entrepreneurship (St-Jean & Audet, 2012, p. 133).

3.2 Transition in Experiential Learning

Skills and knowledge were acquired through apprenticeships in the old days of industrialisation. A learner or student was apprenticed to a tutor or teacher. There was no compulsory formal institution. Currently, apprenticeship is both formal and informal. The formal apprenticeship is undertaken at an academic institution where a learner is first introduced theoretically into a trade before the practical specialisation. The informal stage is like the traditional apprenticeship where a willing learner is introduced to a mentor to work with and learn from. Though the formal apprenticeship system involves classroom tasks, it does not guarantee skills' acquisition. Research conducted in the United Kingdom by Walker and Zhu (2013) attempted to draw a relationship between education and productivity and argued that it is not always the case that education affects people's productivity. This is possibly the case because there are mismatches that occur at academic institutes: some learners do not enrol in courses that include some form of vocational module that will build their skill capability.

Within the ERP domain, if an employer refuses a learner access to its system, the learner cannot benefit from the skills' training. Without an ERP system at the host employers' environment, learners cannot be beneficial to employers after completing training because the core knowledge and skill acquisition of any learning programme are embedded in its practical component.

Apprenticeships consist of paid work and on-the-job training. Most apprentices have a contract of employment with their sponsoring firm and work for the firm, so they learn while they work. Following an apprenticeship model of learning, students can learn through a process of observation and gradual participation (Akkerman & Bakker, 2012, p. 154).

In SA, EL is better suited as it is learning by experience or learning by doing (Kolb, 1984, p. 20). EL is necessary within the concept of empowerment in ICT sector. EL is better suited here because the act of performing an activity makes-up for the act of learning. Following the assertion that education does not always affects people's productivity, and particularly that Black youths were deprived of quality learning in the past due to unjust educational system, the act of doing as an experiential form will make-up for knowledge deprived or lost for SA youth.

The authors argue that Service Learning (SL) is a better option to apprenticeship where empowerment is concerned. SL is closely related to skills programme, only that it involves an academic institution (such as universities) and the community in which it operates. SL simply is a teaching method that facilitates the creation of a knowledge-based reciprocal relationship between the academic institute and its community (Calvert, 2011, p. 123). It is closely related to Cooperative Education (CE).

This is another form of EL involving university undergraduate students undertaking full-time paid and discipline-related employment as a structured part of their programme of study. CE programmes provide learning opportunities for students that enable them to integrate their work and their academic experiences (Eames & Coll, 2010, p. 181).

There is also the concept of 'learning by doing'. It gives learners access to expertise through applied knowledge and infrastructure that is normally unavailable through public training systems (Kolb, 2014). We can only learn so much in the class but this will not take us far considering the continually changing ICT challenges. While researchers accept and acknowledge the importance of theory in learning, they do not disagree with the evidence that experience incorporated into learning far exceeds just classroom learning. Rudman and Terblanche (2012, p. 70) undertook a study within South Africa aimed at determining university auditing students' perceptions of the benefits of and constraints imposed by work experience gained from vacation work during their tertiary education, and whether the practical application of theoretical knowledge in a real-life situation helps students to better understand, conceptualise and contextualise auditing. Their findings demonstrated that vacation work enables students to reflect on and apply their theoretical knowledge when applying this knowledge in a business scenario and vice versa. In addition, the authors concluded that 'it is evident that work experience, as an educational tool, adds value to auditing students during their tertiary education'. This is an evidence that an ideal learning process of skills development is one that integrates practical experience with other ways of acquiring theoretical knowledge.

3.3 Experiential Learning Models

Experiential Learning was proposed by Kolb (1984, p. 20) and adopted by other researchers such as Rogers and Freiberg (1994), who explained knowledge creation in the context of psychology translating into human behaviour. Rogers and Freiberg's (1994) study focused on the use of EL in capacity building and empowerment and relates to psychotherapy, a humanistic approach and psychology which is manifested in certain principles. These principles are as follows:

(a) Significant learning takes place when the subject matter is relevant to the learners' interests;
(b) Learning which is threatening to the learner (e.g. new attitudes or perspectives) is more easily assimilated when external threats are at a minimum;
(c) Learning proceeds faster when the threat to a learner is low;
(d) Self-initiated learning is the most lasting and pervasive.

Other EL learning models and cycles were developed by researchers such as Greenaway (1995) who proposed a 3-stage learning cycle better applicable to management or staff training within a business. The three stages are Do, Review and Plan (DRP). The first stage is Do, which is to go forth and have an experience. Review reviews what happened and what can be learned, and Plan plans a way to tackle the next round of experience. James (1980) and Bacon (1987) proposed a 1-stage model where experience alone is supposed to be sufficient for learning while Neill (2002) proposed a 2-stage model that shifts from experience to reflection. Juch (1983) proposed a 4-stage learning cycle as well as a 5-stage model proposed by

Joplin (1981), Kelly (1955), and Pfeiffer and Jones (1975). A 6-stage EL proposed by Priest (1990) and Priest and Gass (1997) consists of six stages of experience-induce-generalise-deduce-apply-evaluate.

The Kolb (1984, p. 21) EL learning cycle (model) is the more appropriate cycle as it allows for a step-by-step learning process for a learner with an aim to build capacity. It is applied to this study. The methodology section below describes the way data were collected and analysed. This section is relevant to ascertain the quality of data collected and how relevant the data is to this study.

4 Methodology

This study attempted to answer the research questions addressed and was based on a qualitative research design that used a descriptive case study approach. According to Yin (2012) a case study focuses on a single object or subject and in this study, it is a South African skills programme. A case study is appropriate for this study because it allowed for the exploration and understanding of complex issues of society-based problems such as unemployment. The skills programme was developed for a real-life setting to ascertain its impact on learners and the organisation in which it was implemented.

The data sources used relating to the case study were secondary data and consisted of documents and archival records obtained from the SETA and SAQA websites. Of the ten accredited ERP specialised unit standards, purposeful sampling was used to select five unit standards appropriate for the skills programme. Purposive sampling was chosen based on the objectives of this study which are to explain the structure of an ERP skills programme to promote experiential learning and to understand how the skills programme can build capacity and employability for Black youths. Though purposive sampling is a non-probability sampling technique (Mukono & Tokosi, 2019, p. 3) of participants as espoused by Leedy and Ormrod (2014), the goal of its application is to understand a specific phenomenon (experiential learning) and not to represent a population by selecting information-rich cases for research. Purposive techniques were adopted to source only relevant unit standard documents related to the development of the skills programme. Participants were not recruited as the study objectives relate to the development of an ERP skills programme and not the assessment of participants' learning outcomes.

Purposive sampling enabled the selection of all documents and archival records most likely to provide data required for meaningful understanding of the phenomena (skills programme) under study (Poulis, Poulis, & Plakoyiannaki, 2013, p. 304).

4.1 Research Questions

The research questions that guided the scope of the study were as follows:

1. How can a skills programme for ERP be structured to promote experiential learning?
2. How can the skills programme build capacity and employability for Black youths?

5 Analysis

The analysis section showcased how meaning was derived from the data collected and its output presented. The unit standards chosen to develop the skills programme are presented as well as the application of the chosen Kolb's learning model to the study.

5.1 Skills Programme Requirements

Each unit standard was at NQF level 5 except one, but all were aimed at building theoretical knowledge upon the next unit standard as the learner progresses in the learning process. Each unit standard has an expiry date after which it is re-assessed and re-registered or phased out depending on its relevance to the industry. Unit standards are designed by SAQA in collaboration with industry experts and subject experts from a relevant industry and or SETA. NQF level 5 requirements meant that learners must have been adequately equipped with communications, computer and mathematical literacy skills at minimum NQF levels of 3 or 4. A total of five unit standards equaling 41 credits were used in developing the skills programme. All unit standards are part of an existing registered SAQA qualification. A description of each unit standard is provided in the next sections and arranged according to the sequence in the skills' learning process.

5.2 Unit Standards, Learner's Competencies, Knowledge and Outcomes

The five unit standards were purposed with empowering a learner with theoretical understanding of ERP concepts. Further information is provided in Table 4 on each unit standard. An understanding of unit standard 117711 (ICT concept called ERP) is important as this system is complex, thus learners understanding of its integrative approach will allow for a conceptualisation of how each integrative system unit not

Table 4 Unit standards, leaner's competences, knowledge and outcomes

Unit standards	Learners competences	Learners knowledge	Outcomes
Understand the overall concept of an ERP solution SAQA ID 117711	End-user computing NQF 3 Mathematical literacy NQF 3 Communication skills NQF 3	– Understanding of the connection between business enabling systems and the processes they support – Gain an awareness of the way ERP systems can add value in a business environment – Comprehensive technical expertise in ERP systems – Create an awareness of some aspect of the business functionality, be it through direct experience or observation	– Explain how an ERP solution integrates various system-wide business processes – Evolution of a current ERP solution – Understand the overall architecture of an ERP system – Explain the concept of configuring and customising an ERP system
Identify and explain the ERP market, partners and competitors SAQA ID 119178	Communication skills NQF 4 Mathematical literacy NQF 4	– ERP partners, competitors and clients – Identify role players to include but not limited to pre-sales, consulting, training, developers and implementation	– Identify the ERP market – Identify the key players within a specific ERP market – Describe the role of the key players within a specific ERP market
Prepare for and contribute to enterprise resource planning SAQA ID 119181	Communication skills NQF 4 Mathematical literacy NQF 4	– Effective business processes evaluation that Includes but not limited to specific, measurable, value adding, controls and realistic measures.	– Preparing for a business process definition workshop – Facilitating a process definition workshop – Advising on business process fundamentals – Documenting the client's business process

(continued)

Table 4 (continued)

Unit standards	Learners competences	Learners knowledge	Outcomes
Assist in the configuration of an ERP module SAQA ID 115411	Communication skills NQF 3 Computer literacy NQF 3	Not explicit	– Demonstrating an understanding of the fundamental techniques of configuring an ERP module – Assisting in configuring an ERP module according to the identified business requirements – Demonstrating an awareness of the integration points between the relevant ERP modules – Carrying out procedures to test and verify the accuracy of the module configuration
Configure and customise the transactions to business requirements within an ERP system SAQA ID 119087	Communication skills NQF 4 Mathematical literacy NQF 4	Not readily available	– Explaining the detailed design requirements within a business process according to client's needs – Configuring or developing the enterprise resource planning system according to detailed design requirements – Carrying out procedures to test and verity the accuracy of the configuration

Source: South African Qualification Authority [SAQA], 2020. [Online]: http://regqs.saqa.org.za/search.php?cat=unit only functions efficiently and effectively within, but also how the system activities and user decisions affect the functions of other units (Nwankpa & Roumani, 2014, p. 224).

The unit standard 119178 is an understanding of ICT commercial products and ERP software that is offered by a range of vendors that specialise in this software market segment. According to Jacobson et al. (2007, p. 2), the main ERP vendors are SAP SE (Germany), Oracle (USA), Sage (UK), Microsoft (USA), Unit 4 (Netherlands) and SYSPRO (South Africa) (Fortune Business Insights, 2019). ERP systems are highly configurable to accommodate the diverse needs of users across most sectors of the economy and are therefore usually offered in three different forms: generic, pre-configured and installed.

The unit standard 119181 empowers learners with capabilities of how to organise and prepare an ERP workshop for either in-house training or client training. An understanding of ERP will facilitate a successful workshop and training will contribute to both employer and client business.

Where a learner's ICT competence is below par, unit standard 115411 is designed to be practical and to enable learners to contribute to ERP configuration. Configuration is complex and advanced but with the assistance of a mentor, learners can participate in the configuration process, since configuration can constrain a business process (Lubis, Lubis, & Muda, 2016).

The unit standard 119087 is also practical in nature and allows for learners to develop and enhance their acquired manipulation skills got from their prior course. ERP customisation can be thought of in terms of systems development and organisational decision-making (Koch & Mitteregger, 2016, p. 103) and so requires advanced conceptualisation and analysis; thus, empowering learner's competence through capacity building.

An integrated EL process is depicted in Fig. 1 (Hawk & Shah, 2007, p. 4). The use of EL is proposed in this research in order to establish capacity building skills and empowerment through skills and knowledge acquisition through the skills programme and its impact in helping youths gain employment. In understanding the integrated EL framework to this study, an application of the Kolb's EL model is explained in the next section.

5.3 Applying Kolb's 4-Stage Experiential Learning Model

South African companies are reluctant to employ youths with no form of expertise as work experience can only be obtained through an opportunity to work. Kolb's 4-stage EL model was considered appropriate for this study because it takes a learner through a step-by-step process of becoming skilled and competent.

On the other hand, the ERP skills programme developed and proposed is outcome-based and aimed at developing learners to reach an appropriate level of competence. Competence means that learners can translate theory learnt in the classroom into problem-solving solutions when exposed in the workplace. The

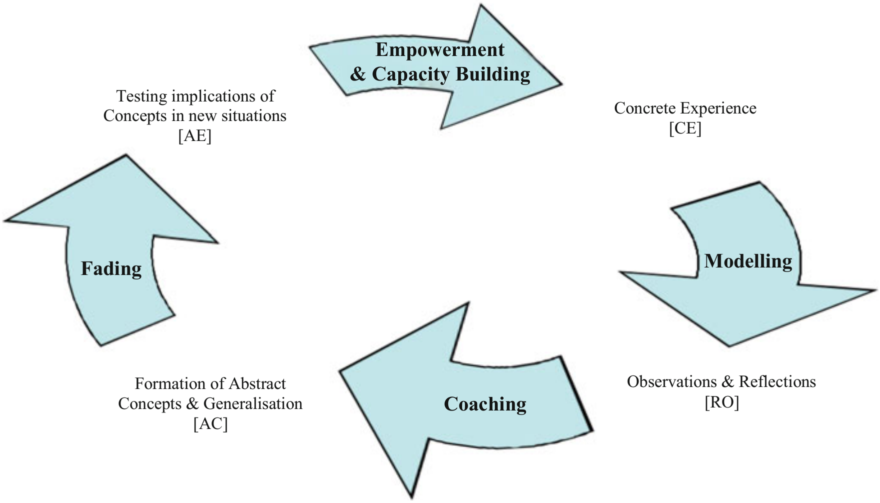

Fig. 1 An integrated EL framework. Source: Kolb (1984, p. 21) and Billet (1994)

method of instruction is adapted from Billet's (1994) study involving modelling, coaching and fading. Combining Kolb's 4-stage EL and Billet's instruction method produced an integrated EL model to achieve the skills programme objective of learner capacity and empowerment.

In the proposed model/framework, actual learning starts at the CE stage and develops learners using a modelling technique. Modelling is where an expert (ERP professional) at a firm executes a task so that learners can observe and build a conceptual model of the processes required in accomplishing that task successfully. In the ERP arena, there is a need to practically show learners how tasks are carried out. Unit standards 117711, 119178 and 119181 are important for this stage as they are theoretical in nature and can be conducted in a class setting. This forms the 30% classwork for the learners where theory is paramount. Key understanding of concepts, definitions, history of ERP and its environment are all taught here. This is necessary to broaden the learners' thinking. These concepts are important to initiate the learner into the practice phase, the RO.

Coaching is where learners perform the task at hand at the RO stage as the expert observes and monitors their activities. ICT requires hands-on work to understand and master. This approach develops the learners much quicker as they gradually begin to understand the concepts of the task. Repeated tasks, instructions and comments build confidence in the learners and act as a support tool towards their understanding. While the experts perform the task at experimental stages of the practice work, learners observe and learn. When learners are initiated into performing these tasks, experts observe and monitor their progress. Within the skills programme phase, unit standards 4 and 5 are necessary. These unit standards are practicably designed requiring physical manipulation of an ERP system, be it a dummy or live system. The coaching is necessary to guide learners towards building confidence in themselves as well as learning from mistakes made. Experts undergo a state of reflection after each task through assessments and feedback. Learners also undergo reflections through self-evaluation and outcomes.

While the RO stage is more extensive and time-consuming because of its practical nature, the AC adapts learners to techniques of information gathering through fading. Fading is where expert's support to learners is gradually removed to enable learners to conduct their task independently. Unit standards 115411 and 119087 will be continuously used as support and referral aids for learners. Distant support is still provided to learners by way of advice and hands-on work in areas that are complex and requires complex manipulation to be done. Empowerment starts here as learners gradually take part in the decision-making process resulting in capacity building. Actual empowerment starts here as learners can develop additional methods of solving problems as well as mentor others. Capacity building takes place afterwards as learner's skills are developed through strategic thinking as they seize to be called learners. AC is a state of independence. At this stage, fading enhances knowledge creation, as well as skills development. Learners are not coached further, but rather monitored and supervised. Actual performance appraisal and evaluation take place here as tasks are not simulated any more, they are real tasks requiring real solutions. At this stage, it is appropriate to say that empowerment takes place because outcomes can now be measured.

Skills acquired at the fading process empowers learners to become consultants who advice clients, test systems during and after project completion as well as train other learners. While entering the AE phase, learners are not learning theory and concepts but deciding through participation. Although the AE stage is supposed to be part of the entire learning process, it may not be part of the skills programme depending on the firm or service provider conducting learner training. At AE, skills and knowledge acquired through this spiral of learning are translated into full empowerment and capacity. Learners can be known as consultants and can initiate projects, become supervisors and team leaders as well as project coordinators. This is where every firm would want learners to be at the stage where they are fully independent of experts but still interdependent on teams.

The central research questions guiding the study are now addressed below.

5.4 How Can a Skills Programme Be Structured to Promote Experiential Learning?

The programme must include a combination of both theoretical classroom tasks (30%) and practical tasks (70%). The theoretical outcomes involve understanding ERP concepts, markets, partners, costs and features of the ERP system. The skills programme should be conducted at a training facility where training facilitators and coaches must be provided to guide and mentor each learner. Training materials should conform to unit standards so as to meet the skills programme objective of EL acquisition. The skills programme structure should incorporate projects, assignments and case studies embedded in it especially into unit standards 117711, 119178 and 119181, which are all purely theoretical. These are the fundamental building blocks of an ERP consultant, that is, the ability to have a conceptual knowledge of ERP systems and its processes.

5.5 How Can the Skills Programme Build Capacity and Employability for Black Youths?

The skills programme can build capacity and employability based on the success of the level of skills a learner acquires and a subsequent employment thereof. Success is relative in meaning as the employment of a learner today may not necessary translate into success for the employing firm, but it is accepted in this study as a success. Another measuring scale will be the length of sustained employment after completion of the skills programme. The impact of this skills programme on unemployment in SA is anticipated to be significant especially among Black youths considering the high demand for Black (EE/AA) ERP professionals in the areas of SAP, Sage and Oracle domains.

The outcome of a random job search on the websites of PNET (PNET, 2013, 2019) and CareerJunction (CareerJunction, 2013, 2019) which are the two most popular job sites in SA is shown below (Table 5). First search was undertaken in 2013 and a recent search was undertaken in February 2019. Results for PNET, 2019 were based on new advertised jobs. Some jobs were re-advertised, notwithstanding, ERP skills demand is high.

With this demand, capacity and other opportunities can be created using an ERP skills programme framework by way of self-employment as independent contractors, or private consultants. This improves and increases a pool of human resources, which is beneficial to potential employers and clients.

Table 5 January–May (2013 and 2019) job search for ERP jobs

ERP domains	PNET (2013)	PNET (2019)	CareerJunction (2013)	CareerJunction (2019)
SAP	184	155	14	498
Sage ACCPAC	14	66	0	3
Oracle	93	45	6	231
Microsoft dynamics	10	666	3	45

6 Discussion

A skills programme is a short- to medium-term effective solution for any organisation seeking skilled individuals, while it is employment, empowerment and capacity building for learners. Short and medium-term effectiveness means it will address skills needs for organisations and for learners who enter the labour market as they can be employable because of their acquired skill. Firms will benefit from a skills programme largely because of immediate labour availability and government subsidy via the skills development fund. It is a three-month learning process; though formal qualifications are not issued after completion, it should be encouraged as a first step in bringing SA Black youths to a level that was formally difficult for them owing to their historical past.

The study makes it clear that work experience allows learners to better contextualise and apply their theoretical knowledge in real life or work place setting (Rudman & Terblanche, 2012, p. 70); it allows learners to gain much needed practical experience. Implementation of what Bloom (2010, p. 90) calls "second chance" programmes such as experiential learning programmes should be carefully designed. In the beginning, proper eligibility criteria (Abramovsky, Battistin, Fitzsimons, Goodman, & Simpson, 2011, p. 177) should be used to select learners and to test their baseline competencies. The latter will allow one to evaluate the effectiveness of such programmes or in other words whether the learning programme raised the training levels of the learners. The matching of employer and learner is therefore very important. The authors concur with Bloom (2010, p. 105) that paid work through learnerships as an example and EL programmes act as a tool to engage youth in training (the "carrot") and in the long term it also assists in building capacity for long-term labour needs.

Since the Service SETA in South Africa does not have an existing ERP skill or learnership programme, this makes the development and skills programme accreditation costly, lengthy and time-exhausting. Measuring success using prior data on a learner's participation in any ERP programme is not possible. However, lessons from other disciplines and countries highlight the success of EL (see McLeod, 2013). This is a reason why the ERP skills programme framework was developed to be simplistic and adjustable to meet challenging ICT issues. A skills programme should be implemented at other SETA's that do not currently have it. Service SETA is one of the very few SETAs that has and implements a skills programme.

7 Limitations

In developing the skills programme, the time-line was lengthy, cumbersome and costly because of the processes required in the accreditation process as set-out by Service SETA. All ERP unit standards used in this study were more than 5 years old thus lacking currency as they were designed by SAQA and are still not been updated. This may affect the relevance of the inclusion of some unit standards in this study. No available study of this nature in SA can be found to make comparisons and learn lessons from. It is important to note that with the advent of COVID19 and its consequence on employment, there is a possibility of an overhaul of SA educational curriculum which may reduce EL practices because of fewer employers.

8 Future Research

Avenues for future research could include a quantitative study aimed at evaluating the skills programme framework implementation and its actual impact on a broader scale on both the learners gaining employment and firms employing learners. It is important to undertake a longitudinal study to first track the sustainability of an ERP skills programme within an industry: and secondly to track learner employability. There is an opportunity to undertake an academic study to improve on existing EL models and implementations.

Abbreviations

AC	Abstract concepts and generalisation
AE	Testing implications of concepts in new situation
CE	Concrete experience
EL	Experiential learning
ERP	Enterprise resource planning
ICT	Information and communication technology
IT	Information technology
NQF	National qualification framework
RO	Reflections and observations
SA	South Africa
SAQA	South African qualification authority
SDG	Sustainable development goals
SETA	Sector education and training authority
SL	Service learning
WBL	Work-based learning

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Part III
Resilience in Smart Communities

Identifying Stakeholder Value in Smart City Implementation in Nelson Mandela Bay Municipality

Ifeoluwapo Fashoro, Brenda Scholtz, and Anthea van der Hoogen

1 Introduction

Cities are centres for cultural and economic development, contributing to about 80% of the world's Gross Domestic Product (Estevez et al., 2016; Meijer & Bolívar, 2016); they are said to be a positive force for economic growth, human development, and poverty reduction (United Nations Department of Economic and Social Affairs, 2018b). Currently, more people live in cities than in rural areas around the world and there is an increase in urban migration from rural areas. This phenomenon of urbanisation began in the 1950s and has since grown at a rapid pace. The world's urban population is expected to grow by 63% between 2014 and 2050 (United Nations Department of Economic and Social Affairs, 2018b). As at 2018, 55% of the world's population lived in cities and this number is expected to increase to 68% by 2050 (United Nations Department of Economic and Social Affairs, 2018a). This population growth has led to increasing demands for energy, water, sanitation, housing, and other public services causing a strain on existing infrastructure. Cities consume 67% of global energy and are responsible for 70% of global greenhouse gas emissions (Estevez et al., 2016; Khatoun & Zeadally, 2016). These issues challenge the sustainability of cities and have led city managers to seek out solutions that will enable them to cater for current demands on public infrastructure as well as prepare for the future of their cities. Governments, researchers, and industry regard Information Communication Technology (ICT) as an enabler and catalyst to providing solutions to these challenges. ICTs are particularly prominent in the functioning of smart cities; enabling cities to address existing challenges through

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solutions like smart energy, smart buildings, smart transport, and smart healthcare (Estevez et al., 2016).

Smart cities have emerged as a response to the growing challenges and opportunities created by this urbanisation (Estevez et al., 2016). Smart cities are described as resilient cities that are able to adapt to the challenges of a changing world while continuing to function (Naden, 2019). Resilience is an important quality for a city in a world filled with unexpected shocks and disruptions such as terrorist attacks, adverse weather effects, health pandemics, and cyber-attacks (Naden, 2019). Smart cities and technologies enable cities to respond with speed during crises. In times of crises, cities are now reliant on social media to inform citizens due to the increased adoption of mobile technologies and social media (Remes & Woetzel, 2019). The role of social media in city governance has been made more imperative due to the COVID-19 crisis (United Nations, 2020). Smart technologies such as Internet of Things (IoTs) sensors help cities synchronise traffic to help first responders optimise their response time by as much as 35% during crises (Remes & Woetzel, 2019). Monitoring and analysing data from people's daily interactions enable cities to discover ways in which they can address the many challenges experienced. Big data can provide solutions that are flexible and responsive through early warnings, real-time awareness and real-time feedback (United Nations, n.d.).

As seen in the examples in the previous paragraph, technology is essential to smart cities. Technologies enable cities to transform into smart cities by augmenting basic city infrastructure with advanced technologies (Estevez et al., 2016). ICTs like mobile technologies, IoTs, big data, ubiquitous sensor networks, cloud services, and social media are commonly used in cities to achieve "smartness". ICTs help smart cities deliver public value, enhance the quality of life of citizens, improve the interconnection of people, systems, and processes, enable the integration of information, promote citizen participation and social inclusion, and improve the decision-making process (Estevez et al., 2016; Meijer & Bolívar, 2016). ICTs should be employed in collecting and managing information, aggregating and analysing data, and advancing analysis to optimise systems and processes in the city (Estevez et al., 2016).

While there is a tendency to focus on the technological aspects of smart cities, technology should be in the background, seamlessly improving day-to-day experiences of the humans (Hubert, 2017). This means that the focus of smart cities should go beyond implementing new technologies and processes to actualising non-tangible benefits for smart city stakeholders such as liveability, sustainability, and knowledge. These benefits can also be viewed as the resulting values experienced by the stakeholders in a smart city initiative and each have their own set of value expectations. These values help to legitimise smart city initiatives and serve as a way of measuring the success of these initiatives when properly defined (Dameri, 2017; Meijer & Bolívar, 2016). Values are vital in every smart city initiative.

Smart cities are focused on producing quick solutions to urban problems (Schmitt, 2020). The United Nations has identified sustainable cities or smart cities as a major tool for achieving the Sustainable Development Goals (SDGs), in particular Goal 11, which is focused on making cities and human settlements inclusive, safe, resilient, and sustainable (Estevez et al., 2016). These SDGs were established as a mechanism for addressing global urban challenges that transcended the capabilities of local and national governments and require the joint effort of global communities. The SDGs, formally known as the 2030 Agenda for Sustainable Development, are a call to action for all United Nations member countries to achieve a better more sustainable future. The SDGs focus on people, planet, and prosperity; comprising the three pillars of sustainability: social, environmental, and economic. There are 17 SDGs with 169 targets that address sustainability challenges in areas such as health, gender equality, poverty, energy, climate change, and energy (United Nations, 2015). Table 1 lists the 17 SDGs for ease of reference.

Smart cities have grown in popularity in the last decade with the earliest reference being in 1999 (Meijer & Bolívar, 2016). The popularity of the smart city concept has led to a plethora of definitions, research projects, and initiatives, all of which vary according to goals, actors, target groups, and people's perspectives with contradictions existing between academia and industry (Dameri & Rosenthal-Sabroux, 2014; Schmitt, 2020). Smart city research fits within three perspectives: human, technology, and governance (Cocchia, 2014; Meijer & Bolívar, 2016).

Table 1 Sustainable Development Goals

SDG1. End poverty in all its forms everywhere
SDG2. End hunger, achieve food security and improved nutrition, and promote sustainable agriculture
SDG3. Ensure healthy lives and promote Well-being for all at all ages
SDG4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
SDG5. Achieve gender equality and empower all women and girls
SDG6. Ensure availability and sustainable management of water and sanitation for all
SDG7. Ensure access to affordable, reliable, sustainable, and modern energy for all
SDG8. Promote sustained, inclusive and sustainable economic growth, full and productive employment, and decent work for all
SDG9. Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation
SDG10. Reduce inequality within and among countries
SDG11. Make cities and human settlements inclusive, safe, resilient, and sustainable
SDG12. Ensure sustainable consumption and production patterns
SDG13. Take urgent action to combat climate change and its impacts
SDG14. Conserve and sustainably use the oceans, seas, and marine resources for sustainable development
SDG15. Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
SDG16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
SDG17. Strengthen the means of implementation and revitalise the global partnership for sustainable development

Smart city research and initiatives are predominantly conducted in developed countries. Estevez et al. (2016) report that 92% of smart city policy work, 88% of smart city research publications and 87% of leading smart city research are from developed countries. This points to a dearth of research from developing nations even though smart cities have been recognised as having great potential to improve circumstances of developing countries (Estevez et al., 2016; Joia & Kuhl, 2019). Smart city research is especially essential in developing countries because recent urbanisation data shows that 90% of the expected growth in urban population will come from these countries (Joia & Kuhl, 2019; United Nations Department of Economic and Social Affairs, 2018a). In Africa, the population in cities is expected to increase from 40% in 2014 to 56% by 2050 (Estevez et al., 2016). The continent is also predicted to have the largest increase in city population.

The aim of this study is to investigate and evaluate the smart city activities in Nelson Mandela Bay Municipality (NMBM) in South Africa to identify the values stakeholders accrue from these activities and highlight best practices for similar cities. This study seeks to contribute to and advance smart city research in the context of developing countries by presenting empirical evidence on smart city activities in NMBM to create a sustainable and resilient city. The study will focus on categorising elements of the smart city activities, highlighting value provided to the different stakeholders involved and will align NMBM's smart city activities with the SDGs and assess the achievements of the municipality in achieving these goals. For this reason, this study is an interpretive study based on a single case study. The research strategies employed in the study were data collection from existing literature related to the topic, an Internet-based search and an interview with NMBM's smart city custodian and promoter.

The book chapter is structured as follows: Section 2 discusses the main concepts related to smart cities by presenting a review of relevant literature. Section 3 presents empirical evidence on NMBM's smart city activities focusing on smart city dimensions and value derived from these activities. Section 4 discusses concluding thoughts and further research opportunities.

2 Smart Cities

The smart city concept, although popular in academia and industry, is polarising in terms of definition, approach, and central concepts. Several studies have addressed the diversity of smart city definitions and presented several of these definitions (Alawadhi et al., 2012; Albino et al., 2015; Allwinkle & Cruickshank, 2011; Cocchia, 2014; Meijer & Bolívar, 2016). The disparities seem to be based on the focus of the smart city initiative; these are usually technology, human or governance/institution (Cocchia, 2014; Meijer & Bolívar, 2016). Studies relating to the technology focus perceive smart cities as cities that use technology especially ICTs to transform and improve life within the city and address urban challenges. The human focus sees people as the factor that makes cities smart and emphasises education, learning, and knowledge (Cocchia, 2014; Meijer & Bolívar, 2016). The governance/institution focus is related to the interactions between smart city stakeholders, and policies that support collaboration of stakeholders.

The smart city definition adopted in this chapter was developed by the International Telecommunication Union (ITU) after analysing 116 definitions of smart cities. The ITU defines smart cities as “an innovative city that uses ICTs and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects” (International Telecommunication Union, 2015). This definition highlights a key objective of smart cities, which is the life of the citizens (Khatoun & Zeadally, 2016; Schmitt, 2020). It also addresses the importance of ICTs in the implementation of smart cities which is one of the uniting premises in the smart city conversation (Alawadhi et al., 2012; Dameri, 2017; Khatoun & Zeadally, 2016). Another focus point of this definition is the value, aim or benefits of the smart city which is also an important topic relating to smart cities (Dameri, 2017).

Smart city value describes the expectations and benefits accrued by citizens and other stakeholders from smart city initiatives. Estevez et al. (2016) describe this as “what needs are important” to these stakeholders. According to Bris (2019) when discussing smart cities and technology, “smart cities only make sense when technology meets citizens’ needs”. Smart city value is predominantly discussed in terms of “public value” which refers to value that the government/public sector aspires to and value added to citizens (OECD, 2019). Dameri and Rosenthal-Sabroux (2014) assert that the creation of public value should be the final goal of smart cities. Meijer and Bolívar (2016) describe these values in terms of “outcomes” of the smart city initiative. Various categories and examples of value are provided by different authors; these categories include social, economic, governance, environment, human capital, and infrastructure (Dameri & Rosenthal-Sabroux, 2014; Estevez et al., 2016; Meijer & Bolívar, 2016). There is a consensus that stakeholder participation is necessary to gain smart city value. If smart city initiatives are going to be beneficial to stakeholders, then stakeholders need to be involved in planning and executing these initiatives. Smart city values should be aligned with stakeholders’ needs (Bolívar, 2017).

Two approaches to the planning and implementation of smart cities have been identified: the top-down and the bottom-up approaches. The top-down approach is driven by the government and is focused on technology as the catalyst for smart city implementation. The government provides the strategy, incentives, and funding for the smart city initiative and also provides publicity to ensure adoption (Estevez et al., 2016). In the top-down approach, governments set up foundations for supporting smart city initiatives such as technology infrastructure in the city. The bottom-up approach has emerged as smart cities evolved. This approach is collaborative, involves multiple stakeholders (research institutions, citizens, and the private sector) and is focused on citizen engagement. The strategy is driven by citizens and enterprises and the government plays the role of facilitator and mediator (Estevez et al., 2016). Initiatives that are executed using the bottom-up approach would presumably be more aligned to stakeholder needs since these initiatives are initiated by stakeholders. Some of these initiatives might exist independent of each other with stakeholders implementing a solution to an identified problem using public infrastructure. Initiatives executed by different stakeholders in the city may result in a lack of synergy in achieving the city's smart city goals. There also may be a lack of evidence of these goals even when they are achieved, which may result in a failure to communicate the "smartness" of the city to citizens (Dameri, 2017). The next section elaborates on smart city initiatives with reference to smart city dimensions.

2.1 Smart City Dimensions

Smart cities are heterogeneous in initiative implementation with each city focusing on aspects that are relevant to their specific city challenges. The diversity in initiatives could be attributed to economic constraints, the difference in city characteristics and the different needs and expectations of citizens in each city (Dameri, 2017). However, these different initiatives can be classified into one of the nine dimensions of smart cities that represent the facet of the city that the initiative affects (Monzon, 2015). The first six dimensions are the most widely accepted categorisation of smart city initiatives and were proposed by Giffinger et al. (2007). These dimensions are smart mobility, smart environment, smart people, smart living, smart governance, and smart economy. Van Der Hoogen et al. (2019) extended these dimensions to add smart technology, smart policy, and smart organisation. Figure 1 shows the resulting nine dimensions of smart cities.

Smart mobility is related to international and local accessibility to sustainable, innovative, and safe transport systems (Giffinger et al., 2007). Smart environment focuses on environmental protection, attractive natural conditions such as green spaces, pollution, and resource management (Giffinger et al., 2007). Smart people relates to the level of qualification and education of citizens and extends to the quality of social interactions, creativity, social and ethnic plurality, and open-mindedness (Albino et al., 2015; Giffinger et al., 2007). This dimension is essential in smart cities and is sometimes acknowledged as being central to the smart city concept (Albino et al., 2015; Meijer & Bolívar, 2016). Smart living is related to the quality of life in the city and includes factors such as culture, tourism, health, and housing (Giffinger et al., 2007). Smart governance is associated with political participation, transparent governance, and public administration (Giffinger et al., 2007). It ensures various stakeholders are involved in decision-making and public services (Albino et al., 2015). Smart economy focuses on economic competitiveness and is associated with innovation, entrepreneurship, productivity, and integration with national and international markets (Giffinger et al., 2007). Smart policy relates to the relationship between the smart city initiative and the city's policies (Van Der Hoogen & Scholtz, 2019). It also involves the innovative policies that address smart city challenges. Smart organisation includes organisational culture,

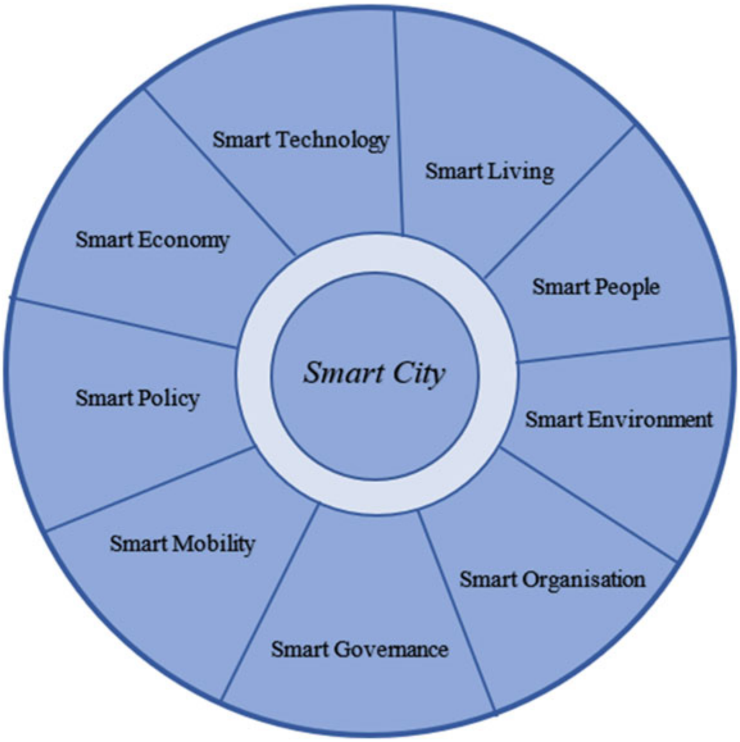

Fig. 1 Smart City Dimensions (Based on Van Der Hoogen and Scholtz (2019))

innovative leadership and management which are necessary for successful smart city implementation (Van Der Hoogen & Scholtz, 2019). The final dimension, smart technology focuses on the ICT infrastructure available, and the technologies used in the city. It also involves the use of data in a smart way.

2.2 Smart Cities in Africa

African cities are characterised by poor governance and administration, insufficient infrastructure, and poor urban planning with issues such as poor sewage systems, missing networks of water and electricity, and poor drainage leading to flooding (Mboup & Oyelaran-Oyeyinka, 2019). According to Mboup and Oyelaran-Oyeyinka (2019), urbanisation in Africa is largely caused by the migration of people from rural areas to cities, which has consequently led to the growth of slums and increase in poverty because these migrants are poor and unskilled. These challenges are multifaceted and require solutions that go beyond implementing ICTs, which have been the automatic response in Africa to social challenges.

ICT implementations need to be integrated with other factors such as economic and social development, legal policies, and environmental sustainability (Mboup & Oyelaran-Oyeyinka, 2019). Smart cities are recognised as a solution to these challenges because they are holistic, addressing city challenges from different perspectives such as policy, infrastructure, technology, and human capital.

Smart cities exist in two forms; Estevez et al. (2016) explain these as the two approaches to establishing smart cities. Firstly, the regeneration of old cities to reframe themselves as smart. Secondly, the establishment of new cities that brand themselves as smart from the get-go. There has been an increase in the number of smart city initiatives in Africa; however, more research focus is placed on the latter of the two forms of smart cities. These initiatives are initiated by governments and various industry sectors and do not involve citizens who are the intended inhabitants of these cities (Estevez et al., 2016).

A school of thought promotes the establishment of brand new cities as a way of meeting Africa's rapid urbanisation (Haas, 2019). One reason for this thinking is the estimation that restructuring existing cities will cost three times more than building a new city due to poor designs of existing cities (Haas, 2019). Another reasoning is that dissociating these cities from existing cities will protect them from societal problems like crime and that the cities do not inherit the complex infrastructure issues (Boykova et al., 2016; Reboredo & Brill, 2019). According to Boykova et al. (2016), these cities employ the top-down approach, are technology-focused, and have the advantage of being comprehensively smart from the start. Up to 18 different new smart city initiatives currently exist around Africa (Kazeem, 2018). These initiatives are idealistic in nature and in several cases cater to the wealthiest of citizens (Reboredo & Brill, 2019). The human aspects of cities are largely ignored, and citizens are not consulted on these initiatives, which has led to the criticism and slow uptake of these smart city initiatives, raising fears that these initiatives will be abandoned and the cities left as ghost towns (Haas, 2019; Reboredo & Brill, 2019). Potential failures of these initiatives cannot be ignored not only because they lead to an increase of financial debt for the continent but also because Africa's urban population is growing at an exponential rate and smart cities are a way of meeting the ever increasing demands on existing city infrastructure and planning for the future (Estevez et al., 2016; Haas, 2019).

Smart cities that are created by regenerating old cities are ideally suited to cities with substantial historical and cultural backgrounds such as in Europe and North America (Boykova et al., 2016). Older cities face problems arising from their existing infrastructure, which require a major overhaul to be adapted to smart cities. These cities are typically redesigned using the bottom-up approach because the interests of a diversity of actors need to be considered (Boykova et al., 2016). This is advantageous to the development of the city because public and private sector stakeholders as well as citizens are engaged in these initiatives leading to better outcomes. According to Boykova et al. (2016), these cities established from older cities are difficult to transform completely into smart cities; only certain aspects (dimensions) can be implemented. In Africa, the agenda of establishing new cities are being pushed by government, but the consequence in terms of funding is that budgets are diverted from existing cities and transferred to these new cities (Haas, 2019). However, if the older cities are transformed economic returns from these initiatives remains in the city and will help address the city's problems (Boykova et al., 2016). The next section contextualises this chapter by focusing on smart city endeavours in South Africa and especially the NMBM.

3 The South African Context: With the Focus on NMBM

South Africa has a history of apartheid that has led to lopsided spatial planning in its cities with huge disparities in wealth and living standards (SALGA, 2015). During this period, parts of the population were prohibited from living in affluent areas of the city and instead forced to live in under-developed "townships" that had no planning or infrastructure and were far from work and economic opportunities (Reboredo & Brill, 2019). These apartheid-era infrastructures are still in existence and challenge the provision of solutions that are applicable to all citizens. Part of the challenge in implementing solutions is fixing these discrepancies in infrastructure and, at the same time, taking the nation forward. Smart city solutions are considered to be a way of undoing inequalities and creating a balance in South African cities (SALGA, 2015). Smart cities are acclaimed to be fixes to the "dumb" designs of the previous century that did not take into account scalability of cities, and a preparation for challenges of the future (Khatoun & Zeadally, 2016; Schmitt, 2020).

3.1 Overview of the Nelson Mandela Bay Municipality (NMBM) Smart City

NMBM is no exception to the inequality in living standards experienced in South Africa. The municipality is located in the Eastern Cape of South Africa and incorporates the three cities of Port Elizabeth, Despatch, and Uitenhage. It has a population of 1.23 million people and approximately 27.12% of households in the municipality live in poverty. The city serves as an economic hub for the Eastern Cape region of the country.

The municipality has been recognised and listed as a smart city as early as 2011 (Nam & Pardo, 2011). The city is making crucial efforts through diverse activities to become smarter and innovative, with the help of a variety of stakeholders. The city embarked on its smart city journey in 2006 in preparation for the FIFA 2010 World Cup, which saw the city hosting matches at its stadium. This initial effort was focused on designing a "smart stadium" and was initiated by the government. Subsequently, a smart city initiative called "Smart City Nelson Mandela Bay" that involves over 50 stakeholders from civil society, industry, academic institutions, and government institutions was launched (Smart City Nelson Mandela Bay, 2017).

NMBM initially started with the top-down approach to a smart city with the government setting out to establish necessary infrastructure around the city. The city set up its Internet Protocol infrastructure by combining wireless and fibre networks to ensure all municipality buildings were connected and all public applications ran on the same network, its telephone infrastructure was also set up so all calls made in municipal buildings are free. This infrastructure enabled the municipality to reach communities that were initially excluded by providing ICT access. The bottom-up approach was established later as explained above. NMBM's approach is a combination of the top-down and bottom-up approaches. According to Estevez et al. (2016), this two-pronged approach is required for successful smart cities.

NMBM recognises that smart cities that focus on technology alone do not work, which is an argument posed by Yigitcanlar et al. (2020), it therefore uses a hybrid of technology, human and governance/institution in its smart city focus. The municipality set out to provide technology infrastructure within the city including free Wi-Fi to citizens. NMBM realised a need for smart employees while setting up the technology infrastructure. It set out to train its employees on the technology implemented so that these employees could be efficient in meeting the needs of the citizens especially related to providing smart city services. The municipality had a goal of creating "smart employees". The "Smart City Nelson Mandela Bay" initiative is involved in educational projects targeted at citizens of the municipality. The governance/institution focus is related to stakeholder and government co-operation. This happens in NMBM through the "Smart City Nelson Mandela Bay" initiative, which involves the municipal government and stakeholders including businesses, civil society, non-governmental organisations, government agencies, and academic institutions in the city.

3.2 Smart City Activities within NMBM

The smart city activities implemented by the city government and other stakeholders will be presented and categorised according to the smart city dimensions previously discussed. These activities will also be linked to the SDGs in a bid to determine the municipality's current status in achieving these goals, while these are not completely achieved by the activities implemented by the municipality, the activities show that the municipality is taking action regarding these SDGs. Many of these activities exist independently as described in the bottom-up approach to smart city implementation (Estevez et al., 2016). The activities were identified through an interview with the city's smart city custodian and promoter, document analysis of reports, and an Internet-based search. The investigation revealed that there is no central point of information on NMBM's smart activities, which led to a tedious research process.

Smart Mobility

The city's smart mobility activity enables easy traffic flow and closure of roads when there are floods. This is achieved through sensors that act as early warning systems during heavy rainfall. The sensors are placed in riverbeds and would trigger the closing of bridges and boom gates when the water reaches a specific level, so road users are aware that those roads are flooded. The sensors are also linked to traffic lights which would flash red to alert road users. Traffic lights around the city are also connected to the city's network infrastructure and regulate the flow of traffic, especially during peak times. According to the smart city custodian they "*use a 'scoot' system that regulates the flow of traffic and that runs on our network"* (NMBM Smart City Custodian, Interview Transcript, Pg. 6).

In relation to the SDGs, these activities are aligned with *Goal 11 - Make cities and human settlements inclusive, safe, resilient, and sustainable*. One of the targets of this goal is to "provide access to safe, affordable, accessible, and sustainable transport systems for all, improving road safety" (United Nations, 2015). The use of sensors on the roads in the city enhances safety on the roads and makes the transport system sustainable.

Smart Environment

In recent years, NMBM has experienced water shortages that have required constant monitoring of its dams to determine water levels and implement water saving measures. As part of its smart city goal, the municipality has installed sensors on its dams and connected these sensors to its network. This has enabled data collection from these dams to enhance city planning and save costs that would previously have been incurred by city officials travelling to these locations to manually measure water levels. The smart city custodian stated that *"that's why we could actually, every day we get feedback from the dams to look at what the dam levels are, quality of water . . . Where previously we had messengers bringing data samples from 60 – 80 kilometres away, bring it down to us to analyse the data, where now they could do it there and then send it via the network"* (NMBM Smart City Custodian, Interview Transcript, Pg. 9).

The municipality has been recognised as a "hotspot for green/renewable energy" in Africa. Through a partnership with the Nelson Mandela University and Propella – a business incubator that focuses on renewables and a member of the "Smart City Nelson Mandela Bay" initiative, the city hosts a ground-mounted solar energy harvesting plant. The city also hosts a 1.8 MW wind farm that is privately supported in partnership with the municipality (Motyka et al., 2019; SACN, 2016).

The water management activities address *Goal 6 - Ensure availability and sustainable management of water and sanitation for all*. NMBM is taking action to meet the targets of substantially increasing water-use efficiency and implementing integrated water resources management at all levels (United Nations, 2015). The renewable energy activities implemented by the city are aligned to *Goal 7 - Ensure* *access to affordable, reliable, sustainable, and modern energy for all*. The city is making efforts to meet the targets of ensuring access to renewable energy, increasing the share of renewable energy in the global mix and expanding infrastructure and upgrading technology for supplying modern and sustainable energy services for all in developing countries (United Nations, 2015).

Smart People

The Smart City Incubating Great Engineering Minds (iGEMS) project focuses on developing smart citizens in the municipality. The project's objective is to increase the number of technical and engineering graduates from disadvantaged communities in NMBM (Project Nelson Mandela Bay, n.d.). The project has four phases; phase one provides selected candidates with weekly tutorials, company site visits, career and leadership development workshops. In phase two, candidates are provided with a one-year work experience in selected companies. Phase three provides tertiary education to candidates and in the final phase, candidates take up full-time employment in companies that are part of the project (Project Nelson Mandela Bay, n.d.).

The smart people activities are aligned with Goal 4 of the SDGs which focuses on *ensuring inclusive and equitable quality education and promote lifelong learning opportunities for all* (United Nations, 2015). The following targets are addressed by the city's smart people dimension:

- By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university.
- By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs, and entrepreneurship (United Nations, 2015).

Smart Living

The municipality has implemented several projects in its different communities that can be categorised as smart living. These include promoting safety in the city by introducing CCTV cameras and LED powered street lights in communities with high crime rates (Daniels, 2019). The municipality has integrated their housing application system with the national government's system to allow its citizens to apply for housing easily. Citizens are added to the national housing database and are therefore able to get houses allocated efficiently and timeously. According to the smart city custodian: *"we are one of the only cities . . . because we have a system and through using the network it engages itself with national government so, people that register here gets immediately onto the national database"* (NMBM Smart City Custodian, Interview Transcript, Pg. 5).

These activities are aligned with *Goal 11 - Make cities and human settlements inclusive, safe, resilient, and sustainable*. The city is taking action to meet the target of ensuring access for all to adequate, safe, and affordable housing and basic services and to upgrade slums (United Nations, 2015). There is a long way to go for the city to completely achieve this target, however, improvements have been made in the city infrastructure.

Smart Economy

The city's "Small Business Hub" has empowered citizens to be innovative and entrepreneurial by providing support for citizens to set up online businesses through the provision of internet facilities. Therefore, the activity can be classified in the smart economy dimension of smart cities. The smart city custodian stated that *"immediately we saw the benefits of it by us providing those facilities out into the community and especially in the disadvantaged areas, we touched on a very forgotten part of the community and that was the small business community. Immediately we saw that from a small business a lot of the people came to our, we call them the 'economic development hub' ... "* (NMBM Smart City Custodian, Interview Transcript, Pg. 3).

Smart economy is also facilitated by Propella, Nelson Mandela Bay iHub, and other business incubators within the city. These facilities provide mentoring, business development support, and co-working spaces to start-ups and entrepreneurs in the city (Nelson Mandela Bay iHub, n.d.; Propella, n.d.). Some of these activities are supported by the Nelson Mandela University, which is the city's main tertiary education provider. The Propella incubator is focused on providing support for start-ups and entrepreneurs that develop smart city technologies (Propella, n.d.).

The city's technology infrastructure has also attracted new investments from both national and international businesses. These businesses have set up offices in the city because of the lower cost of telecommunication they achieve using the city's infrastructure. According to the smart city custodian: *"I think that we all are aware that Telco costs is huge for businesses even for the normal, the normal household and for us as ... and they wanted to get involved in there and a lot more investment from your, I would say bigger cities started to bring down their offices down here and that's one of the big areas that, like our IDZ, they connect onto our backbone and it's because of that integrated approach of how we provide the Telco services there, that's why today Koega has got so many foreign investors that has come down now, if you look at Keoga, if you go down there you will see the amount of foreign investment that has come in there ... "* (NMBM Smart City Custodian, Interview Transcript, Pg. 9).

The smart economy dimension addresses these three SDGs:

- Goal 1 - End poverty in all its forms everywhere.
- Goal 8 - Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.

- Goal 9 - Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation.

With regard to Goal 9, the municipality is involved in efforts specifically aligned to Targe 9.3 - *Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets.*

Smart Technology

The technology infrastructure set up by the municipality enables connectivity between all municipality buildings and provides citizens with internet access. There are two projects that provide Wi-Fi in public venues; the e-Connect and BConnected. The e-Connect service is an indoor service that provides free Wi-Fi for browsing the Nelson Mandela University learning website, as well as the municipality's website (Nelson Mandela Bay Municipality, n.d.-b). For browsing other websites, each person receives 100 Mb per device per day, free. This service is provided at libraries and service centres within the municipality. The BConnected Wi-Fi service is a broadband service that delivers affordable wireless voice and Internet services to residents and businesses of the municipality and residents get certain data amounts free dependent on payment of their municipal accounts (Nelson Mandela Bay Municipality, n.d.-b). Another project, the "Iziwe Connection campaign" is run by a non-profit organisation and provides Wi-Fi connection on public buses that run in the city so that commuters stay connected (R News, 2016). The connectedness achieved through these projects are deemed necessary in a smart city to enable citizens to share knowledge and experience (Khatoun & Zeadally, 2016).

NMBM also developed a self-help mobile phone application that enables citizens to pay bills, register for housing, report incidents, participate in surveys, report corruption and fraud as well as provide input for the city's Integrated Development Plan (IDP) (Nelson Mandela Bay Municipality, n.d.-a). Figure 2 presents a screenshot of NMBM's mobile application. Another technology introduced and aimed at supporting tourism in the city is the development of the ConnectedCity mobile application. The application allows users to connect and discover places around the city (Project Nelson Mandela Bay, n.d.).

There might not be any direct links between the smart technology projects and the SDGs, however, technology enables the achievement of all SDGs (Gordon, 2019).

Smart Governance

NMBM has fostered smart governance in three areas: public participation in decision-making, improvement of public and social services, and transparency in government. Through its ICT infrastructure especially the city-wide Wi-Fi and the

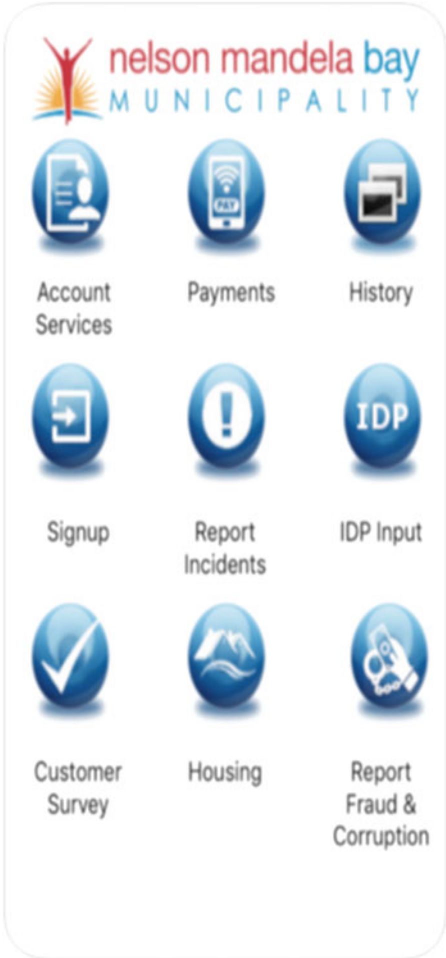

Fig. 2 Nelson Mandela Bay Municipality Self-Help Mobile Application Screenshot

mobile application, citizens can participate in decision-making by providing input to the city's IDP process and report fraud and corruption, which enhances transparency and accountability in government. The municipality can improve its delivery of public and social services to citizens using technology; by linking its offices in remote areas to the municipality network, employees can address citizen queries and provide services more conveniently. Citizens can also report service delivery issues on the municipal mobile application and get these issues addressed faster.

This smart city dimension is aligned with *Goal 16 - Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels* (United Nations, 2015). Smart governance addresses the targets of substantially reducing corruption and bribery in all their forms, developing effective; accountable and transparent institutions at all levels; and ensuring responsive, inclusive, participatory and representative decision-making at all levels (United Nations, 2015). This target has not been completely achieved and can always be improved, however, efforts are being made by the municipality. The next section seeks to identify the value these activities provide to the stakeholders in NMBM.

3.3 Stakeholder Value

Smart city initiatives should be beneficial and create value for all stakeholders. These values represent positive outcomes that legitimise these initiatives (Meijer & Bolívar, 2016). The importance of determining the value produced by smart cities has been emphasised. It has been noted that smart city benefits are not defined, measured or communicated to stakeholders and therefore impact the transparency and awareness of smart city initiatives (Dameri, 2017). This could lead to an abandonment of these initiatives before their benefits are derived.

For the sake of simplicity, the stakeholders of a smart city will be classified into public institutions, private institutions, government, and citizens. Stakeholders classified as public institutions include educational institutions, civil society, non-governmental organisations, and government-owned public service providers; private institutions include incubators, businesses, and industrial stakeholders, and research institutions; government includes the local government and government agencies that operate in the city and citizens include individuals that live, work, and study in the city.

Many different stakeholder values are identified in the literature, each relating to the smart city initiative implemented by a city. The stakeholder values to be investigated are categorised according to the following themes: social, economic, governance, environment, human capital, and infrastructure. These themes were identified from literature (Dameri & Rosenthal-Sabroux, 2014; Estevez et al., 2016; Meijer & Bolívar, 2016; Neuroni et al., 2019).

Social

Social values relate to community, relationships, and making the city liveable (Neuroni et al., 2019).

Enhancing public safety and security: Public safety is a necessity for cities (Meijer & Bolívar, 2016). It improves the life of citizens, contributes to the reputation of the city, and therefore encourages business investments. The municipality has invested in CCTV cameras around the city that enable surveillance and is accessible to the traffic department, the metro police as well as the national police. Other ways safety has been improved is by enabling online payment of bills, which eliminates the need for citizens to walk around with cash, especially in areas prone to crime. The smart city custodian stated "*that was one of the benefits I would say, by having that technology already there from 2006 / 7 onwards it allowed us to put the* *surveillance in the city that would assist the, our traffic, traffic department, the metro police as well as our South African police they could get footage off from the network that we built"* (NMBM Smart City Custodian, Interview Transcript, Pg. 6).

Improving quality of life for citizens: Many smart city activities improve citizens' lives in terms of time, money, and convenience by improving city infrastructure and service delivery (Estevez et al., 2016; Meijer & Bolívar, 2016). Citizens save costs on energy through consumption of renewable energy. Paying municipal bills, reporting issues, and public participation can be done through NMBM's mobile application saving time, money, and effort. Smart transport systems discussed previously improve citizens' quality of life by saving time and fuel costs from traffic congestion. Citizens can register on the national housing database without having to leave the city and can also conveniently access municipal services from offices in their vicinity saving on transportation cost and time. The smart city custodian believed that *"on a daily basis what we've done is try to minimise the people, the communities of travelling into the cities, by us providing these type of services out there which are now becoming digital... to sort of and that had an impact on their pocket, where previously they had to take buses and taxis, now they can, in their own communities get the same type of services as previously they would look up to coming into the cities to, because that was you major, our big offices. Whereas the same type of application or services we could take out to the community*" (NMBM Smart City Custodian, Interview Transcript, Pg. 10).

Economic

Economic values impact the wealth, income, and economic growth of the city and the stakeholders in the city (Neuroni et al., 2019).

Cost saving: Many areas of cost saving have been identified and relate to all stakeholders in NMBM. Firstly, the government can save costs by setting up its own Internet and telephone infrastructure, eliminating the need to pay telecommunication companies for these services. According to the smart city custodian: "*Which up to today, I think we are one of the only cities that can be very proud that we are, that we manage it and it has also brought down the costs from the actual utility bills that we have. Telcom bills*" (NMBM Smart City Custodian, Interview Transcript, Pg. 5).

The use of sensors at the city's dams also eliminates the cost of sending out technicians to monitor dam levels on a regular basis. The smart city custodian reported that "*we saw that all our dams, we could link our dams in there, that could collect data from there as well. And today, that's why we could actually, every day we get feedback from the dams to look at what the dam levels are, quality of water... Where previously we had messengers bringing data samples from 60 – 80 kilometres away, bring it down to us to analyse the data, where now they could do it there and then send it via the network"* (NMBM Smart City Custodian, Interview Transcript, Pg. 9).

Citizens also save costs based on the Internet services and mobile application provided by the municipality, as they do not need to visit municipal offices to accomplish tasks like paying bills, reporting issues, and registering for housing. The ICT and telephone infrastructure have also contributed to cost savings for businesses and institutions in NMBM. As stated by the smart city custodian "*through this whole connectivity people had . . . we still got it up to today, where you could buy pre-paid electricity through your mobile app"* (NMBM Smart City Custodian, Interview Transcript, Pg. 3–4).

Attracting new investors: The ICT and telephone infrastructure are basis for new investors coming into the city and setting up offices in the industrial zone. This influx of new companies creates jobs for citizens and improves the economy of the city. The city has attracted international investors in the last few years including car manufacturers from Asian countries. The smart city custodian stated that "*bigger cities started to bring down their offices down here and that's one of the big areas that, like our IDZ, they connect onto our backbone and It's because of that integrated approach of how we provide the Telco services there, that's why today Koega has got so many foreign investors that has come down now, if you look at Keoga, if you go down there you will see the amount of foreign investment that has come in there . . . "* (NMBM Smart City Custodian, Interview Transcript, Pg. 9).

Encourage entrepreneurship and innovation: The ICT infrastructure provided by NMBM and the presence of several incubators provide new economic opportunities for citizens. Citizens have launched small businesses online and started companies that provide innovative technical solutions addressing the needs of the city with the help of the various private and public incubators in NMBM (Propella, n.d.). According to the smart city custodian: "*One, we had two good stories there. There were two small business, I would say youngsters that started off their business building these little, we use to call them . . . these little toys with the wire and stuff and that was just before the 2010 World Cup, and then they made the logo, the municipality's logo with the FIFA World Cup logo, and they put that onto the internet. Immediately they had a huge influx of orders coming through and eventually they became so, such in demand for this product that their business grew*" (NMBM Smart City Custodian, Interview Transcript, Pg. 3).

Governance

Governance values impact on the role stakeholders play in government action and the provision of public services by the municipality.

Fostering citizen participation: The municipality has established electronic avenues for public participation via their mobile application. Citizens can get involved in IDPs (which are an approach to city planning that involves the entire community) by submitting their inputs on the municipality's mobile application. Citizen surveys run by the municipality are also available on the mobile application.

Improving access to public services: The ICT infrastructure and mobile applications provided by NMBM allow stakeholders convenient access to public services. NMBM has been able to connect municipal offices in previously disadvantaged communities to its network which provides citizens with municipal services closer to their homes. According to the smart city custodian: "*It was our customer care centres, our housing development, where people use to come in and register to get a house. Previously they had to walk all the way or take taxis or take a bus and come into the city to apply for homes*" (NMBM Smart City Custodian, Interview Transcript, Pg. 10).

The mobile application provides services such as submitting water and electricity metre reading and paying for electricity, providing convenience to stakeholders.

Environment

These values impact the environmental quality of the city and prevent further environmental degradation (Dameri & Rosenthal-Sabroux, 2014).

Promoting production and consumption of renewable energy: Cities are the highest consumers of global energy, which means changing energy production and consumption patterns in cities will have the highest impact on the global environment. The renewable energy activities in NMBM will directly impact global energy positively. These activities also impact all stakeholders in terms of energy cost reduction, job creation, technological innovation by start-ups, and opportunities for research by academic and research institutions in the city.

Human Capital

Human capital values increase the talent and education level of the citizens. The human capital value leads to economic growth, competitiveness, and better quality of life (Estevez et al., 2016; Meijer & Bolívar, 2016).

Promoting knowledge development: Knowledge development is crucial to all stakeholders of the municipality. The development of knowledge and promotion of learning is seen as crucial to sustainable wealth creation of a city. The Smart City iGems project as well as the involvement of academic and research institutions in NMBM's smart city foster the creation of knowledge among citizens.

Promoting skills development: By integrating workshops and internships with companies into the Smart City iGems project, education goes beyond what is taught in the classroom and develops tangible skills of students. The incubators in NMBM also contribute to entrepreneurial skill development. This is beneficial to all stakeholders as it increases the talent pool for employers and increases employability of citizens.

Empowering municipal employees to perform their jobs: Through training on the technology systems adopted by NMBM, employees have been empowered to perform their jobs better and equipped to better serve the community. The technical capabilities of employees were as important as the technology adopted to NMBM. The smart city custodian's view was that "*... to become a 'smart city' you have to have 'smart employees'. And to become 'smart employees' you have to look at* *efficient ways of providing services out to the, to our citizens"* (NMBM Smart City Custodian, Interview Transcript, Pg. 12).

Infrastructure

Investments in the city's infrastructure impacts all stakeholders, increases the efficiency of city operations and improves the management of city resources (Estevez et al., 2016).

Fostering city planning: City planning has been improved due to the introduction of several infrastructures in NMBM. One of these ways is the introduction of ICT infrastructure that integrates with the national and provincial housing databases, allowing citizens to register for government provided housing and allowing the government plan around housing. NMBM can estimate the number of citizens needing houses and plan the city around these numbers. This information also enables all levels of government (local, provincial, and national) plan budgets in the area of housing. The installation of sensors that monitor water levels in the dam around NMBM help the municipality plan around water consumption which is essential to battling the drought the city currently faces. Citizens and government are impacted positively by the improved city planning.

Providing enhanced transportation systems: Sensors that control the flow of traffic and access to roads during floods have impacted the lives of citizens by reducing traffic congestion and keeping citizens safe. This value is also linked to environmental values.

Advanced ICT infrastructure: ICT infrastructure is crucial to city development; it offers connectivity to citizens, institutions, organisations, and government. Connectivity is essential to all stakeholders because it promotes business opportunities, offers opportunities for online learning, provides access to government services, and improves citizen life in many more ways.

4 Discussion

The investigation of smart city activities revealed that there is a profusion of projects and initiatives aimed towards achieving the city's smart city goal. However, it was also observed that these projects are executed in isolation in most cases. For instance, the project aimed at providing CCTV cameras and LED street lights is focused on only one community and the flood sensors were also installed in a specific area instead of the entire city. The city would have a more comprehensive smart city if projects are uniformly executed. These smart city activities are initiated by different stakeholders and address different challenges of the city. There is a lack of evidence of the strategic nature of these activities; for example, is there a clear, strategic vision for these activities? Or are they initiated because they are convenient and gratify the needs of each stakeholder rather than meeting the citizens' needs and resolve the challenges of the city? The provision of Internet is the only project that is city-wide and has been beneficial to all stakeholders. The city would benefit from the integration of all smart city activities into a single smart city initiative. The city should appoint a champion and create a repository for this initiative. This would make it easy to identify and link activities, which could lead to an easier evaluation of the value of these activities.

NMBM has smart city activities linked with seven smart city dimensions, two dimensions: smart policy and smart organisation were not evident. These dimensions require the creation and reformation of existing policies and restructuring of government organisations, which face challenges of bureaucracy, red tape, and resistance to change (Mergel, 2012). These challenges could possibly limit the smart city goals of the municipality. However, the municipality has recognised the need for smart policies and has included this in its smart city plans (Nelson Mandela Bay Municipality, 2018). The city also plans to lobby the national and provincial government to amend policies that might hinder its smart city efforts (Nelson Mandela Bay Municipality, 2018). The gap for the smart organisation dimension could indicate a need for NMBM to add this dimension to its smart city strategy going forward. Figure 3 illustrates the classification of NMBM's smart city activities in relation to smart city dimensions and SDGs. Figure 3 does not include smart

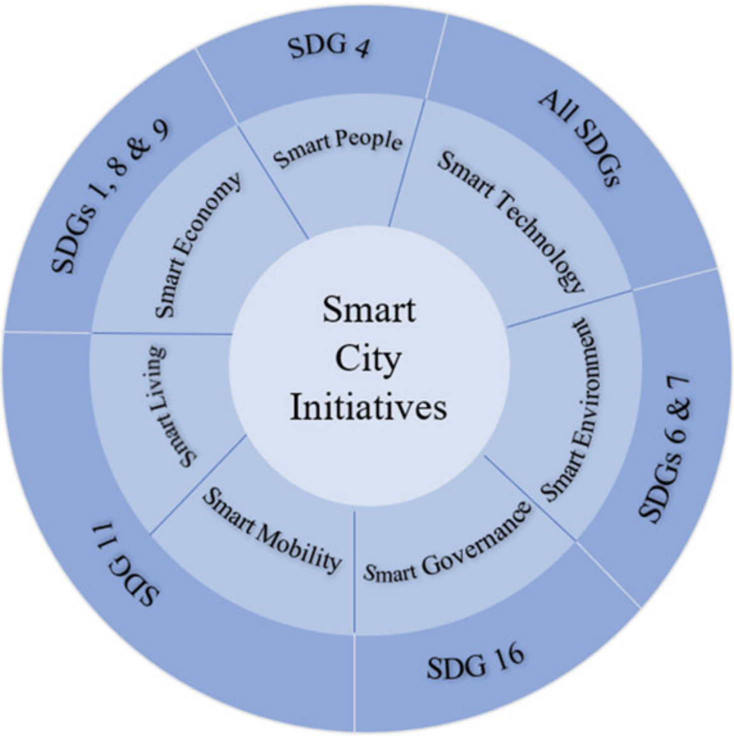

Fig. 3 Smart City Dimensions showing associated Sustainable Development Goals in NMBM (Authors' construct)

policy and smart organisation because they have not been implemented yet. SDGs 2, 3, 5, 10, 12, 13, 15, and 17 were not identified among the smart city activities of the municipality.

The municipality's technology infrastructure projects have provided Internet access and reduced telecommunication costs around the city and seem to be the highest value producing activity to all stakeholders. Technology appears to be the backbone for other smart city dimensions in NMBM such as the smart economy, smart living, and smart people. Establishing technology and telecommunications infrastructure has been identified as a best practice for cities. This practice is consistent with suggestions for a two-pronged approach to establishing smart cities, where the government builds foundations through infrastructure development (Estevez et al., 2016). Cities in Africa that plan on establishing themselves as smart cities should ensure technology and telecommunication infrastructure are available to citizens and city stakeholders who might be interested in launching smart city initiatives.

Regarding the smart people dimension, the city would benefit from increased partnership between existing incubators, business hubs, the university, and government. Resources can be pooled, and citizens can collaborate on projects, making it easier to identify innovative solutions to the city's problems and ensuring these solutions are implemented. A partnership between the government and more prominent incubators in the city will provide small and medium enterprises with resources they may be lacking. These resources can aid the small and medium enterprises with the skills required in a way the government is not able to do, due to a lack of expertise in this area. Since the government has business hubs established in less developed areas of the city, these could be used as a way of identifying more complex and innovative ideas that the more prominent incubators could support.

From the myriad smart city activities in the city, it could be assumed that the city has data that could be fed into an open data portal. However, there was no indication of such a portal during this study. This is an opportunity that is not being utilised by NMBM. Open data have social and economic value; they enable innovation and better decision-making (Kassen, 2017). Open data is becoming an essential part of modern service delivery and can help governments save costs (Open Data Institute, n.d.). Several countries have integrated open data initiatives in their smart cities. In France, the *Le Base Adresse Nationale* is an open data initiative that allows citizens tag their current locations, which enables the government respond effectively during emergencies (Dinah et al., 2019). Businesses could build new services that are beneficial to the city if provided with access to the city's data. For instance, NMBM has been experiencing drought in the last 3 years and have issues relating to water management (AlgoaFM News, 2019). By providing data from its dams and water usage to the public, the municipality could encourage the development of innovative solutions to this challenge. Open data solutions could also improve the city's responsiveness and resilience.

Table 2 illustrates the smart city value identified in NMBM and highlights the stakeholders who benefit. A tick is used to indicate which value items are applicable to a stakeholder and a boxed x indicates where value items are not applicable. The

Table 2 Aligning Smart City Values to Stakeholders (Authors' construct)

Value Category	Value Item	Public Institutions	Private Institutions	Government	Citizens
Social	Enhancing public safety and security	☒	☒	☒	✓
	Improving the quality of life for citizens	☒	☒	☒	✓
Economic	Cost saving	✓	✓	✓	✓
	Attracting new investors	✓	✓	✓	✓
	Encourage entrepreneurship and innovation	✓	✓	✓	✓
Governance	Fostering citizen participation	☒	☒	✓	✓
	Improving access to public services	✓	✓	☒	✓
Environment	Promoting production and consumption of renewable energy	✓	✓	✓	✓
Human capital	Promoting knowledge development	✓	✓	✓	✓
	Promoting skills development	✓	✓	✓	✓
	Empowering municipal employees to perform their jobs	☒	☒	✓	✓
Infrastructure	Fostering city planning	☒	☒	✓	✓
	Providing enhanced transportation systems	☒	☒	☒	✓
	Advanced ICT infrastructure	✓	✓	✓	✓

smart city activities provide economic and environmental value to all stakeholders. All stakeholders also obtain value through the promotion of knowledge and skills development opportunities as well as the provision of advanced ICT infrastructure. Citizens obtain the most value from the smart city activities; this is most likely because the activities identified influence the day-to-day lives of citizens.

5 Conclusion and Future Work

Smart city literature is abundant and diverse, but there has been a significant deficit in research focusing on developing countries. This chapter set out to fill that gap by assessing the implementation of smart city activities in NMBM in South Africa. The focus of the chapter was identifying the value these activities provide to the different city stakeholders as well as linking these activities to the SDGs. NMBM's smart city activities are approached from top-down and bottom-up with the government providing the foundation for other stakeholders to build on. The activities identified are associated with seven smart city dimensions: smart mobility, smart environment, smart people, smart living, smart economy, smart governance, and smart technology. Two smart city dimensions: smart policy and smart organisation are not evident in NMBM. The dimensions identified are linked to SDGs 1, 4, 6, 7, 8, 9, 11, and 16 as shown in Fig. 3.

By evaluating the different smart city activities in NMBM, this chapter has been able to highlight the benefits of these activities to the various stakeholders in the city as well as link these activities to the SGDs. The smart city activities provide social, economic, governance, environmental, human capital, and infrastructural benefits to stakeholders in the city. These values prove the efficacy of the activities initiated in NMBM. The study identified the municipality's telecommunication and technology infrastructure projects as a best practice for smart cities in developing nations, where cities struggle with access to data. Cities in developing nations like South Africa can achieve "smartness" by initiating similar projects, as well as work towards achieving the SDGs. Cities in developing nations should prioritise setting up telecommunications and technology infrastructure to ensure the success of their smart city initiatives. In the NMBM, this was the one activity that contributed to the propagation of other smart city activities. It is also recommended that smart city initiatives should also be complemented with open data initiatives as the many activities in the smart city produce a lot of data which can be used to improve the operations of the city, provide citizens and businesses opportunities for innovation, and help the government solve city challenges using real data (Open Data Institute, n.d.). One weakness to NMBM's approach to smart city is isolation; activities tend to focus on single communities rather than the city-wide. To be a comprehensive smart city, cities should adopt a city-wide rather than community-based approach.

While this chapter has identified value provided by the various smart city activities in NMBM, there is a need to measure and quantify the value. This would require initiators to have strategic goals for each activity and to assess value at the beginning and end of each activity (Dameri & Rosenthal-Sabroux, 2014; Neuroni et al., 2019). Future research should investigate methods of assessing, measuring, and quantifying smart city activity value as this will further the legitimacy of claims for these activities. The study is limited to the subjective view of the smart city custodian and the researchers' interpretation of the documents analysed, so that could be biased.

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A Resilient Approach to Social Solidarity During Covid-19. Evidence from Smart Communities in South African Cities

Maria Rosa Lorini and Jorge Marx Gómez

1 Introduction

In March 2020, South Africa entered a severe Covid-19 lockdown that would last several months and is still on following scientists' advice to the government. In South Africa the risk of fast spread of the virus among the most vulnerable people is high due to the health conditions of the population affected by tuberculosis, HIV positive cases, malnutrition, and due to the living conditions of the poor sectors of the society (Boffa et al., 2020; Hogan et al., 2020).

South Africa detected its first novel coronavirus infection on 5th March. In the weeks that followed, the epidemic mimicked an exponential curve similar to those in other countries. On 15 March, the country's President declared a national state of emergency banning visitors from high-risk countries, prohibiting large gatherings, closing more than half of the land borders, and shutting schools. On 27th March, the country started a 21-day lockdown with further extensions in the following months, closing all borders and confining everyone except those performing essential services to their homes except to buy groceries and medicine or to collect welfare payments. The schools, borders, public transport, bars, and restaurants were shut; alcohol, cigarettes and other 'non-essential' commodities and services banned.

The country was using that time to prepare the health system to manage the cases that would rise in the coming months. Using the knowledge and expertise gained in combating HIV/AIDS (Whiteside et al., 2020), the country deployed tens

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of thousands of community health care workers into villages and towns to screen people and refer those with symptoms for testing. The South African government hoped to flatten the curve by reducing the spread above all in the highly populated areas such as the townships, the underserved neighbourhoods created during the apartheid era and which up to date are still a reflection of the social divide of the country. The inequality rate is in fact one of the highest globally (Seekings & Nattrass, 2008) and in the biggest metropoles of the country the legacy of apartheid is more visible (Leibbrandt et al., 2009; Noble & Wright, 2013).

In the townships the rate of people living below the poverty line, the rate of unemployment, and the limited access to services (in particular, water pipes and toilets) contrast with the statistics of the residential areas (Barrar, 2010). In those areas, a lot of people live on social grants and day-to-day jobs. The restrictive measures of the lockdown were directly affecting these vulnerable categories who could no longer continue with their way of life. South Africa begun lifting lockdown restrictions in carefully considered stages to decrease the impact of the lockdown on the social and economic well-being of the population while also avoiding further increase in the social divide.

The study will present the response to the pandemic carried on by networks of support in the city of Cape Town. Cape Town ended up as one of the most affected areas of the country. Within the metropolitan city, the areas that registered the fastest rise in numbers of infected people were the townships, peripheral areas where the number of inhabitants is in constant growth, the living conditions are difficult, and the social divide is matched by the digital divide (Bornman, 2016). Cape Town is considered the smartest city in Africa. It represents a municipality focussed on managing electricity and billing crisis using novel technologies with varying success (Slavova & Okwechime, 2016). But Smart City solutions are not yet operational in every neighbourhood and do not target all the existing issues.

In the different disciplines, Smart Cities had been defined differently but the main characteristic remains the integration of an interrelation of technology, municipal organisation, citizen, and business processes. A Smart City is citizen-centric and adopts and uses Information and Communications Technologies (ICTs) and other innovative means to improve the quality of life of its inhabitants ensuring efficient urban operations while making the city services and monitoring more interactive and efficient (Ismagilova et al., 2019). It provides sustainable solutions which caters for the current and future population of the city in terms of the economic, social, cultural, and environmental needs (Jin et al., 2014). Smart Cities with the support of technologies can develop Smart Transport, Smart Health, Smart Energy, Smart Grid, Smart Governance, and Smart Citizens. In the literature, several areas of Smart City had been studied and analysed through specific frameworks (Marx Gómez et al., 2019).

The study will present the context and activities carried on by groups of citizens of Cape Town to respond to the local realities of Covid-19. It highlights how a smart response from the bottom could achieve timely results. In particular, the analysis of the community responses to the pandemic will support the discussion over the potentiality of ICT to reduce the social divide while answering the question: 'how can Smart Communities cope with a crisis and what role can ICT play?'

The digital solutions proved their efficacy in dealing with the crisis and supporting the most vulnerable people through a flexible, non-bureaucratic, and non-hierarchical approach. The solutions developed were framed within the Smart Citizens and Communities' literature. The discussion of the findings will highlight the elements of novelty in comparison to the majoritarian literature on Smart Cities, usually focused on the role of the authorities and of ICTs. The analysis suggests a series of propositions related to the increasing role that e-Participation of Smart Citizens can have on developing social innovation in Smart Cities while reducing the digital and social divide.

2 Literature Review on Smart Cities Vs Smart Communities

Cities are becoming more complex and larger as the population of urban areas increases. It is estimated that by 2030, more than 5 billion people will live in urban areas (Founoun & Hayar, 2018). Africa is fast becoming an urbanised continent facing urbanisation challenges. The increased population size in agglomerated spaces in fact requires additional infrastructures, repair of existing ones, attention to the impact on global climate change. Furthermore, increasing urbanisation usually relates to increased inequality (Behrens & Robert-Nicoud, 2014).

Hence African countries are starting to adopt Smart City initiatives (Slavova & Okwechime, 2016); in line with the Africa agenda 2063 (Slavova & Okwechime, 2016). The need for new infrastructure provides a unique opportunity for citizens and government to come together and build Smart Cities that promote health, well-being, equity, and sustainability (Xie et al., 2018). There is currently a lot of hype and buzz around the concept of 'Smart Cities' in the government, in academia and the private sector (Gurstein, 2014). Due to the various socio-economic and sustainability issues being faced globally, cities all over the world are looking to implement various smart initiatives as solutions (Trindade et al., 2017). Smart Cities in fact present the opportunity for technology to improve city planning and management. Integrating technology into the operation of cities should ameliorate the lives of citizens. Various models of implementation exist and research is needed to show what the potential benefits and pitfalls are, to allow for improvement, and to encourage hesitant organisations to investigate implementations of their own.

The rise of Smart Cities should succeed in improving access to services while delivering them more efficiently (Batty et al., 2012); some examples of socio-economic issues are related to the expected increases in city populations, unemployment, under-resourced health and education systems. Examples of global environmental challenges are global warming, waste management, water and energy management, and food security (Marx Gómez et al., 2017). A Smart City is based on the intelligent exchanges of information that flow between its different subsystems. This flow of information is analysed and translated into citizen and commercial services. The city will act on this information flow to make its wider ecosystem more resource-efficient and sustainable. The information exchange is based on a Smart Governance operating framework designed to make cities sustainable (Albino et al., 2015). The Smart Governance operating framework includes an interrelation of smart politics, smart citizens, smart science and technology, smart environment, smart living, and a smart built environment (Mardacany, 2014).

However, in certain countries such as South Africa, one could argue that Smart City approach represents a misplacement of priorities (Musakwa & Mokoena, 2018). In cities where people struggle with lack of essential services and basic infrastructures, inequality, and poor living conditions it is all the more important to consider the needs of the people while analysing the potential benefits of the implementation of Smart City technologies as well as the possible side effects. In order to maintain the focus on the actual involvement of the people affected the different solutions, this study considers the distinction raised in the literature between ‘Smart City’ and ‘Smart Community’ initiatives. In a Smart Community, emphasis is placed on shared governance, participation, and cooperation (Normalini et al., 2019). The goal of a ‘Smart Community’ is to improve the way citizens interact and contribute to society. ICTs not only provide the required physical infrastructure but also educate and empower citizens, who are an integral aspect in building a ‘Smart Community’ (Hollands, 2008).

The distinction between the two expressions can be seen through the definitions and focus on specific constructs. According to Van den Bergh et al. (2018), ‘Smart Cities’ are often associated with the increased use of ICT such as sensors, big data, Internet of Things, and volunteered geographic information in urban planning. For these authors, the backbone of Smart Cities is the access to data and its utilisation. On the other side, the expression ‘Smart Communities’ is often preferred and used when ICT projects focus on social inclusion, empowering citizens, and supporting communities (Gurstein, 2014). In particular, Gurstein (2014) argues that the application of ‘Smart Cities’ in developing countries risks to benefit the already prosperous and well-serviced citizens while simultaneously pilfering resources and benefits from the poor. In the literature on Smart Cities, equity and fairness of the solutions are evaluated but always with a focus on the technology (Batty et al., 2012).

In South Africa the debate over Smart Cities, inclusion, and sustainability is growing. Inequality has further increased in the post-apartheid era (Leibbrandt et al., 2012); urbanisation is having harmful consequences on the vulnerable side of the population (Turok, 2012); and migration movements are posing new challenges above all in the cities (Tevera, 2013). In this context, the contribution will illustrate the solutions adopted by resilient communities which through the increased and intensified use of digital platform—due to the lockdown restrictions—are becoming Smart Communities. In particular, activities carried on by active groups of citizens living in different areas of the metropolitan Cape Town, are presented to showcase a resilient approach (Berkes & Ross, 2013) to the pandemic. As defined by Masten and Reed (2002), ‘Resilience in human development is defined in relation to positive adaptation in the context of significant adversity, emphasizing a developmental systems approach' (p. 74). The communities in fact tried to limit the potential damages of the restrictions imposed during the lockdown on the socio-economic aspects. To do so, the communities embraced the possibilities offered by technologies to keep informed, create networks, and discuss solutions. This kind of approach is similar to the organisational resilience studied in case of responses to natural disasters (Chewning et al., 2013). In the literature, organisational resilience usually refers to the responses adopted by enterprises to crises (Burnard & Bhamra, 2011a, 2011b). In this scenario, the study presents the collective actions of citizens who acted as organised groups. Their resilient attitude allowed for positive management of the traumatic events, adaptation to new situations, sensibility towards others, and openness towards potential opportunities, particularly the ones offered by ICTs.

Cape Town during Covid-19 is experimenting smart solutions, adopted and adapted to the local context in an approach that privileged the most vulnerable sectors of the city. Potentially, the efforts can develop into the creation of a Smart City based on the needs and requests of Smart Citizens. When they actively collaborate as Smart Communities, they share intents and network with all the relevant stakeholders in order to be efficient and relevant.

3 Context—Cape Town Solidarity Grouping System

In Cape Town, as the pandemic spread, networks of citizens developed in almost every neighbourhood of the city that are part of the metropolitan area. Richer areas of the city paired with a section of a township, formal Black authority areas created during the apartheid. These areas are still suffering from the limited availability of essential services. In particular, the citizens' response to tackle the effects of the lockdown had to deal with the conditions of the informal settlements: deteriorated, neglected, deprived, overcrowded areas increasing at the border and sometimes within the townships.

The communities that are part of the study present severe conditions of inequality due to forms of oppression similar to those described by feminist and race theories (Medina, 2013). Such oppression presents itself mostly as unequal access to essential services such as health, education, and information, limited participation in knowledge creation and fruition, and social marginalisation. With the outbreak of Covid-19, the living conditions of these areas did not allow for the required safety measures of physical distancing, washing of hands, and isolation. The main issues being lack of water supply in the majority of houses or shelters, use of communal toilets, high number of people living in the same house and health situation (related mainly to TB, HIV, and malnutrition; see Karim et al., 2009a, 2009b). Complying with the lockdown seems impossible for millions of South Africans living in densely crowded settings, often sharing a one-bedroom dwelling with multiple members and the difficulty of washing hands with soap and water as 7.5 million people across the country share communal taps in the overcrowded neighbourhoods of the cities (Maxmen, 2018).

In this context, where traditional development issues are striking, various networks of people have been emerging since the apartheid era and succeeded in recreating social ties, to cope with the lack of services and to support each other (Bolnick, 1993). The people presented in the research are part of those groups active in several communities. The results of previous ethnographic research are presented to demonstrate the diffusion of the grouping and solidarity system. The case study will instead show how the lockdown and present crisis created the bases for an increasing involvement of activists to support the most vulnerable people in their respective neighbourhood.

The existence of self-help groups and activists was studied and analysed in the previous years in order to elaborate development projects which could ameliorate the working and living conditions of the people involved. In 2010 the main researcher started from the mapping of 100 active groups: 70 groups of women and 30 groups of youth. The vast majority of the women groups were running soup kitchens and informal crèches to cater for the most vulnerable people in their communities. Some groups also created small urban gardens to grow the necessary vegetables for the food preparation. While the role of these groups was crucial before the pandemic, during the crisis the number of soup kitchens increased. Above all, the number of meals that every soup kitchen was preparing grew exponentially. In fact, soup kitchens are playing a pivotal role in subsidising the possibility for school-age children having meals (and sometime two meals) per day during the lockdown while the schools are closed. School feeding schemes closed down along with the schools, leaving many children without their 'one meal a day' (the school system in South Africa feeds nine million learners, Devereux et al., 2018). Soup kitchens are catering also for the elderly and for any person in need, particularly for women, children, and vulnerable people. Women ended up forced into lockdown with their abusers in a country with one of the highest rates of domestic and gender-based violence in the world (Abrahams et al., 2009).

The mapping of 100 active groups in the underserved peripheral areas of Cape Town demonstrated how common and spread the grouping system is. A socio-economic questionnaire with more than 160 youth detailed the representation of these communities; the majority of the people live in similar conditions, with similar economic, social and cultural backgrounds. In particular, more than half of the population of the interested areas live below the poverty line (Lorini et al., 2015). Results that are in line with the official census done in 2011 (City of Cape Town, n.d.).

In 2015, during the development of new projects related to the use of technologies for empowering scopes, an economic test and survey were carried out with 330 adults. The participants were divided by their group of belonging to verify the solidarity structure that supports the existing long-term groups (Grieco et al., 2016). To deepen the analysis, a purposive sampling method was used to select groups for interviews and focus groups. In 2016 a series of digital storytelling videos were created with some of these groups to present the daily activities carried on by each group operating in the illustrated underserved conditions. The videos show how the groups come together to collaborate to strengthen their potential

(Lorini et al., 2017). The African Ubuntu philosophy, 'I am because we are' (Gade, 2011; Sulamoyo, 2010), was used as framework of reference to analyse the social capital system inside the community. The quantitative data gathered demonstrate the diffusion of the grouping system as well as their solidarity scope.

The analysis of Covid-19 responses illustrates how, in reaction to the lockdown and the related economic side effects, new groups emerged in every area of the city, for the first time connecting underserved areas with residential neighbourhoods. The new technologies and social media platforms allowed communities to connect, discuss the novel and ancient issues, showcase examples of difficulties and solutions, and, over time, become smarter communities.

4 Methodology

The study developed from the engagement of one of the authors in the activities carried out at community-level in response to Covid-19 pandemic in Cape Town. The involvement was not structured as a community-based participatory action research (Maiter et al., 2008). The choice to elaborate over the experience and analyse the data collected, emerged as a potential contribution to the response of the communities. The research could support the activities in two ways: sharing the analysis to new network members; becoming a source of suggestions for other responses to the pandemic. The study is a qualitative research based mainly on secondary data collected from social media.

The sources of the data are extensive and diversified. The new groups created in reaction to the pandemic are called Community Action Networks (CAN). The initial information about their formation are taken from the Facebook pages of the networks. Certain pages are closed to the participating members. The main author is a member of some of the groups and requested the authorisation to use the shared information granting the members the possibility of verifying the data (following the ethical standards for secondary data from social media, see Kosinski et al., 2015; Lunnay et al., 2015). The main network, called Cape Town Together (CTT), represents an overarching umbrella for all the CANs. It is managed by a limited number of administrators who try to verify the information before sharing and approve new members as well as potential debates. Weekly debates are organised over Zoom platform. CTT administrators operate as moderators of the network. The main author contacted them for authorisation to report about some of the choices taken, as well as about the guidelines and principles that emerged over time. In particular, the thematic division for the data analysis was done starting by the subsections created by the CTT administrators regarding the main issues to deal with. The different CANs usually refer to the same categories during their exchanges.

The main author is also part of three WhatsApp groups, of specific CAN areas, as well as inter-CAN groups where debates are taking place to discuss issues common to every network. Discussions concern the creation of informative pamphlets, guidelines on how to operate, the leading principles as well as practical information about adopted solutions for physical distancing or cloth masks production. Another part of the data had been directly collected by the main author in the communities of reference through personal contacts and direct involvement during the pandemic for food collection and distribution. Due to the knowledge of the underserved communities, the author was able to suggest partnerships, opening up dialogue with active groups via personal WhatsApp conversations, and eventually intensify the debate with community members during the deliveries.

Table 1 highlights the elements used from each source for the study.

Facebook data from CTT page are available for further research as well as the WhatsApp groups' conversations. The discussions that took place in the underserved communities were more informal and only field notes are available. Concerning the Zoom meetings where the debate and exchanges were taking place, only certain sessions were recorded. Some sessions, due to the sensitivity of the topic and the vulnerability of the involved people, were not recorded (for instance, the discussion over Gender-Based Violence).

Due to the risk of bias related to the direct involvement and engagement with the CANs activities of the main author, the discourse analysis of the WhatsApp communications and Facebook pages was conducted with a co-author who does not live in the country and who is not active in the support of the networks. The discourse analysis started from the division of the topics into the main themes as decided by CTT administrator. The choices do not correspond to the number of posts related to the topics but to the relevance of the same as perceived by the involved actors. The authors decided to analyse the messages written by the CTT administrators to the main group and to the CANs. All the messages written by individuals to request support or to offer assistance were not considered. Concerning the Facebook pages of the CANs, three groups' activities were followed. Only the

Table 1 Source of the data and their use

Data source	Selection	Use of data	Analysis
CCT FB page	Administrators messages	Topics division	First division of themes by importance given by the administrators
2 CANs FB pages	Groups messages	Confrontation with CCT FB page	Numerical confrontation of number of posts relating to specific themes (e.g. highest number of posts relate to food security and homeless debate)
WhatsApp CAN Group	All messages	Debate deepening	Division of the messages into the main categories (as expressed by the CTT FB page)
WhatsApp inter-sectional groups	Title of the group	Prioritisation of topics	The inter-sectional groups focus on an individual topic (e.g. gender-based violence) and had not been analysed due to their specificity and to the fact that the author is part of only 2 specific groups
Zoom webinars	Titles	Confirmation of choice of action	The titles entered in the system analysis to confirm the importance given to certain themes.

messages written on behalf of the group and addressed to the general public were analysed. Further analyses can be conducted selecting other CANs Facebook pages and considering all the messages shared by individuals on the CTT Facebook page and on the CANs Facebook pages.

5 Case Study—Bridging the Social Divide

The city response to Covid-19 developed in Cape Town since the beginning of March 2020. Activists and people engaged in support organisations started to create network over WhatsApp and later on over Facebook to discuss the possibilities of community responses to the pandemic. Initially every group was created to evaluate potential activities for the neighbourhood, such as the care for the elderly or the homeless. In a few weeks, a series of community groups or CANs developed at neighbourhood level and connected to the broader CTT network. Every CAN is self-organised and try to approach local challenges while reporting to the CTT Facebook page in order to share the experiences as well as the lessons and resources across the networks (with CTT and with other CANs). There are currently over 170 CANs in Cape Town and they cover the majority of the metropolitan area (which, as per the 2011 census, has a population of 3.740.026 inhabitants and following the 2016 Community Survey, 4.004.793; cfr. Resources of City of Cape Town, n.d.).

The main platform that allowed for CTT network to expand, be recognised, and motivate new groups is Facebook while at group level, WhatsApp represents the main communication tool between the members. To share the experiences and facilitate the exchanges among CANs, webinar meetings are regularly organised on Zoom. Different CANs suggest a topic and a methodology to present and discuss. The organisers share the link through the WhatsApp groups together with options for people who cannot afford to buy data for a Zoom meeting. In South Africa, airtime and data are still very expensive above all for the majority of people who lives below the poverty line (Phokeer et al., 2016).

In the city residential neighbourhoods, the CANs activities focused on the following: organisation of food collection in the main shops and malls of the city for the people in need; preparation of sandwiches for homeless and vulnerable people; fundraising for food parcels to supply a family for 2 weeks and their delivery; collection of clothes and blankets for winter. In the townships, the main activities carried out were an extension of what active people were regularly doing due to the systemic issues related to poverty, malnutrition, and health issues (on TB and HIV, see Karim et al., 2009a, 2009b; on orphans and vulnerable children due to HIV or to alcoholism, see Setshedi & de la Monte, 2011).

The number of soup kitchens increased regularly as well as the number of meals prepared per day. One of the soup kitchens operating in Nyanga moved from preparing 30 meals per day to 100 meals. Nyanga is a typical township with a population of 57,996 inhabitants, 99% black, 74% of who live below the poverty line and 33% of who live in informal dwellings (City of Cape Town, n.d.). The reasons for the increased request relate to the closure of the schools where kids were used to receiving their main daily meal, and with the rising unemployment (of daily workers such as drivers, cleaners, construction workers; Budlender, 2011).

Considering the growing needs of people who were already living below the poverty line, the CANs established a pairing system between wealthier and less privileged neighbourhoods in order for every network to focus on the needs and responses of a specific area. The system proved its efficacy in bridging the social divide at different levels: the knowledge of the communities, the logistic for delivery, the storytelling opportunities facilitated by the growing familiarity, and understanding of context and people.

CTT and CANs do not claim to be the only actors responding to the pandemic. On the contrary, since the formation of each network, one of the main goals was the mapping of existing actors, organisations, and resources available in the hoods. At the same time, a critical point is to relate with the government's responses to Covid-19. The networks in fact try to strengthen and support the government's response knowing the difficulties to act efficiently and rapidly. One of the strengths of the network is the possibility to map the communities, to maintain a constant dialogue with the most affected people, and monitoring the responses. At the same time, all CANs activities are following the official guidelines of the Department of Health in order to avoid an increased exposure to the risk for the activities as well as the beneficiaries. The CTT networks are mostly for non-medical needs but during all the initiatives people shared the guidance to all stakeholders involved. During the weeks that followed, people involved and active became more aware about how to behave during the activities, about what essentials collect, and which kind of information is needed and how they could be shared (via social media, posters, leaflets, . . .).

By the end of April, the CTT experience gained a certain relevance on the social media and citizens of other cities of South Africa requested support to start creating similar experiences in other provinces.

6 Findings—Smart Communities Resilient Approaches

The community response to the lockdown imposed to fight Covid-19 pandemic was quick and effective: while the lockdown created the premises for a serious increase in the malnutrition of children and poor families, the responses succeeded in supplying the necessities on time. The government responses were in the same line of the community ones but due to the bureaucratic system, these could not be deployed at the same speed. The community response was quicker due to its structure: flexible, locally relevant, available-resource oriented, widely spread, sensitive to the requests, and ready to adapt.

The patterns that emerged along the data analysis of the platforms can be described through the lenses of the qualities of organisational resilience. CTT and CANs are not enterprises but reacted to the crisis following similar resilient approaches characterised by flexibility, successful use of resources, effective

Table 2 Communities resilient approaches

Resilient qualities	In the case study	In the literature
Flexibility	Decision to not register the network to remain flexible and adaptable; use of social media to inform and above all discuss about the best solutions to intervene (in the different phases of lockdown and in the different areas)	Burnard and Bhamra (2011a, 2011b)
Successful use of resources	Street committees, NGOs, existing networks; Digital platforms; Municipality opportunities (e.g. police support for distribution; medical guidance)	Sutcliffe and Vogus (2003)
Effective responses	Operationability of the soup kitchens; Food distribution; online fundraising and petitions systems	Horne and Orr (1998)
Adjustment of old responses and creation of new ones	Soup kitchens strengthening; petitions for increased social grants; creation of new urban gardens	Mark et al. (2009)
Development of new capabilities	Discussions about sustainability of the solutions (from emergency to post-Covid-19); webinars oriented to co-learning; deployment of new ICTs approaches (e.g. online quiz for fundraising)	Kendra and Wachtendorf (2003)

responses, adjustment of old responses and creation of new ones, development of new capabilities. Table 2 highlights how these characteristics have been reflected in the case study.

Cape Town together in fact searched to integrate and support existing realities and activities such as long-standing street committees in some neighbourhoods, community-based organisations, NGOs, and social justice movements. While some actors became active during the pandemic, a lot of the involved people were used to advocate for an equitable, permanent, and sustainable solutions to inequality. Activism has a long history in South Africa from the time of apartheid till the recent students' movement for free education (Bosch, 2017; Britton et al., 2009).

Even though many structures existed, the CANs succeeded in creating connections among them, bringing community-based associations, NGOs, and activists into relationship with one another and with new volunteers. Furthermore, the network evaluated the possibilities to become an NGO or an organised movement and decided to avoid it. The choice to not register officially supported the possibility for the network to maintain its flexibility, to avoid bureaucratisation and hierarchical structure, and the risk of internal unbalanced power dynamics. Registered organisations are subject to audit and public presentation of financial reports; the transparency of the network is guaranteed by the visibility on the social media.

Despite the decision to remain a digital footprint, the network engaged with local officials to maximise the possibility of the response, to coordinate the responses, and, when needed, to request for support (for instance, for the registration of new soup kitchens, for the permit to deliver food, or for support during the distribution in unsafe areas of the city). The other critical element for the success of the digital network is the fact that it offers homogenous opportunities to everybody to become part of it, independently of the skills, capacities, resources. The network builds on relationships, locally relevant, that emerged in every neighbourhood and allowed a dynamic structure to grow and choose how to operate, particularly to inspire new people to take part in the action.

Along the process, the reflection over the responses and decisions was constant. The co-learning webinars are run every week. CANs share experiences, reflections, and advices regarding common challenges and solutions adopted and possible collaborations. Guidelines as well as principles concerning the way to act had been part of the discussion together with the CANs formations. One of the main principles concerns the relationships that are built; the premise is to act as a community which shares the value of social solidarity, trying to avoid solutions of pure charity. In line with this vision, the topic of the use of images over the social media has been discussed with an overall agreement to avoid the use of children and suffering people to move donors. At the same time, the storytelling approach had been developed further to give to every community a voice to tell their story.

To deepen the discussion over the principle of solidarity, the network during the open virtual co-learning debates requested people to engage with the topic and its approach. The discussions during the months evolved around the different forms of privilege, power dynamics, politics of donor models, and practices present in the society. An on-going reflection regards the sustainability of certain responses knowing that the pandemic is only the last issue which exacerbated existing social problematics. An open and growing discussion regards the potential for food security responses: a food growers' idea developed within the network, to connect small-scale farmers, community gardeners, and backyard food growers, to share knowledge and seeds and to contribute to a vision of food sovereignty in the city.

7 Discussion

The findings highlight the response to the pandemic as developed and managed by Smart Citizens acting as Smart Communities in a city that is trying to emerge as Smart. Smart Citizens seemed to react to the new challenging situation faster than the City, which had to deal with a lot of bureaucracy and lack of enough data from the field. As seen in the findings, the communities' reactions and solutions are resilient and mainly digital. The specific approaches of CTT and CANs during Covid-19 are compared to the literature of Smart Cities and e-participation to highlight the novelty of the responses and potential lessons for resilient and inclusive solutions.

In the majority of the literature, the assumption is that a City is Smart enough when it enables the citizens to be more active and participate; the City is the driver for e-participation (Vázquez & Vicente, 2019). In our scenario, what we highlight is the civic participation of Smart Citizens who use ICTs to make a difference, to engage between citizens and with the City. E-participation develops before the City transformation into a Smart City. Many of the CANs responses represent the only source of relief for residents to turn to in their areas. While governments' resources lie out of reach, tangled up in bureaucracy, the citizens' network succeeded in bringing solutions, organising with the resources that are immediately available.

Proposition 1 When citizens engage with technologies to develop and support civic activism and social engagement, e-participation from the bottom can develop and bring solutions.

Instead of focusing only on how Smart Cities can favour e-participation (Alcaide-Muñoz et al., 2017), the CTT experience suggests to assess the opposite approach and study how e-participation can become a driver for the transformation of a city into a Smart City.

The literature also shows that less than 50 percent of the Smart Cities examples have created citizens' participation platforms to promote citizens' involvement in public affairs and only a few of them promote online public consultations, discussions, and petitions (Bolivar, 2018). The analysis of Bolivar highlights how limited the results are. Furthermore, it demonstrates how in Smart Cities e-participation of the citizens in the public space is created and managed by the use of new technologies by city governments. The case study highlights how the analysis could move towards or consider also the use of ICTs by the citizens to inform and engage with the City. The CTT platforms succeeded in reaching out to all the neighbourhoods of the city and gathered wide consensus in the social and public media.

Proposition 2 When e-participation is decided and managed at citizens' level, the digital platforms have more possibilities of engaging the public, to reach out to stimulate active citizenship.

While citizens engagement is a key element of most definitions of Smart Cities, scholars highlighted that little research has focused on actual practices of citizens' involvement in Smart Cities so far (Granier & Kudo, 2016). Simonofski et al. (2017) studied citizens' participation in Smart Cities where ICTs have great potential for facilitating public participation and investigated the role of the citizens to transform a city into a Smart City. Their approach focuses on the democratic process involvement and the potential for the citizens to become co-creators of the solutions. Once more though, the paper highlights how along the process the citizens are using the city's ICT infrastructures.

One aspect that seems underestimated in the literature is related to how Smart Citizens and Smart Communities can be the driving force of Smart Cities' discourses and even develop innovative ICTs solutions. Being socially and needs driven, the digital platforms presented in the case study could address and tackle emerging city issues in a direct way. Instead of waiting for options presented by the city, the citizens are actively suggesting solutions.

Proposition 3 When e-participation develops from Smart Citizens in the Communities, social solutions can develop through ICTs innovations.

Few articles present alternative views over the Smart Cities development. One of those is written by Capdevila and Zarlenga (2015). They recognised that so far, Smart City approaches have generally been related to top-down processes of technology diffusion. They intended to showcase a broader view on 'smart' initiatives to analyse both top-down and bottom-up dynamics in a Smart City.

A cornerstone point of reference to analyse these emerging options for a more comprehensive view of Smart Cities is the consideration of the communities as innovators (Charalabidis et al., 2019), not only as users of the ICTs solutions, and not only as source of data. Between the contributors for the development of Smart Cities, Smart Citizens and Smart Communities should play an increasing role to develop sustainable and inclusive solutions. Professional stakeholders, particularly municipality officials and experts, should be able to recognise their role and collaborate. In the case study, the community networks searched for official support and collaborations developed.

Proposition 4 If digital footprints created and managed at Smart Citizens level are coherent, transparent, and formally developed, including the support and networking with the city officials, their credibility and impact can rise.

A Smart City should be seen in all its complexity which integrates different developmental dimensions: economic competitiveness and competence, goods and people mobility, environmental understanding and care, people's quality of life, and governance participation and representativeness (Bencardino & Greco, 2014). In this comprehensive view of a sustainable and inclusive city, Smart initiatives can be driven by the City as well as its Citizens. ICTs should become the necessary means for their connectivity to target social sustainability, inclusion, and potentially economic and environmental solutions, for example, the urban gardening. The projects and solutions should be directed towards the well-being of the citizens. So far, the literature is still verifying whether Smart solutions are explicitly developed for the citizens (see, for instance, Gil et al., 2019). In this effort to meet the society needs and hear the different voices, Smart Citizens should play an essential role in directing the use of technologies. Citizens can suggest ways of using existing means, develop innovation, and avoid to wait for supposed-to-be 'intelligent technologies' to guide the City into imagining and managing urban development (Chamoso et al., 2018). In the case study, the community networks used existing ICTs, mixing platforms and assessing how people could better interact. The scope of the platforms was to actively engage in the pandemic response. The groups started their activities with digital discussions to agree over a collective agenda. Over the weeks, they moved forward in two directions: supportive activities for the most vulnerable, and digitally opening the debate around the social divide and inequality.

Proposition 5 When Smart Citizens utilise digital tools to build a collective public agenda, possibility for inclusion and support to the democratic debate can increase.

8 Conclusion

In the optic of 'Smart Communities', planning that can rely on community-based responses, and not only on top-down official decisions, represents an innovative approach for city management and organisation that revers the order of priorities. A community-focused ecosystem gives priority to the communal goods, to the environment, and to support present and future generations as a premise for community and personal well-being. With the big data analytics capability (Jin et al., 2014), the potential of the Smart Communities and Citizens to make a difference could even increase. Its greatest affordance is the collection and presentation of data using its multiple sensing capabilities. A Smart City should be able to process and analyse those data to the benefit of the people.

The case study suggests that the possibility to build a Smart City is to start from the streets, the neighbourhoods, the communities where citizens are active, responsive, and interested in developing different types of engagement within the society and with the government. CTT and CANs initiatives showed the potential to galvanise significant numbers of people from different areas of a city around a shared experience using existing digital platforms. The ICTs solutions adopted fit the needs and the available resources and knowledge. At the same time, they stimulated the interest of involved citizens to improve the necessary skills to exploit ICT potential further.

This opportunity could be used to connect the different stakeholders, to open a discussion about the re-shaping of the city through the creation of a shared public agenda, including the use of new ICTs solutions, with a focus on the public service. Social innovations driven by digital forms of collective actions can represent a potential direction for the responses to the needs as well as for the reflection-on-action open to all citizens. The opportunity offered by ICT to include all citizens in the discussion and planning creates the bases for reducing the social divide.

Through communities' resilient approaches, such as the ones that emerged during the lockdown in Cape Town, the changes might occur without traumatic phases. It will be of interest to compare the responses adopted in different cities during the pandemic. This research claims the relevance of the pre-Covid-19 conditions related to resilient attitudes, communitarian behaviours, and on-going smart solutions adoption. The limitation of the study relates to the choice to analyse the activities carried on by specific networks (CTT and CANs). They are a representation of driven communities and citizens and not of the entire city.

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Urban Agriculture and the Organisation of Urban Farmers in African Cities: The Experiences of Cape Town and Dar es Salaam

Tinashe P. Kanosvamhira

1 Introduction

A wide body of literature has detailed the major benefits of urban agriculture in African cities, for instance; reducing household food expenditure and providing access to fresh produce (Gallaher, Kerr, Njenga, Karanja, & WinklerPrins, 2013; Mougeot, 2006; Smart, Nel, & Binns, 2015; Thornton, Nel, & Hampwaye, 2010). Despite the benefits offered by urban agriculture practices, it continues to face several challenges such as limited access to land, a lack of resources, limited water availability, and climatic variations, among others (Crush, Hovorka, & Tevera, 2011; Hampwaye, 2013; Mkwambisi, Fraser, & Dougill, 2011; Schmidt, 2011; Tambwe, Rudolph, & Greenstein, 2011). Most scholars agree that some of the challenges stem from unfavourable policy environments that prohibit the practice and its development (Hampwaye, 2013; Simatele, Binns, & Simatele, 2012). The literature suggests that robust urban farmer organisation is essential in countering the challenges largely because urban farmers are more likely to address obstacles they face as a unified unit as opposed to individuals (Mougeot, 2005; Schmidt, Magigi, & Godfrey, 2015). Urban farmer organisation was identified as a fundamental need in the success of urban agriculture at a conference of Local Government Ministers from Southern and Eastern African countries held in 2003 (MDPESA, 2003 in Mougeot, 2005).

Urban farmer organisation involves the union of urban farmers into groups at various scales, for instance, producer groups or associations to accomplish shared goals (Mougeot, 2005). Such unions enable urban farmers to improve the policy environment within which they operate. In other words, urban farmers are more

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likely to influence sustainable planning if they are united and present a better-articulated viewpoint (Simatele & Binns, 2008). Besides this crucial advantage, concomitant benefits extend to reduce production costs through jointly procuring inputs, easy access to credit, improved processing and marketing produce, and establishing partnerships (Hellin, Lundy, & Meijer, 2009; Voleníková & Opršal, 2016). Essentially, urban farmer organisation is crucial as it improves urban agriculture (Schmidt, 2011) which can simultaneously result in the fulfilling of sustainable development goals (SDGs) (Game & Primus, 2015). For instance, improving urban agriculture practices can contribute towards the realisation of SDGs 1 poverty reduction, 2 zero hunger, 3 good health and well-being, and 13 climate action.

While the benefits of urban farmer organisation are clear, the information on urban farmer organisation in Africa remains scanty (Schmidt et al., 2015). Most of the literature on urban agriculture focuses on the contributions of urban agriculture to food security and income generation or the ecological benefits of the practice (Schmidt et al., 2015; Simon, 2012). Urban farmer organisations are actors involved in the urban food system, hence play an important role in urban food resilience (Maconachie, Binns, & Tengbe, 2012). Therefore, development practitioners must appreciate the nature of urban farmer organisation as a prerequisite before implementing any successful developmental programs and policy.

On this background, this chapter examines urban farmer organisation in two Sub-Saharan African cities, namely Dar es Salaam and Cape Town. The chapter aims to explore the organisation of urban farmers and how they influence urban food production in the selected cities. The chapter proceeds with a description of what constitutes an urban farmer organisation and the types thereof. It will also present a brief description of the selected cities before examining the nature of urban farmer organisation in the selected cities.

2 Urban Farmer Organisation Typologies

Wilbers, van Veenhuizen, and Castro (2007) identify three different types of urban farmer groups, namely first-line, second-line, and the third-line. First-line organisations are defined as those that have members of a specific group or groups of the community. This definition implies that if two or more urban farmer group farms unite together within the same community, they are still considered a first-line organisation. Second-line and third-line groups operate from local and national levels, respectively. Wilbers et al. (2007) further classify urban farmer groups as either a primary or secondary group. Primary being those formulated at the grassroots level such as community farms in a community, whereas secondary is a combination of two or more primary groups.

In contrast, Voleníková and Opršal (2016) categorise urban farmer groups according to formality. Voleníková and Opršal (2016, p. 82) distinguish between the two types of urban farmer groups in legal terms. On the one hand, informal groups are referred to as urban farmers 'as the first step in community institutionalisation' and formal groups as cooperatives. In other words, the distinguishing factor between the two is whether the group is formally registered with the local authorities or not. Once a group is registered it is generally visible among stakeholders such as the local municipality and civil society. The literature suggests that formal groups are more recognisable as they are usually registered with the relevant authorities within the municipality (Castro & Santandreu, 2007) and this makes them easily accessible to supporting actors for collaborations and funding. However, Hellin et al. (2009) describe informal farmer organisations as simply collective action. In other words, collective action can exist in the absence of a formal organisation. For example, Voleníková and Opršal (2016) report urban farmers in Ndola (Zambia) working together despite not being formally registered as a cooperative with the relevant authorities.

Another categorisation is offered by Castro and Santandreu (2007) who separate urban farmer groups into either sell-organised organisations or sponsored organisations. Self-organisation is portrayed as urban farmer groups formed by the interest of members of a particular community in response to a specific need. Their bottom-up formation means they are highly self-driven and possess support from the group members; however, they may suffer from limited external support. Castro and Santandreu (2007) note that they face a challenge in accessing resources and establishing linkages with strategic partners due to limited connections. On the other hand, sponsored urban farmer groups include those that are initiated by an external organisation such as local government, churches, or a non-governmental organisation. By this very nature, they have access to resources and partnerships which are largely facilitated by the initiating organisation. Such associations include those that were formulated under the Urban Vegetable Promotion Project in Dar es Salaam. Regardless of the classification Castro and Santandreu (2007) report that sustainability can be threatened across both types hence capacity building is vital to meet the needs specific to each group.

From the above discussion, it is clear that scholars classify the organisation of farmers into various groups using different yardsticks. However, there are several significant points which can be drawn from the classifications. Primarily, urban farmer associations can be formed from a bottom-up or top-down approach with the varying influence from external stakeholders. Secondly, urban farmer groups usually form from a local level hence terms such as primary organisations, producer groups, and first-line organisations which are more or less synonymous. These small-scale farmer groups could then work together with other groups and organisations, resulting in an inter-group association, producer network or second-line associations. Further, if the primary group is affiliated with a group from a wider area then that becomes a second-line organisation. Formality or informality in this case simply distinguishes whether the urban farmer group is a recognised group or not. Collective action can exist without any organisation (Hellin et al., 2009), although recognition with relevant authorities could become a challenge (Voleníková & Opršal, 2016). Accordingly, this chapter adopts the definition by

Wilbers et al. (2007) while at the same time distinguishing between the formal organisation and informal collective action as suggested by Hellin et al. (2009).

3 Methodology

The study is based on an in-depth analysis of peer-reviewed articles, grey literature and policy documents on urban agriculture of the selected cities. Peer-reviewed articles were salvaged from Scopus and Google Scholar following a flexible systematic literature review process. The research question was formulated as ‘what is the evidence on urban farmer organisation in Cape Town /Dar es Salaam?’ The emphasis was on peer-reviewed material from the last 20 years, but a few crucial publications which were older or not peer-reviewed were also included. During the first search, the literature on urban farmer organisation in Cape Town and Dar es Salaam presented 1 and 5 results, respectively. As a result, the scope had to be broadened to urban agriculture in general. Consequently, the search result was increased to 27 and 33 for Cape Town and Dar es Salaam, respectively. The journals from which the peer-reviewed articles were selected include themes such as food policy, sustainable cities and agriculture development.

Scanning of abstracts was conducted to identify articles which fit the scope of the study from the retrieved documents. Thereafter, the full journal articles were downloaded and reviewed. Grey literature in the form of policy documents and study reports were harnessed from Google scholar. Due to the limited amount of scholarly literature on the subject, the search was broadened to include documents captured from this search engine. Unpublished literature was also retrieved from websites of organisations which support urban agriculture, for instance, the resource centre on urban agriculture and food security (RUAF). Policy documents and official reports were retrieved from Google Scholar as well including the urban agriculture policy of the City of Cape Town. Other policy documents selected include the national land policy of 1995, agricultural and livestock policy of 1997, the national human settlements development policy of 2000 of Tanzania. The documents gathered were selected based on their availability, ease of access and whether they conform to the scope of the research.

This study intends to obtain a deeper understanding of the nature of urban farmer organisation across the selected cities. It achieved this by comparing the experiences of Cape Town and Dar es Salaam. In terms of analysing the literature, the study adopted the hermeneutic approach since it is most suitable for textual work (Kinsella, 2006). Kinsella (2006) explains that this approach is characterised by the meticulous reading of text since language plays a crucial role in formulating interpretations.

The chapter assembled peer-reviewed articles, grey literature and policy documents to improve the understanding of urban farmer organisation. Therefore, the content of the text was carefully studied multiple times to try and appreciate the meaning and relative implication of some of the articles. Official reports and policy documents were crucial to understanding the policy environment within which urban agriculture was conducted across the selected cities. The analysis intended to identify the impact of specific policies on the urban farmers across the different localities. As a result, some of the experiences of urban farmers could be explained based on the policy environment within the two cities. The next section will provide a brief description of the selected cities for this chapter, namely; Cape Town and Dar es Salaam.

4 Study Areas

The selected cities for this chapter were Dar es Salaam in Tanzania and Cape Town, South Africa (Fig. 1). Both cities were selected based on their well-established urban agriculture systems that are rooted in very different urban planning approaches and contrasting political systems. For instance, Dar es Salaam represents East Africa in terms of urban agriculture and several studies have been conducted in Cape Town. These two cities differ in terms of their urbanisation patterns and economic, environmental and institutional context, which aids in providing a better understanding of the organisation of urban agriculture initiatives within their different contexts. Moreover, compared to other cities in the region where urban agriculture is prominent, for example, Lusaka (Simatele et al., 2012), Harare (Drakakis-Smith, Bowyer-Bower, & Tevera, 1995; Mbiba, 2000), Lusaka (Rakodi, 1988), Maputo (Paganini, Lemke, & Raimundo, 2018; Sheldon, 1999) and Johannesburg (Malan, 2015), significant literature exists on urban agriculture on the selected cities which makes them suitable for this particular study.

Cape Town is the second-largest city in South Africa harbouring a population of approximately 4,004,793 residents (City of Cape Town IDP (CoCT IDP), 2017) and is expected to grow at a rate of 5.4% by 2023 (City of Cape Town (CoCT), 2016). Similarly, Dar es Salaam has approximately 6 701 650 inhabitants and has an annual growth rate of 5.23%. These figures suggest that there is the presence of rapid urbanisation which is steadily increasing ultimately affecting the employment and service delivery within these cities. The high population growth rates in Cape Town and Dar es Salaam can be attributed to both natural growth and in-migration. This growth is attributed to the dominance of a tertiary industry as opposed to other cities dependent on the volatile mineral sector (City of Cape Town IDP (CoCT IDP), 2017). Unemployment rates are estimated at 24% with around 186,000 individuals in the informal sector (Haysom, 2015). Conversely, Dar es Salaam, the former capital of Tanzania functions as the commercial, administrative, and industrial hub of the country.

Despite these above-mentioned specificities, the different cities share some commonalities which provide a strong base for comparisons. Generally, urban agriculture receives support from both non-state and state actors across all cities (Kanosvamhira, 2019; Schmidt et al., 2015). Both cities have a non-governmental organisation (NGO) presence which has been significant in supporting urban

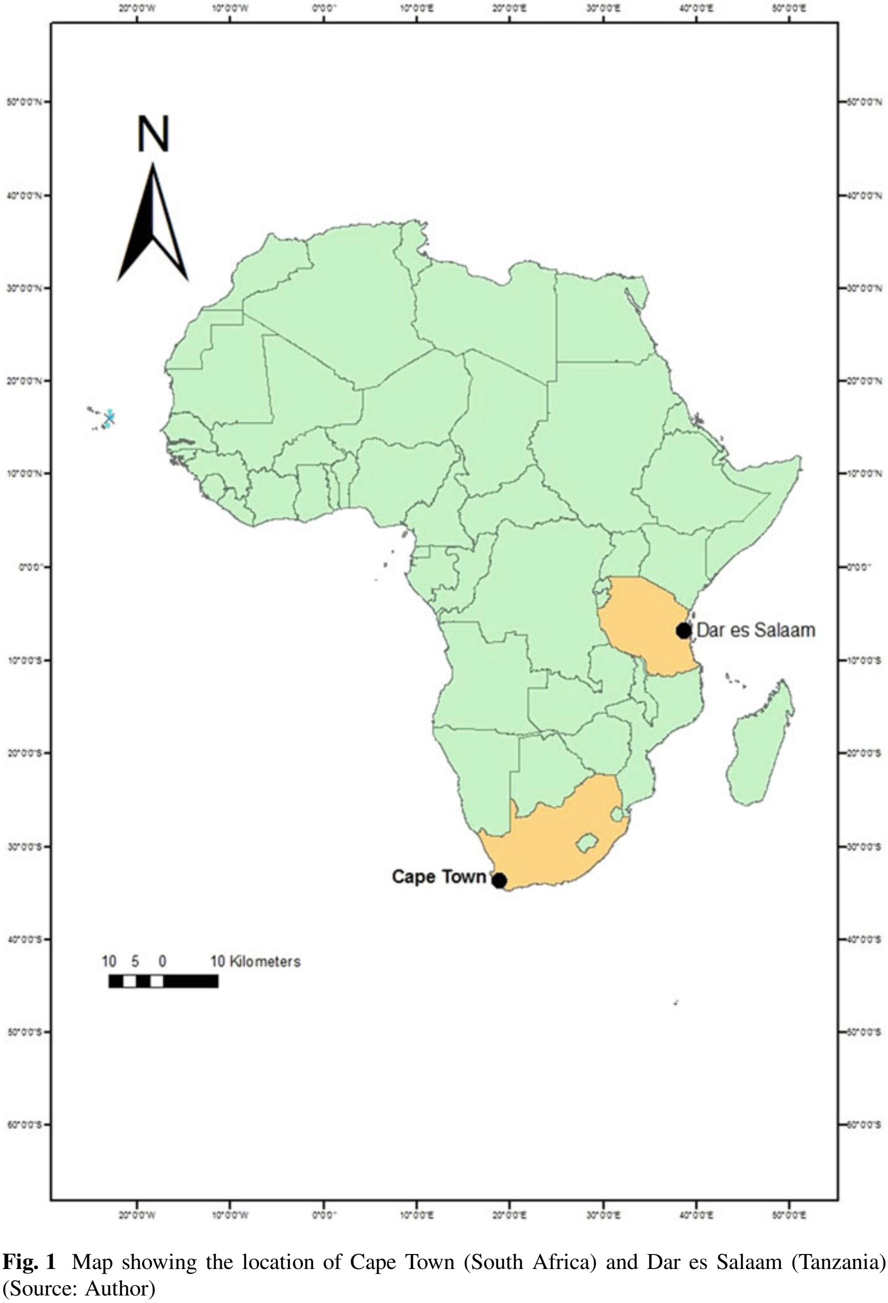

Fig. 1 Map showing the location of Cape Town (South Africa) and Dar es Salaam (Tanzania) (Source: Author)

agriculture although the levels are varied. Also, the municipal government has been instrumental in supporting urban agriculture initiatives in both cities through the adoption of urban agriculture policies or legislation which recognises the activity within cities borders. For instance, Cape Town passed the now-defunct Urban Agriculture Policy of 2007.

Similarly, Dar es Salaam passed one of the most elaborate bodies of legislation on urban agriculture across Africa (Sawio, 1993) although the activity is not formally recognised (Halloran & Magid, 2013). Nationally the Town and Country Planning (Urban Farming) Regulations of 1992 deal with urban agriculture, the other urban-related policies, namely the National Human Settlements Development Policy of 2000 do not explicitly address issues of urban agriculture (Mkwela, 2013). As a result, unlike Cape Town, it is not formally recognised although the policy facilitates its occurrence. Moreover, the formalisation of urban agriculture in Cape Town has been deemed as consultative (Rogerson, 2010), whereas it has been labelled as a top-bottom process in Dar es Salaam (Bersaglio & Kepe, 2014). Nonetheless, the urban farmer organisation is generally expected to be prevalent as the policy environment generally seems to be conducive to the support of urban agriculture activities across both cities. In sum, the similarities and differences between these two cities make them suitable as the study areas for this chapter. The characteristics of each city will facilitate a juxtaposition of good practices from each city presenting an opportunity for one city to learn from the other.

5 Urban Farmer Organisation in Cape Town and Dar es Salaam

5.1 Cape Town

Cape Town has the most diversified urban agriculture system in South Africa receiving support from both municipal government and non-governmental organisations (Erik, Fiege, & Kühn, 2019; Kanosvamhira, 2019). Both state and non-state actors have supported urban agriculture as one of the many strategies to promote socio-economic development across low-income communities (Battersby & Marshak, 2013; Paganini & Schelchen, 2018). The City of Cape Town has supported urban agriculture through the now-defunct Urban Agriculture Policy of 2007 which was eclipsed by the Food Gardens Policy of 2013. NGOs are instrumental in subsidising farmer costs through the provision of inputs and infrastructural resources (Kanosvamhira & Tevera, 2020b).

Most of the urban farmers in Cape Town cultivate vegetables in their backyard spaces and on community food gardens mostly located on public land (Paganini & Schelchen, 2018). Most of the food gardens are located in low-income communities in Cape Town (Tembo & Louw, 2013). The community food gardens, therefore, offer an opportunity for the development of first-line producer groups. While there are many community food gardens in Cape Town the literature suggests that the dynamics of community gardening presents several challenges for the sustainability of the gardens (Reuther & Dewar, 2006; Tembo & Louw, 2013). Battersby and Marshak (2013) conducted a qualitative study investigating the benefits of urban gardening among farmers in Vrygbond and Sea winds. This study discovered that one of the major NGOs had stopped supporting community gardening due to the unsustainability of the urban farmer groups.

The Siyazama Community Farm Association (SCAGA) is an example of a food garden where farmers can conduct their activities under the umbrella of a big structure. Small (2007) also reported similar findings to Battersby and Marshak (2013) related to group stability, whereby they face sustainability challenges emerging from disputes among members that often result in some members withdrawing their membership. Reuther and Dewar (2006) have argued that farmers in SCAGA were likely to abandon the activity if they found employment outside the gardening sector. Moreover, most of the urban community farmers in Cape Town preferred to work individually rather than collectively due to issues such as different levels of commitment by some members and frequent membership turnover which often presents sustainability challenges for the garden groups. Ultimately all these dynamics affect the ability of farmers to collectively work together at a grassroots level. In other words, although urban farmers may be constantly meeting on the same garden it is not enough for them to form bonds of solidarity that are a prerequisite successful collective action and subsequent organisation. Collective action may be crucial in activities such as purchasing inputs, transportation of produce, and marketing of produce. As a result, limited collective action at a community garden level potentially hinders the effectiveness of higher-level urban farmer networks in Cape Town.

Although cooperations do exist these do not feed into higher line associations. For instance, the now-defunct Vuka Uzezenzele Urban Farmers Association (VUFA) was an urban farmers association consisting of farmers mostly from the Cape Flats region of Cape Town. The association was formulated to mitigate issues that urban farmers face (Small, 2007). Although VUFA is no longer operation this was an example of a second-line organisation where farmers from different wards could unite as a collective. The failure of the association, therefore, suggests the need for stronger urban farmer groups which can feed into organisations at the next level.

NGO presence has been instrumental in stimulating collective action among urban farmers in many of these gardens through several initiatives which subsidise farmer costs (Karaan & Mohamed, 1998; Paganini & Schelchen, 2018). A case in point was the Harvest of Hope (HoH) enterprise which improved the marketing opportunity of urban farmers. Through this project, urban farmers in Nyanga and Khayelitsha supplied produce to the HoH enterprise a community-supported agriculture system which sold the vegetables to consumers throughout the city (Dyer, Mills, Conradie, & Piesse, 2015). As a consequence, urban farmers within the various organised garden projects were able to work together to ensure that the required amount of produce is met. Due to the perceived monetary benefits, each farmer ensured that the required quantity of produce is met and this creates a sense of unity among the farmers. Therefore, this presents an example of collective action in the absence of a formalised urban farmer organisation. Nevertheless, reliance on external actors can significantly affect the selling of produce, for instance, it resulted in food waste due to poor crop planning (Paganini et al., 2018). Based on the aforementioned cases it is clear that although there may be many supporting actors within Cape Town the prevalence of formal urban farmer associations is limited. However, urban farmers are organised informally. In other words, collective action may exist without formal organisation as argued by Hellin et al. (2009).

5.2 Dar es Salaam

In Dar es Salaam the situation on urban farmer organisation is different from Cape Town as the practice is not formally recognised by the city (Mkwela, 2013). Nonetheless, in terms of legislation and policy, Dar es Salaam has the most elaborate policies on urban agriculture (Sawio, 1993). In other words, while urban agriculture is accommodated it is not formally recognised through a guiding policy as in the case of Cape Town, South Africa. In comparison to Cape Town, the policy environment may be more prohibitive. Furthermore, Bersaglio and Kepe (2014) argue that the formalisation of urban agriculture has been characterised by a top-down approach and this has excluded urban farmers from the consultative process, hence hindered the development of the sector. Urban agriculture is prevalent in the city and all indicators point to its continuity given the harsh economic conditions in the Dar es Salaam (Schmidt et al., 2015).

Like in Cape Town, urban agriculture exists in various forms, particularly as home-based and community gardening. According to Jacobi, Amend, and Kiango (2005), community gardens exist in either formal or formally organised groups in different communities. Nonetheless, they are also characterised by individual ownership. The level of organisation of these community farmers enables them to access extension services and inputs (Jacobi et al., 2005). Besides such benefits, the gardening groups perform social functions which include credit and savings, access and financial assistance with weddings and funerals. Also, community gardens cultivation exists in open spaces where more than one farmer operates; however, the individuals do not necessarily work together in such cases.

Urban farmers in Dar es Salaam are formally organised into structured organisations. A study by Schmidt et al. (2015) reported the prevalence of urban farmers associations in Dar es Salaam that are fairly structured. As such, they possess a constitution and general aims of the association. Although the urban farmer groups are presented with challenges such as land tenure security, they were able to counter such problems collectively. Due to their organisation, they were able to negotiate for land from the local municipality. Ultimately, Schmidt et al. (2015) argue that the associations in Dar es Salaam play an active role in promoting urban agriculture for its members. Furthermore, the urban farmer associations can collaborate with various supporting organisations which aid the development of the sector. This is because they are easily approachable by interested stakeholders due to their registration with relevant authorities in the city. However, the formation of urban farmer organisations in Dar es Salaam is equally a challenge as in with Cape Town. Schmidt (2011) reveals this by focusing on the Urban Vegetable Promotion Project (UVPP) which attempted to improve urban farmer organisation in Dar es Salaam. The UVPP attempted to organise urban farmers in the city through the provision of organisational and technical skills training. Nevertheless, the initiative was unsuccessful after the project was concluded in 2001. As a result, many of the urban farmer groups that had been started were characterised by dwindling membership failing to sustain them. Moreover, the local district councils failed to continue supporting the urban farmer groups in terms of extension services which include monitoring and training.

6 Discussion

As evident from the experiences of Cape Town and Dar es Salaam above, the conceptualisation of urban agriculture organisation merely in terms of formal or informal is quite misleading. A more accurate understanding of the organisation of urban agriculture needs to account for variations in the context in which it occurs. Adding to this, this chapter shows that the involvement of stakeholders in strengthening urban farmer organisations is necessary, however, in different ways specific to each case. In light of this, the real character of urban farmer organisation can only be understood by revealing underground realities and factors which might not be immediately visible.

The experience of Dar es Salaam suggests that formal organisations are perhaps the most appropriate form of action in that context. The case of Dar es Salaam shows that they are better placed in making the necessary negotiations when it comes to issues that deal with access and tenure of land for cultivation as compared to Cape Town. As a result, there are improved linkages between urban farmers and the municipality which allows for better access to resources such as land and related inputs. With such visibility, it becomes easier for other urban farmers to recognise and join the network, thereby improving its membership and subsequent bargaining power. This seems to be the rationale behind the prevalence of urban farmer associations in Dar es Salaam as well as other urban farmers across African cities, for instance, in Free Town (Sierra Leone) (Maconachie et al., 2012) and Maputo (Mozambique) (Paganini et al., 2018; Sheldon, 1999). Such structures are usually accompanied by a top-down approach adopted by the government which results in the highly formalised structures among urban farmers. As a result, there is likely to be improved production due to the presence of prerequisite resources such as land, inputs, and extension services.

Conversely, the literature shows that urban farmers in Cape Town are not highly formalised. The history of urban agriculture in the city is responsible for the state of organisation which has resulted in a highly informal state. Nonetheless, there are significant linkages to civil society actors such as NGOs which allow them to access benefits such as improved market access and reduced operational cost without necessarily being formally organised. Although the two cities differ in terms of the level of urban farmer organisation, as it is, it appears that the different urban farmer groups can access resources from the relevant supporting actors, namely the government and NGOs.

The formulation of farmer group networks and associations is an extremely challenging process (Hellin et al., 2009) as the experience of Cape Town suggests that urban farmers struggle to cooperate even within the same locality. While these two cases provide a clear indication that it is possible for urban farmer groups to emerge at local and provincial levels, it is a strong base that is perhaps lacking. Unfortunately, this presents two major limitations. The first limitation relates to the failure of urban farmers to obtain adequate support from supporting organisations such as NGOs or benefit from economies of scale. The case of Cape Town shows the reluctance of specific NGOs in assisting community farming projects due to a lack of sustainability. The next problem is the failure lack of presence of secondary line producer groups. Secondary line producer groups are a prerequisite for the emergence of an urban farmer association at a higher level, for instance, municipal, provincial, or national level. The Cape Town experience shows that if urban farmer organisation is limited at a lower level it directly translates to the absence of a strong second-line organisation. As such urban farmers are not able to influence the policy environment beyond their community borders since they do not possess a more unified voice.

Urban farmers are more formally organised across the city of Dar es Salaam. This reflects strong bonds as urban farmers can join together under one common voice leading to the formation of first and secondary line producer groups. Urban farmers in Dar es Salaam face several challenges, for instance, insecurity of access (Schmidt, 2012), hence the need for them to find a common solution for their problems. Unlike Cape Town, urban farmers in Dar es Salaam have consistency in terms of membership tenure within the different associations. This indicates that there are either fewer disputes or there are mechanisms in place to deal with disputes if and when they do arise. Ultimately the improved organisation of the urban farmers translates to improved associations which can unite under a single voice and influence policy change. Improved urban farmer organisation in Dar es Salaam makes it easier for them to collaborate with supporting actors and enhance their activities compared to urban farmers in Cape Town. Looking at the case of Dar es Salaam, it is evident that such linkages with the state are easier when the farmers are well organised which enables them to acquire resources from the relevant supporting stakeholders. Unlike in Cape Town, where linkages are low in comparison it may be cumbersome for urban farmers to lobby for resources such as land from the state. This does not imply that urban farmers in Cape Town do not receive support, instead, it suggests that support unfolds in an uncoordinated manner due to the lack of formal organisation. Unfortunately, this results in the duplication of activities reducing any significant impact of the initiatives (Kanosvamhira & Tevera, 2020a).

Although urban farmers have managed to unite without the involvement of outside influence it seems this may be failing for urban farmers in Cape Town. Literature from a broader context shows that supporting actors can indeed stimulate the organisation of urban farmers by offering incentives. A case in point is the NELSFAL in Nairobi which clearly shows how stakeholders can influence the sprouting of urban farmer groups at a lower level (Lee-Smith, 2011). Furthermore, Castro and Santandreu (2007) argue that although farmers can be self-organised or sponsored each comes with its limitations. For instance, stakeholder influence is evident in the HoH project in Cape Town. This example shows that NGOs can help stimulate and organise urban farmers to get them working collectively towards a shared vision. Nevertheless, overdependence on NGOs may result in several problems. For example, the demise of the UVPP in Dar es Salaam and challenges faced by the HoH enterprise in Cape Town shows that there are palpable caveats where stakeholders become directly involved with urban farmer organisation issues. Therefore, while sponsorship may be appropriate it has to be in a manner that does not promote dependency but instead stimulates sustainability of the urban farmer organisations and their activities.

Finally, while the policy environment is crucial in urban agriculture activities, they generally seem not to have a substantial impact on the formulation of urban farmer organisations. For instance, the conditions in Cape Town suggest that there is generally a formal recognition of the practice. Unlike Dar es Salaam, Cape Town has managed to craft policies which directly relate to urban agriculture activities (Table 1). Of course, this does not dispel the possibility that there may be a disjuncture between policy and practice in Cape Town as with other cities in the region. For instance, Moyo (2013) reported that although Bulawayo had an urban agriculture policy its implementation was lacking such that urban agriculture activities were not enhanced despite the presence of the policy. Nevertheless, urban

Table 1 Summary of policies affecting urban agriculture in each city

City	Policy	Policy Focus
Cape Town	Urban Agriculture Policy 2007 (now defunct) Urban Agriculture Policy 2013 (under review) Food gardens Policy 2013	To address food security by promoting urban agriculture, home, and community farms To address food security by promoting urban agriculture, home, and community farms. Also appreciates the multidimensionality of urban agriculture including its social, economic, and ecological benefits To establish food gardens to enhance food security in low-income areas
Dar es Salaam	National Land Policy of 1995 Agricultural and Livestock Policy of 1997 National Human Settlements Development Policy of 2000	Land administration To develop agriculture and livestock development Management and regulation of human settlements

Compiled by Author

agriculture seems to be generally accommodated and there is a prevalence of support from NGOs in Cape Town. Despite such conditions, the level of organisation among urban farmers in Cape Town seems to be generally lacking.

Conversely, urban farmers in Dar es Salaam seem to be more organised despite a policy environment which may not be so accommodative compared to Cape Town. The policies identified in Table 1 were crafted primarily for other issues other than that of urban agriculture. For instance, the national land policy of 1995 deals with land administration issues, while the Agricultural and Livestock policy of 1997 was intended to address agriculture issues broadly (Kiduanga & Shomari, 2014). In other words, the provisions for dealing with urban agriculture are rather peripheral. Furthermore, most of these policies are national policies which imply that there is an absence of more location-specific policies for the city of Dar es Salaam. Given that the policies are generally pro-poor although not exclusively in the case of Dar es Salaam, there exists an opportunity for urban farmer organisation to prevail. The situation of these cities is in stark contrast to cities such as Lusaka where there is a lack of pro-poor policies which support urban agriculture (Simatele et al., 2012). Essentially, experiences from Cape Town and Dar es Salaam provide us with important insights in terms of urban agriculture and the potential impact on urban food resilience.

7 Conclusion

Essentially, the union of urban farmers ensures that they present a more articulate viewpoint in influencing policy development and ultimately develop urban agriculture (Simatele & Binns, 2008). While the literature is emerging and presents some significant empirical studies within the identified cities it is clear that more empirical studies are required to understand the linkages between urban farmer organisation and urban agriculture. This chapter shows us that although the policy environment is vital in enhancing urban agriculture activities urban farmer organisation is equally essential. The Dar es Salaam experience shows that urban farmer organisation can exist despite a lagging behind policy framework. Urban farmers play an important role in the urban food system; therefore, such groups must be strengthened to enhance urban food resilience. Nevertheless, improving the policy environment will significantly enhance urban agriculture activities in both cities. As such cities have a vital role to play in governance interventions that will facilitate food availability (Haysom, 2015). In other words, local governments need to cultivate a conducive policy framework if urban agriculture is to be developed sustainably. Another important finding is that collective action does exist in Cape Town although it is not formalised as in the case of Dar es Salaam. This shows that the distinguishing of formality is not as pronounced as the literature tends to portray. Instead, all the typologies are not rigid but are rather permeable. Therefore, instead of attempting to identify the type of urban farmer organisation what is important is perhaps appreciating and strengthening the nature of the existing networks across the different environments.

In sum, this chapter contributes to the literature by providing a step in presenting an overview of urban farmer organisation across Sub-Saharan Africa through the focus of the two selected cities. Ultimately, other Sub-Saharan African cities can learn from the experience of Cape Town and Dar es Salaam, thereby enhancing urban agriculture activities in their respective cities. That being said, other cities must take into account their local context when deciding strategies to adopt towards their urban agricultural development, hence the need for more location-specific studies. Overall, it is clear from the presented examples of Cape Town and Dar es Salaam that the nature of urban farmer associations varies across the cities. It is a challenge to have urban farmers to work collectively let alone organise formally. The involvement of supporting actors in stimulating collective action and organisation should be adopted with caution.

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Smart Energy Sharing in a German Living Lab

From Participation to Business Model

Tobias Brandt, Lucas Schmeling, Antonieta Alcorta de Bronstein, Ernst Schäfer, and Alexandra Unger

1 Introduction

Modern cities are confronted with a variety of short and long-term challenges that question urban planning and urban development of the last 70–100 years. These challenges include growing urbanization, growing demand for energy and resources, climate change, digitization, and demographic change (Hodson & Marvin, 2010). Cities are affected by these challenges in two ways. On the one hand, they are vulnerable to these changes, as numerous weather extremes in the last decades and the recent Corona pandemic have shown. On the other hand, they are source and driver of these changes. Although cities occupy only about 3% of the earth's surface, they consume over 70% of the energy produced and emit over 70% of the energy-

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related greenhouse gases (Seto et al., 2014). Therefore, the question has arisen again in recent decades, how cities must be shaped and structured in order to be able to cope with the changes, to reduce their hunger for resources and energy, and how to become drivers of positive development (Dawson, 2011). In this context, the concept of resilient cities and municipalities has been established. Resilient cities can be understood as places that can both deal with short-term shocks (resistance) and adapt in the medium and long term to requirements that are necessary for sustainability (transformation of urban structures) (Deppisch, 2017). What at first glance sounds simple and comprehensible is in practice a complicated, if not a complex undertaking.

Furthermore, as Kemp and Van Lente (2011) argue, transformation encounters two major challenges: (1) long-term changes in technologies and infrastructures, and (2) changes in the opportunities available to people in their daily lives. Technologies and infrastructures are strongly linked to consumer demand and also to legal and financial opportunities. Transformation of urban structures is therefore not only a question of technology, construction processes, or markets but also of cultural and social values that influence transformation (McCormick et al., 2013). Resilient cities deliberately create opportunities for fundamental changes in the system in order to be able to deal better with the conditions that are emerging (Nelson et al., 2007).

One important transformation of urban structures is to build a more sustainable and resilient energy supply, establishing energy-efficient urban neighborhoods as a key point. On the technology aspect, the shift of the energy supply toward renewable sources implicates huge challenges for the energy system in general and for the electricity system in particular. Renewable energy sources are more volatile than fossil fuel-fired power plants and do not necessarily generate the electricity when needed. At the same time, more and more renewable energies are needed in the heating and mobility sectors IEA (2019a, 2019b), with an increasing amount of (renewable) electricity being used instead of fossil fuels in the context of so-called sector coupling (IRENA et al., 2018). Managing the energy supply system to guarantee the availability of electricity, heat, and other forms of energy is becoming more complex and requires the development of new solutions (Khodayar et al., 2012; Müller et al., 2015).

In terms of the social and cultural values influencing a transformation process, the living lab approach offers the space to bring together the relevant stakeholders and the opportunity to co-create and elaborate solutions that consider technical, business-oriented, citizen-oriented, and legal aspects.

The lessons learned in this chapter are derived from a project that organizes a local energy system through a co-creation process for a new urban neighborhood. The *ENaQ* project (in German for “Energetisches Nachbarschaftsquartier”,[1] in English “Energetic Urban Neighborhood”) includes, among others, the design and

[1]Full: “Energetisches Nachbarschaftsquartier Fliegerhorst Oldenburg”, https://www.enaq-fliegerhorst.de.

realization of the technical infrastructure in the district neighborhood and the development of a digital platform that enables the residents to get actively involved in the local energy market. Both of these aspects are to be realized within a participative process, common to living labs and taking into consideration the local stakeholders, finally improving the neighborhood's resilience.

1.1 Research Question

This research's aim is to answer how a local energy market can be co-designed by the stakeholders in an urban living lab promoting transformation of urban structures, and hence building more resilient neighborhoods. This participatory approach can help increase awareness for a greener energy supply and to develop a business model which will have a better chance of acceptance and application in the citizen's daily life. To answer this question, Sect. 2 provides background knowledge, including related work, distributed energy systems, and information about the *ENaQ* project. Section 3 gives insights into the concept of living labs and particularly the aspect of participation. It provides ideas for different participation intensities and dimensions in a living lab. The establishment of a local energy market is described in Sect. 4. This energy market needs to consider the ideas and wishes of the stakeholders, local citizens included, but is also bounded by legal considerations. Subsequently, to reduce the effort and give simple tools to incentivize the residents toward a better energy consumption, Sect. 5 describes how digitalization can help achieve this goal. Section 6 explains how participation contributes to building a resilient city not only with technical innovations, but due also to the participation process. In Sect. 7, the chapter closes with a brief description of the future steps in *ENaQ* as a living lab. Finally, Sect. 8 concludes the chapter.

The main contribution is the report of the field research, including participant observation and surveys, by which the participation process in general and the co-creation process in particular, is analyzed. Special consideration is taken to the needs and project goals, the legal and economic considerations, and the technical implementations of this particular case. The results can be used as an example for other similar (research) projects. As this is an ongoing project, the results are preliminary and the evaluation is yet to be done.

2 Background

The following section gives relevant background information in order to better understand the chapter. The related work in Sect. 2.1 introduces other living lab projects in the domain of energy systems in urban areas and shows how resilience is connected to this topic. Additionally, an overview of distributed energy systems is given in Sect. 2.2. In Sect. 2.3, the *ENaQ* living lab project is presented to explain the general setup in which the research takes place.

2.1 Related Work

The concept of living labs has become more popular since around the turn of the millennium (Bergvall-Kåreborn & Ståhlbröst, 2009). This can be seen in the number of other living lab projects next to *ENaQ* which are working on renewable energy supply solutions.

The projects that are closest to *ENaQ* can be distinguished by two different approaches. On the one hand, there are projects aiming mainly at creating an energy solution together with local residents, with a focus on the participation part. These projects create a living lab in collaboration with local stakeholders and focus on a more climate-friendly energy supply. Examples are the German projects *EnStadt:Pfaff*[2] Polst and Elberzhager (2020a, 2020b) *QUARREE100*[3] (Röder et al., 2020), and *Zwickau Energiewende Demonstrieren (ZED)*[4] (Werner et al., 2020; Nefodov et al., 2019). On the other hand, some living lab projects mainly focus on the local energy market (in which the prosumers can actively participate) as well as on technical aspects of the energy system. Examples are two projects in the Netherlands, namely *PowerMatching City* in Groningen (Wijbenga et al., 2014; Geelen et al., 2013) and "De Ceuvel"[5] (Andoni et al., 2019; Spectral, 2020) and one project in Switzerland, "Quartierstrom" project[6] (Meeuw et al., 2020; Brenzikofer et al., 2019). The last two projects, for example, focus on blockchain technology (Andoni et al., 2019; Spectral, 2020; Meeuw et al., 2020; Brenzikofer et al., 2019).

In contrast to the mentioned projects, *ENaQ* aims to combine both approaches, i.e. designing a local energy market while having a wide participation.

2.2 Background on Distributed Energy Systems

Currently, the electricity supply of most industrialized countries is based on a top-down model: electricity is generated, mostly by burning fossil fuels, in a few centralized large-scale power plants before being transmitted to the consumers via different voltage levels (Bradford, 2018). Driven by political efforts in cli-

[2] https://pfaff-reallabor.de.

[3] https://quarree100.de.

[4] https://www.energiewende-zwickau.de.

[5] https://deceuvel.nl/en.

[6] https://quartier-strom.ch.

mate change mitigation and by the will of the population to participate in the electricity supply, this scheme is currently undergoing partial changes. Small, mostly renewable energy-based micro-generators such as Photovoltaic (PV) or wind turbines are being built close to the actual energy demand (Jenkins et al., 2010). This type of generation close to consumption at lower voltage levels is called distributed generation (Ackermann et al., 2001). Even natural persons have the opportunity to produce the electricity they consume themselves. In this case, they are referred to as prosumers (Jacobs, 2016). The associated national supply model can be described as bottom-up, since electricity also flows from the lower to higher levels (Bradford, 2018). A graphical representation is shown in Fig. 1. The transformation process toward this new form of distributed and renewable energy supply is known in Germany as "Energiewende" (energy transition) (Hake et al., 2015; von Hirschhausen, 2014).

The benefits of distributed generation are much more palpable in a residential neighborhood given the proximity, the limited size, and the possibility of having prosumers. In addition, controllable generators such as Combined Heat and Power Plants (CHPs) and controllable consumers such as heat pumps are often used for heat generation. Through intelligent control, these could be used to stabilize the power grid (Lund, 2005) and reduce emissions (Tsikalakis & Hatziargyriou, 2006) compared to traditional heat supply solutions. Making the aforementioned transformation processes visible and tangible to the residents and letting them participate and benefit directly can be achieved easier in residential neighborhoods compared to larger residential areas. In the following sections, the *ENaQ* project is used as an example to describe how the integration of distributed energy supply systems in an urban environment can be approached with the participation of various stakeholders.

2.3 The ENaQ Project

The *ENaQ* project was preceded by participative practices which ultimately laid the foundation for the project. As living space has been scarce in the city of Oldenburg, the municipal administration decided to repurpose the Fliegerhorst district, which is a former military airbase, into an urban settlement area. As this area is the last in its size which is still located within the city boundaries, it offers a unique potential for developing an innovative and exemplary housing settlement. Apart from the project partners, regional and local stakeholders were also involved in its development.

A citizen-centered approach focusing on the needs and expectations of the population within the framework of spatial planning law and the technical possibilities can also anticipate resistance in the implementation of the project (Alcántara et al., 2016). Hence in the period from February 2015 to February 2016 a participative process was carried out with the aim of creating a spatial development plan, in German "Masterplan", for the Fliegerhorst area.

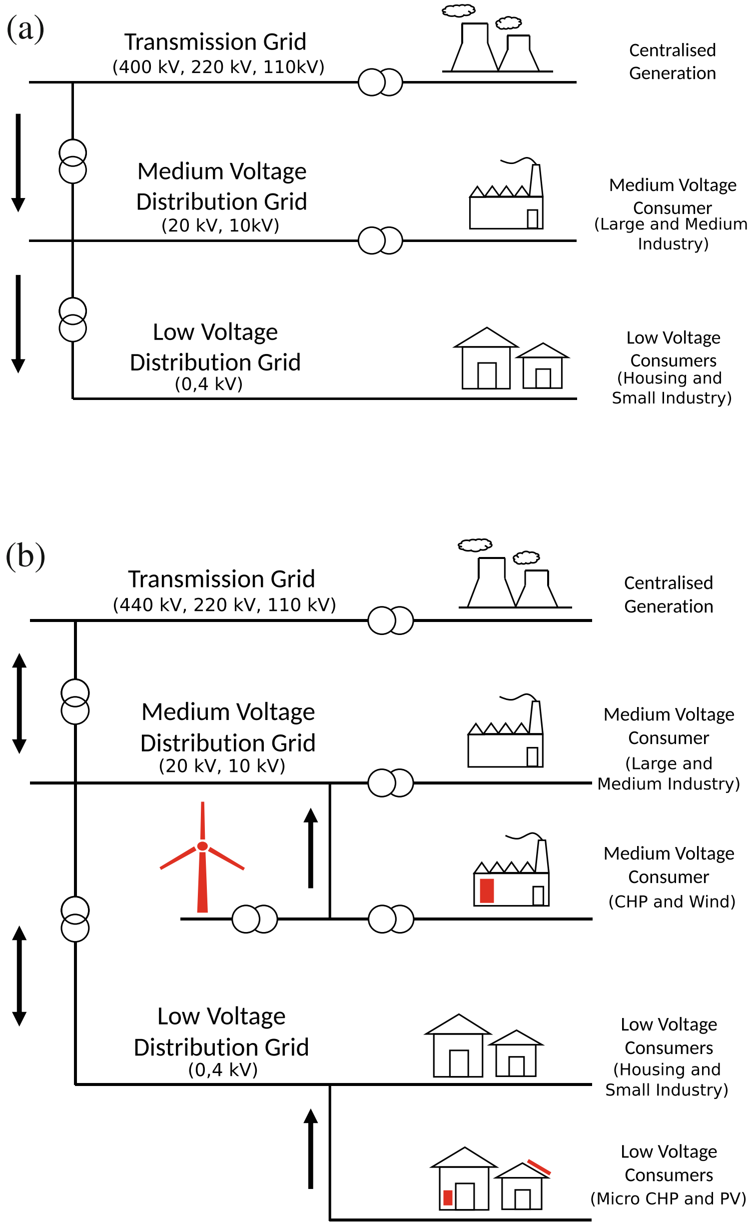

Fig. 1 Illustration of the different electricity supply models at national level. The distributed generation plants are shown in red (based on Schulz, 2007). (**a**) top-down. (**b**) bottom-up

The “Masterplan” contains, among others, the establishment of a model neighborhood in the form of a living lab for sustainable energy usage. Here, new energy technologies and other new neighborhood concepts, such as communal housing projects, could be set up and evaluated regarding its visibility and contribution to a sustainable city.

The first transdisciplinary research project in the living lab district called Helleheide, which is located within the Fliegerhorst area, is *ENaQ*, and it will comprise about 125 housing units. The project’s goal is to make the energy supply of the new neighborhood climate-friendly by using locally produced energy, mainly from renewable sources, while keeping the energy costs affordable. The project thus pursues the transformation processes of the energy sector described above.

Figure 2 shows the area of the urban neighborhood Helleheide with the rough construction plan for the buildings. When using the word “neighborhood,” we refer to a residential area with clear borders, as depicted in Fig. 2.

ENaQ uses the lower right half of the area, marked with a red border in the map. The entire Helleheide area will continue to be used as a living lab area in

Fig. 2 Map of the planned living lab urban neighborhood Helleheide, in which *ENaQ* is the first research project. The *ENaQ* project uses the lower right half of the area as a living lab, marked with a red border. The smaller part marked with a blue border is the “Technology Island”

future research projects. The building above the larger street (in dark gray) will be a kindergarten while the larger building on the left is planned to be the district's garage. The empty space in the middle of the map, marked with a blue border, is called the "Technology Island." It is a space to show, test, and explain results and new technologies developed in the research projects taking place within the living lab.

Project Goals

The main focus of the *ENaQ* project is to co-design a reliable, climate-friendly, and affordable local energy supply in the new neighborhood with the residents' active involvement in the process. Therefore, Key Performance Indicators (KPIs) have been defined in regard to both electricity and heat, as well as, in regard to participation. The main goals and KPIs for the energy supply are:

1. Low environmental impacts,
2. Affordable energy for the residents, and
3. A high ratio of own consumption of the locally produced electricity.

The requirement for a high supply guarantee is taken for granted. More details on the technical KPIs and the technical planning perspective of the energy system with the participation of various stakeholders can be found in Schmeling et al. (2020). Details on the calculation of the ecological KPI can be found in Wehkamp et al. (2020).

Being a rather technical project, *ENaQ*'s success also depends on the effective stakeholder involvement. KPIs have also been determined for the evaluation of the participative activities. The framework of Goldschmidt (2014) is applied which offers the following complementary evaluation criteria, differentiating process, and effectiveness criteria. The process criteria evaluate the procedures of the participative practices to get feedback on strengths and weaknesses of the process, while the effectiveness criteria assess the outcome of each activity as a performance measurement. Figure 3 presents the six meta criteria to assess citizens participation processes.

A selection of KPIs to evaluate the participation practices within the *ENaQ* project are as follows:

- Comprehension of the decision-making context (competence development)
- Representation of relevant perspectives (fairness)
- Participants' possibilities for active participation (legitimacy)
- Clarity of the participant's mandate (transparency)
- Participants' activation (efficiency)
- Results' implementability (effectiveness)

An active and legitimated citizen's participation process also contributes to the technical project goals, as some goals can only be achieved through certain residents' behavior. Furthermore, *ENaQ* aims to create a model which can be adapted

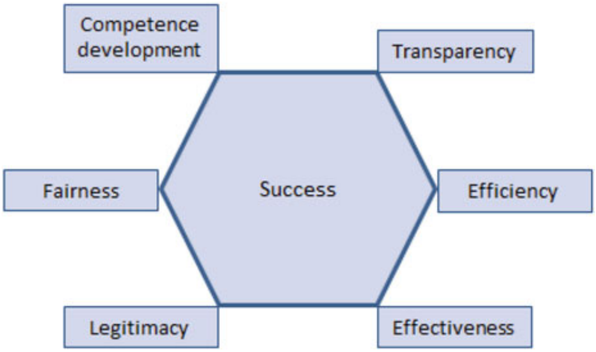

Fig. 3 Evaluation criteria for participant participation processes. Figure source: (Goldschmidt, 2014)

to other urban neighborhoods making transferability an important goal. Technical and digital solutions which might be transferable to other urban neighborhoods, as well as the experience with legal boundaries and possibilities, co-creation activities, and a business model for a district energy system, are to be examined.

3 Participatory Research within a Living Lab

As explained in the previous sections, the research project takes place within the context of the Helleheide living lab and not only the technological part plays an important role, but participation is also key. In this section, these two particularities, the living lab and the concept of participation, including its different intensities, will be explained. Furthermore, seeing that knowledge transfer is also one of the research project's goals, this section will describe how participation within the *ENaQ* project has been experienced.

3.1 The Hybrid Living Lab Concept: Striving for Transformation and Innovation

Given the nature of a society-constructed approach and concept, there is no clear definition in the literature regarding what a living lab is. Two main strands addressing similar or related approaches that strive for transformation and innovation on different societal levels have emerged (Schäfer & Scheele, 2017; Schäpke et al., 2018):

In the social and sustainability sciences, real-world laboratories or (urban) transformation labs aim at a fundamental social transformation, which can manifest itself on different spatial levels. The focus ranges from the individual, to the neighborhood, to entire cities and regions or even to the national level. The emphasis is not only on technological solutions or transformation, but rather on the design of different spatial units, supply systems, and local and regional economies. Furthermore, traditional value systems and behavior patterns are questioned, which are to be replaced by new ones. The value systems, design principles, and behavior patterns will be aligned with criteria of a resource-saving, socially beneficial, sustainable development (Schäpke et al., 2018; Schneidewind et al., 2018; Parodi et al., 2020). In this relation, terms such as "real-world laboratory" (Schäpke et al., 2015) or in German "Reallabor" (Schneidewind & Scheck, 2013), "urban transition lab" (Nevens et al., 2013), "urban living labs" (Evans & Karvonen, 2010) or Eco Innovation Lab (Ryan, 2013) are used.

The second major strand of living lab research handles with product and service innovations along industrial value chains. Terms such as "Living Lab" (Bergvall-Kåreborn & Ståhlbröst, 2009; Mitchell et al., 1997), or "Sustainable Living Labs" (Liedtke et al., 2012, 2015; Baedeker et al., 2017) have become established here. This development focuses on daily human life-product interaction. It is mainly about understanding how people use products in their everyday life, e.g. in order to align the products to the needs of the users, to avoid undesired uses or rebound effects in the application. Potential users are integrated into the innovation process as early as possible with the help of various user-centered design methods and everyday application is seen as the real-world context (Schäpke et al., 2018).

Even when there is no uniform definition in the literature of what living labs are, there are a number of attributes that characterize living labs: normativity, transdisciplinary, collaboration, real world and real social contexts, intervention or experimentation. For a more detailed description of these attributes see (Mulvenna & Martin, 2013; Schäfer & Scheele, 2013, 2017; Parodi et al., 2016; Schäpke et al., 2018).

In this research both strands are combined in a form of hybrid living lab, aspects of real-world laboratories addressing transformation as well as aspects of living labs for product and service innovations are taken into account. The following aspects are included in *ENaQ*:

- Addressing a neighborhood design that is intended to offer future residents the possibility to carry out their everyday lives in the neighborhood with as few resources as possible (e.g., sharing economy, repair possibilities, common rooms, local production, or sustainable mobility options);
- Creating spaces in which different stakeholder groups, including potential residents, can exchange views on issues of sustainable urban and settlement development and reflect on current value systems and patterns of action;
- Addressing the ways in which electricity and heat are generated and used in the neighborhood, toward a sustainable, distributed, multisectoral energy supply;
- Addressing the use of technology in everyday life or in the residential unit, by, for example, visualizing energy consumption, setting incentives to avoid energy consumption or to shift energy consumption in order to use as much local energy as possible but avoiding rebound effects.

3.2 From Information to Co-Production: Understanding Participation

Participation is an essential part of a democratic society. Whereas elections are considered as a formal, mandatory instrument of participation within a democracy, there are also informal participatory forms without any legal obligation (Alcántara et al., 2016). Groups to be involved in public participation reach from individuals, to organized civil society actors as well as business, political, governmental, or administrative institutions. Hence, participation can be understood as an umbrella term for all formats and approaches in which the aim is to involve the abovementioned actors in decision-making processes, i.e. to enable them to participate in these processes (Geißel & Penrose, 2003; Walther, 2010).

Renn (2011) for instance defines citizen participation procedures "as communicative processes in which people who are not entitled to participate in collective decisions by virtue of their office or mandate are given the opportunity to directly or indirectly influence collectively effective decision-making by providing knowledge, preferences, assessments, and recommendations. In doing so, the focus is shifted away from the actual decision toward the way in which the decision is made" (translated from German). A clear trend can be denoted in an increase of such informal processes, as they promise to identify the needs and opinions of different population groups which then can be integrated into certain undertakings to design human-centered structures. Thus, this approach allows incorporating local knowledge as well as anticipating resistance in the implementation of a project at an early stage (Alcántara et al., 2016; Benighaus, 2016).

Participation can manifest itself in very different ways, depending on the goals pursued and the issues addressed, or on who is organizing such a process (Benighaus, 2016). In this chapter, the term participation refers to the informal, not legally binding form of stakeholder involvement and stakeholders are understood not only as organizational actors, but include interested and affected citizens and future residents too. Furthermore, they should not only be informed or act as experts, but also implement ideas and initiate projects themselves at various city layers.

The intention for participation in the *ENaQ* project is based on substantial and instrumental arguments. One aim is to integrate knowledge for the development of a resource- an energy-saving neighborhood, seeing that multi-perspectivity leads to better results than individual decisions (Rohr et al., 2017). A further point is knowledge integration. This involves the exchange of views between the actors in order to supplement decisions with important findings. In this way, a potential of viewpoints and knowledge is tapped that can help in decision-making under uncertainty. Brinkmann et al. (2015) call these substantial arguments for participation. Another substantial reason is empowering the future residents and interested stakeholders to self-efficacy in terms of neighborhood design and the climate-friendly use of resources. This includes the targeted integration of disadvantaged groups (Rohr et al., 2017), as well as empowering participants to self-efficacy (Parodi et al., 2020). Finally, the future residents are sensitized to use technologies that can help them develop climate-friendly and resource-saving behavior in their everyday lives. The substantial reasons therefore do not focus on the representative mix of the participants but on their perspectives and on their personal development (Brinkmann et al., 2015; Rohr et al., 2017). The instrumental argument for participation is based on the aim for better acceptance and thus legitimacy of the results, hence opinions and suggestions from the different stakeholders are sought. In this context, it is important to have a representative group of participants (Rohr et al., 2017; Brinkmann et al., 2015).

Based on Arnstein (1969); Stauffacher et al. (2008); Brinkmann et al. (2015); Rohr et al. (2017), we use a four-level model to describe participation intensities within the framework of our research:

- **Information:** Stakeholders are informed about the progress of the project. There is little or no opportunity for comments and contributions to the discussion. There is no possibility of influencing the decision-making process and the design of solutions.
- **Deliberation and Consultation:** Stakeholders are offered various opportunities to contribute their own views and ideas. The aim is to deepen the exchange between the actors involved. The contributions are integrated in the decision-making process and in the design of solutions. There is no possibility of directly influencing the decision-making process or the design of solutions.
- **Co-Creation:** Stakeholders are offered specific opportunities for planning and designing solutions and results. The contribution of the participants is thus not only verbal, but also includes planning and design elements. The decision-making process lies with the organizers and initiators of such processes.
- **Co-Production:** The participants are not "only" involved in the design, but also in the decision-making, implementation, and possibly the operation of solutions, or the actors organize and initiate the realization themselves. In this way, they cannot only make suggestions, but also actively participate in decision-making and implementation.

Figure 4 shows the different participation intensities and the corresponding delegation of power to the participants. The aim is to achieve a mix of all the participation intensities. According to the scope, the appropriate participation intensity will be applied (Menny et al., 2018).

Apart from the different participation intensities and formats, with over 20 partner institutions, *ENaQ* has a particularity in terms of two kinds of participation: outwards and inwards. While the inward-looking participation is intended to address the formal project partners, which should work co-productively to achieve the project aims, the outward-looking participation is aimed at all the other stakeholders. This distinction is particularly relevant because important considerations are to be taken, for example in terms of legal frameworks. Finally, in order to achieve desirable results, it is important to bring the project partners, which include a real estate company, an energy utility and service company, the city administration, three different universities, hydrogen companies, and computer science and engineering institutes among others, and the external stakeholders to collaborate.

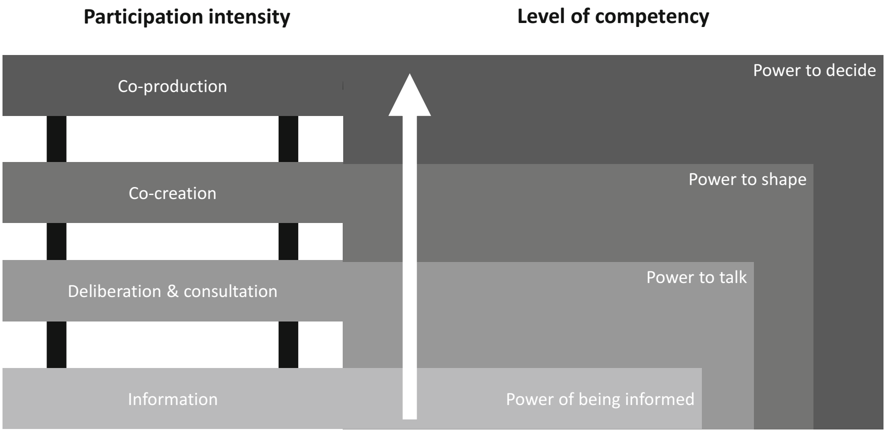

Fig. 4 Different participation intensities and the corresponding delegation of power to the participants (based on Brinkmann et al., 2015)

A particular challenge to the participation processes, especially to the question of who should be involved why and how this should happen, is the lack of a built environment and actual residents. On the other hand, there is the great possibility to involve stakeholders very early in the planning and development process.

3.3 *Planning, Design, and Development Layers: Scope for Participation and Spaces for Interventions*

The development, planning, and design of urban projects can take place at different layers. Within the *ENaQ* project, layers concern infrastructures, neighborhoods, and the digital platform:

- **Smart City Infrastructure:** identification, development, and testing of local energy supply concepts as well as social and financial incentive systems for the use of renewable and resource-saving energies, and designing innovative business models.
- **Smart City Neighborhood:** identification, development, and testing of neighborly housing forms as well as concepts for local economy, social innovations, and social business models.
- **Smart City Platform:** identification, development, and testing of application possibilities and business models for an interactive neighborhood platform.

At each of these layers, different aspects of development, planning, design, and implementation are affected, each of which requires different decision-making competencies or knowledge bases. They also offer different opportunities for participation in the project and neighborhood development. It is therefore essential to consider who can be involved in the project and neighborhood development and why, as well as, when, and how this can happen (Reed et al., 2009; Bell et al., 2012; Luyet et al., 2012).

In the field of infrastructure, for example, it is often primarily a matter of the technical design and feasibility or the regulatory feasibility of local energy production. This can severely restrict the scope for participation and in most cases requires very specific knowledge. In this context, broad public involvement in design and decision-making is less appropriate. However, it is important to observe and keep in mind how the residents deal with the provided systems and solutions in their everyday life. When it comes to the design of operator or business models, there is more space for ideas, solutions' design, and implementation from other stakeholders.

The greatest scope for design and implementation exists at the neighborhood layer. At this level, there is far more room for creativity and for low-threshold implementation of ideas with manageable effort. There are many areas that can and even must be realized by the local people themselves. Examples can be the use and design of public space, neighborly living together, the realization of certain mobility services, etc. This is also where the greatest dependency exists between people living locally, the design, the subjectively perceived quality of life, and the implementation and use of solutions and ideas. For example, public space is only used in a neighborly manner if it is also inviting to do so, and the provision of a commonly used cargo-bike can only be realized if there are enough people who want to operate and use it.

In relation to the Smart City Platform, there is also scope for co-creative and co-productive processes. For example, developing and testing services and functions provided by the platform in connection with neighborly life.

3.4 Participatory Dimensions

Taking into consideration the diversity of stakeholders, the challenge is to offer them different participatory dimensions according to the scope and giving the opportunity to share and shape their ideas. In this context, the *ENaQ* project was able to identify four participation dimensions that enable different formats of participation:

- **Neighborhood Under Discussion:** Events and formats that have an information, consultation, discussion, and deliberation nature. Within the framework of this dimension, both, the project partners and other interested stakeholders will be informed and encouraged to participate in discussions on developments and topics.
- **Neighborhood Co-Design:** Events, formats, and methods that serve co-creation and co-production. These include, for example, citizens' workshops, consortium workshops, and all other formats in which people discuss, develop, plan, and design together.

- **Neighborhood Experience**: Events, formats, and methods that make the neighborhood and its solutions tangible and perceptible. These includes, for instance, serious gaming, a digital image of the neighborhood with a virtual walk, exhibitions within, or guided tours through the neighborhood.
- **Neighborhood Research**: Formats and methods that enable students and scientists to research and implement projects. These include seminars, student research projects, bachelor or masters theses, or student projects. Formats of citizen science are also conceivable, to encourage the general public to participate in research.

These dimensions are implemented in different ways, depending on the addressed target groups and topics that are dealt with. The dimensions can be distinguished between (1) location- and time-dependent formats, which are linked to fixed times and places of participation; (2) location- and time-independent formats, which are usually digital formats so that the participants can decide for themselves from where and when they want to participate (Schäfer & Scheele, 2014; Schäfer, 2017); (3) outreach-based participation, where the participation opportunities are offered in public places, in everyday situations, or at public events, to keep the additional effort and the entry threshold for those involved as low as possible (Orthmann, 2017).

3.5 Section Summary

Participation in general and citizens participation in particular brings important advantages for urban development projects, for transformation and innovation processes, and for the establishment of resilient cities. Although participative processes are not limited to living labs, living labs offer a particular space for such processes to take place. When working with a participative approach, it is important to determine the intention for participation in a particular project. In our case the intention for participation is both instrumental, in order to achieve acceptance and legitimacy, and substantial, in terms of empowerment and knowledge integration from multiple perspectives. When promoting participation processes and designing formats, determining the scope plays a key role. Based on this, different intensities (information, deliberation and consultation, co-creation, co-production) and kinds of participation (inward, outward) should be clearly defined in the participatory process. Depending on the project where participation is being applied, the particular layers should be determined, in our case there are three layers: infrastructure, neighborhood, and city platform. Based on this information, we have determined four different dimensions (Under Discussion, Experience, Co-Design, Research) particular to our research project, but also transferable to others. In our experience there is no one determined dimension, layer, or intensity, but it is the combination of these, depending on the project context, that will bring about the best results.

In order to understand how participation can be applied in a real case scenario, we present one example from our research project within the layer of Smart City Infrastructure: the local energy market, which will be explained in the following section. We have selected an example of this layer since, as seen in Sect. 3.3, the scope in this layer is very much restricted, hence it would seem as participation in this layer would also be limited. But as we will see in Sect. 4.1 and particularly in Table 1 a wide variety of activities fostering participation has taken place.

4 Organizing a Local Energy Market

The establishment of local energy markets is often referred to in the scientific literature as a worthwhile organizational form of energy supply in neighborhoods (Ampatzis et al., 2014; Hvelplund, 2006; Lund & Münster, 2006). This refers to associations of local producers and consumers who not only exchange electricity on a technical-physical basis, but also have direct contractual relationships with one another and coordinate their electricity flows using specific market and control mechanisms. It is hoped that such systems will have various advantages compared to classical distributed supply concepts, where each stakeholder is viewed individually (Mendes et al., 2018). In such markets, consumers are moving from passive price takers to active participants in the transformation processes (Timmerman, 2017) and have the opportunity to participate jointly in national energy and control energy markets (Olivella-Rosell et al., 2018). At the same time, awareness of local resource use is rising and efficiency and coordination with the local environment are increasing (Karnouskos, 2011). For the producers, new sales channels away from state subsidies are opening up (Ilic et al., 2012) with a better acceptance of local energy technology (von Wirth et al., 2018). Prosumers combine these two roles while benefiting from greater independence and more reliable energy supply and purchase. Due to the better coordinated local energy use, the grid operator can partly manage without the supra-regional grid expansion (Varasteh et al., 2019) and the aggregated consumers can, as mentioned, actively contribute to grid stabilization (Koliou et al., 2014). From a societal point of view, it is hoped that the actual costs of the energy system will be distributed more fairly (Mendes et al., 2018), e.g. the network fees. In addition, energy markets become more transparent and accessible through the direct involvement of consumers, and investments in distributed, renewable energies will be further promoted (Izutsu et al., 2012). Therefore, the promotion of renewable energies on a local level and with the direct participation of the citizens can be identified as the overall goal.

Due to its multilayered complexity and interdisciplinarity (engineering, economics, computer science, social and political science), the implementation of such concepts can only be achieved with the cooperation of various partners from industry, administration, and research. In both the development process as well as in the later testing phase, it is particularly important to also consider the needs and wishes of the future participants and to offer them opportunities to contribute. Furthermore, in order to use small, local energy producers and prosumers as efficiently and profitably as possible, not only participatory and technical considerations are required, but also the organizational and legal necessities have to be considered. The Helleheide living lab offers the *ENaQ* project the ideal platform to both test and identify new technologies and opportunities for local energy markets as well as to include the stakeholders in different levels of participation.

Therefore and as mentioned in Sect. 3.5, the local energy market will be used as an example of various processes that can be jointly developed in a living lab. In the following, the various processes are first classified into the participation intensity introduced in Sect. 3.2 and the participation dimensions introduced in Sect. 3.4. A first example directly related to the energy market design is a survey we conducted in 2019 which is found in the participation intensity of deliberation and consultation and took place within the "Neighborhood under Discussion" dimension. On this basis, the market is then designed from an organizational point of view and the corresponding business model is presented, starting from the description of the framework conditions to be considered.

4.1 Participative Design of a Local Energy Market

As mentioned in Sect. 3.5, the participation layer in which this example takes place is the one of Smart City Infrastructure, which is particularly technical, requiring specific knowledge and information. The primary goal is always to realize a rewarding project for all stakeholders, which requires a combination of different participatory methodologies due to the project's already mentioned interdisciplinarity and complexity. In *ENaQ* it has been possible to experience participation in all four intensity levels as well as in three of the dimensions mentioned before. An overview and classification of the already completed and planned participation activities related to the setup of a local energy market can be found in Table 1.

For the development of this solution a high level of inward participation, as mentioned in Sect. 3, took place: the establishment of a consultation group, which researched and analyzed the relevant aspects of the legal framework, followed by several co-creation workshops, in which more than ten project partners took part, contributing with their ideas, knowledge and concerns. The first steps of outward participation in relation to the energy market have also already taken place. Different information events, where for example the way an energy market works was explained, were organized. The survey that is presented in Sect. 4.2, as an important method of consultation, has already been in place. Outward co-creation workshops with Oldenburg citizens in which ideas on how to use energy smartly were contributed have also taken place. In both cases, the results and contributions have been used in the idea design. Selected steps, as referenced in Table 1, are examined in more detail below.

Table 1 Examples of participation activities in chronological order in *ENaQ* regarding the local energy market

Form	Dimension	Intensity	Implementation	Method	Participants
Inward Participation	Neighborhood Under Discussion	Consultation	location- and time-independent	Partner Consultation Group: legal and economic framework (Sect. 4.3)	Project partners
Outward Participation	Neighborhood Under Discussion	Deliberation/ Consultation	location- and time-independent	Survey (Sect. 4.2)	Public in general
Outward Participation	Neighborhood Research	Deliberation/ Consultation	location- and time-dependent	ENaQ Seminar at Leuphana University	Students, project partners
Inward Participation	Neighborhood Co-Design	Co-Design	location- and time-dependent	Partner Work-shop:Business Modeling the Aggregator (Sect. 4.4)	Project partners
Hybrid Participation	Neighborhood Co-Design	Deliberation/ Consultation	location- and time-dependent	Energy Workshop @ the Event Dialog Forum	Project partners, citizens, external stakeholders
Outward Participation	Neighborhood Research	Co-Design	location- and time-independent	Bachelor Thesis (Sect. 4.5)	Student, project partners
Outward Participation	Neighborhood Co-Design	Co-Design	outreach-based participation	Visualization @ Science Truck (planned for Oct 2020)	Public in general
Hybrid Participation	Neighborhood Co-Design	Deliberation/ Consultation/Co-Design	location- and time-dependent	Citizen Workshop about the aggregator and visualization possibilities (in plan)	Citizens and project partners
Outward Participation	Neighborhood Under Discussion	Information/ Deliberation	location- and time-dependent	Public presentation: Energiewende | weiterdenken (in plan)	Public in general

The process as described so far can be transferred to other regions. Above all, it is important to involve a wide range of stakeholders in a variety of dimensions and intensities. In turn, the detailed design of the energy market, as presented in the following, is strongly dependent on regional and national characteristics and cannot be presented in a generalized way. The presentation of the strategy pursued in the *ENaQ* project can therefore be understood as an exemplary implementation and presentation of possible problems and stumbling blocks which, in one form or another, can also be expected in other contexts as well. Experience has shown that the central difference is usually what is politically desired and thus regulatory possible. Many countries, especially outside Europe, have market and supply structures that require fundamentally different approaches. For a comparison of different renewable energy policies on the African continent see Müller et al. (2020) or Erdiwansyah et al. (2019) for more information on southeast Asia. There are also related works in the literature, which design local energy markets for different regions of the world with different approaches and challenges (e.g. India (Etukudor et al., 2020), South Africa (Ledwaba et al., 2019) or Sweden (Brolin & Pihl, 2020)).

4.2 Neighborhood under Discussion: Results of an Online Survey

In order to obtain an initial opinion on the subject of "Future district power supply" and the related energy market, an online survey was conducted between 28.05.2019 and 15.08.2019. The survey was mainly distributed via mailing lists of the project's consortium partners, social media, and word-of-mouth recommendation and was answered by 227 participants in total. The participants were representative of the German average in terms of age, income structure, and housing situation, but relatively often already had a green electricity tariff from an independent utility.

First, the participants were asked to prioritize different characteristics of electricity supply contracts (Fig. 5) in order to find out which marketing arguments would be particularly important for an innovative electricity product.

Affordability and the ecological footprint seem to be in the foreground. Especially aspects such as local production, transparency, and a local energy company seem to have a lower priority.

In order to better understand the two core aspects, i. e., economic and ecological expectations, it was asked how high the potential benefit would have to be in order for people to be interested in buying energy from the neighborhood (Fig. 6).

Only a few of the interviewees are happy with no cost savings, most want to save up to 100 € per year, which corresponds to roughly 10.4 % of the average expenditure for electricity of a German household (Bundesnetzagentur & Bundeskartellamt, 2019; Statistisches Bundesamt, 2019). As far as the savings in emissions are concerned, most of those questioned hope for medium savings, some

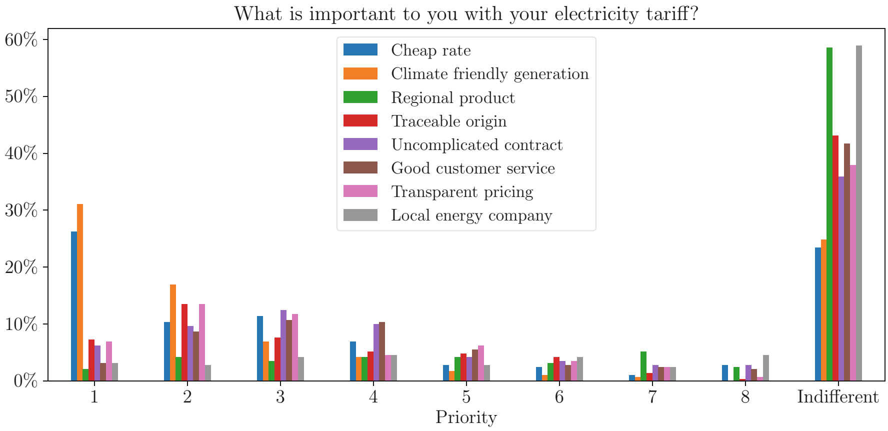

Fig. 5 Percentage distribution of the selected priorities of different possible properties of electricity supply contracts

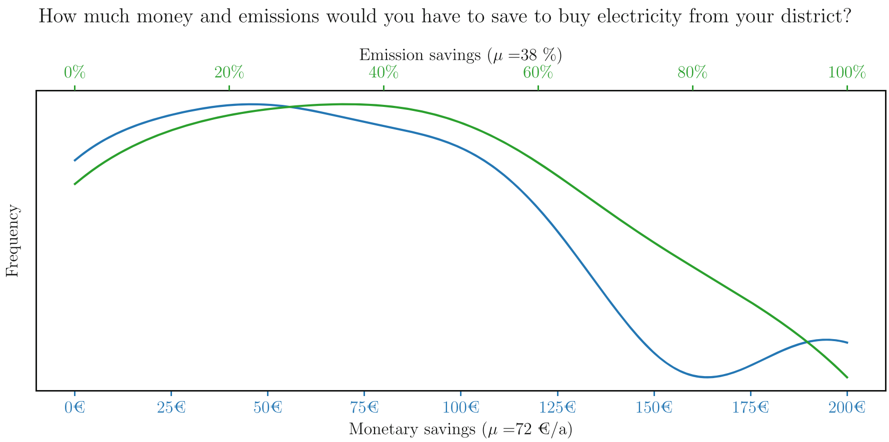

Fig. 6 Distribution function as a core density estimator for the desired monetary and emission savings by purchasing electricity from the district

would also be satisfied with no savings, but very few demand a completely climate-neutral energy supply.

In addition, almost 90 % can imagine participating directly or indirectly in the local production facilities. The model of a cooperative was particularly popular (55 %), but crowdfunding (34 %) and investing in own plants (32 %) also seem attractive.

The survey also asked about innovative electricity price models in which the price is regularly adjusted to the local generation situation and thus provides an economic incentive to change behavior in favor of the local energy system. In principle, 80 % of the respondents would be interested in such a tariff. However, many would like to see further benefits in addition to the monetary incentive (Fig. 7).

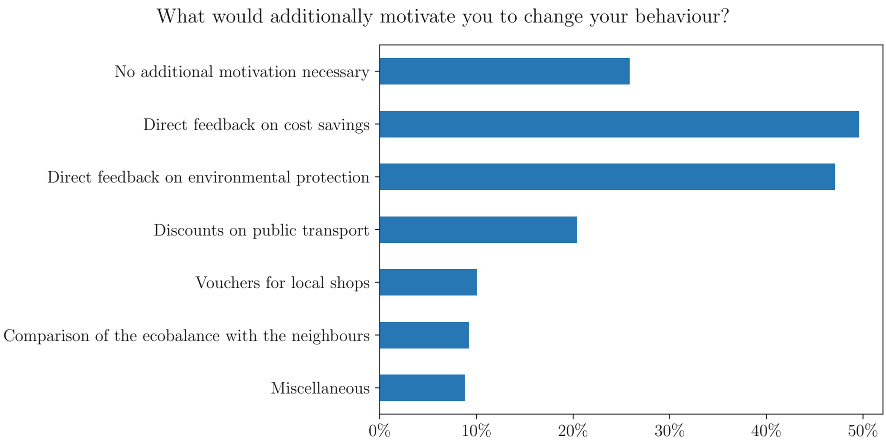

Fig. 7 Percentage distribution of the answers to the question, what could additionally motivate to consume electricity at times when this would be in the interest of the energy system, e.g. when much cheaper local renewable electricity is produced

Especially direct feedback about one's own behavior and its effects is regarded as important, as this is not easily possible with current standard power supply products.

Overall, it can be concluded from the survey that there is a great deal of interest in innovations in the energy industry among the respondents. In many places, the wish to actively participate in shaping the Energiewende can be seen, but also frequently an unawareness of the possibilities and restrictions.

4.3 Prerequisites and (Legal) Framework Conditions of the Local Energy Market

Particularly in the field of smart energy, further aspects and framework conditions have to be taken into account in addition to the wishes and demands of citizens. In general, the electricity market in Germany has been liberalized, so large parts have been privatized and deregulated (Konstantin, 2013). However, the inherent natural monopoly of grid operation (Ströbele et al., 2010) still requires a certain degree of state control over the energy industry in the form of legislation (Pritzsche & Vacha, 2017). Aspects of security of supply, consumer protection, and climate protection are also regulated in this regard.

In order to successfully offer innovative energy services for neighborhoods, two central conditions must be fulfilled: (1) the model must be compatible with the current legal situation and the other framework conditions, and (2) there must be enough participants, meaning the model must be attractive for the stakeholders. This consideration is very specific to the national legal framework, the participating parties, and the time of evaluation, as all these develop very dynamically. Especially for the planned implementation within the *ENaQ* project, there are some key obstacles which will be briefly outlined in the following.

In principle, German energy law stipulates that the fees to be paid by the consumer[7] for the operation of the transmission and distribution grids are incurred irrespective of the actual distance between generation and consumption.[8] This is understandable, as it is difficult to combine physics (actual power flows) and economics (contractual constellations), but it means that an exchange of energy between neighbors does not result in an economic improvement for the consumer. However, a large number of the survey participants would like to see exactly such an improvement to be willing to purchase electricity from the neighborhood (Sect. 4.2). The solution here is to leave the public utility grid[9] and operate a separate grid which is then only connected to the public grid at one point and from there opens to the rest of the district. Such a possibility is offered by the customer system.[10] In general, this is a clear infringement of the basic principles of liberalization, as the network, being a natural monopoly, should be fully regulated by the state. For this reason, clear legal requirements are laid down to allow innovative concepts without allowing unregulated monopoly market positions. It may only reach a very small scale (no more than a few 100 consumers, 10,000 m^2 of supplied area, and 1 GWh of electricity consumption per year),[11] no direct charges may be levied for grid usage, and every resident is still free to choose his or her supplier. In return, electricity traded within the system is subject to significantly lower state taxes and state induced charges. Thus, the planned concept is legally feasible, and there is also enough cost savings to motivate many of the residents to adopt it.

In addition, German energy law stipulates that whoever sells electricity to consumers becomes an electricity supply company,[12] which involves a large number of reporting obligations and administrative work. Since this effort cannot be demanded, especially from private individuals with their own small generation plant, a business model must be designed that takes over such tasks, i.e. ensures the simplest possible integration and interaction with the participants.

There are other legal conditions to be considered, but those are not so decisive here.

[7]Letztverbraucher—§ 3 Nr. 25 EnWG (Energy Industry Act).

[8]§ 17 Abs. 1 StromNEV (Electricity Network Fee Regulation Ordinance).

[9]Energieversorgungsnetz der allgemeinen Versorgung—§ 3 Nr. 17 EnWG.

[10]Kundenanlage—§ 3 Nr. 24a EnWG.

[11]Bundesgerichtshof (German Federal Court of Jusitce), Order of 12.11.2019—EnVR 66/18.

[12]Elektrizitätsversorgungsunternehmen—§ 3 Nr. 20 EEG (Renewable Energy Sources Act).

4.4 *Innovative Business Models for Energetic Neighborhoods*

As already mentioned in Sect. 4.3, the legally compliant and simple organization of an energy exchange between neighbors requires an innovative business model to organize this. The market role here can be described as a district aggregator. In its function, it aggregates the various stakeholders in the district. On the one hand, it meets the required internal needs, and on the other hand, it manages the operations in the external markets better, due to the resulting higher market power. Its function and tasks are based on the already well established aggregator roles, which exist in various national markets (OFGEM, 2016; Stichting USEF, 2015; Bundesnetzagentur, 2017), but here it is limited to the neighborhood itself. In essence, it takes on four tasks:

1. Buying surplus energy from the producers in the district
2. Selling unneeded energy on external markets
3. Buying missing energy quantities from external markets
4. Selling the resulting energy mix to consumers in the district

The graphical representation of the interactions of the parties involved is shown in Fig. 8.

These tasks can now be organized according to the needs of the residents and the other framework conditions. In the following chapter, it will be described how the interaction between producers (point 1) and consumers (point 4) could be designed.

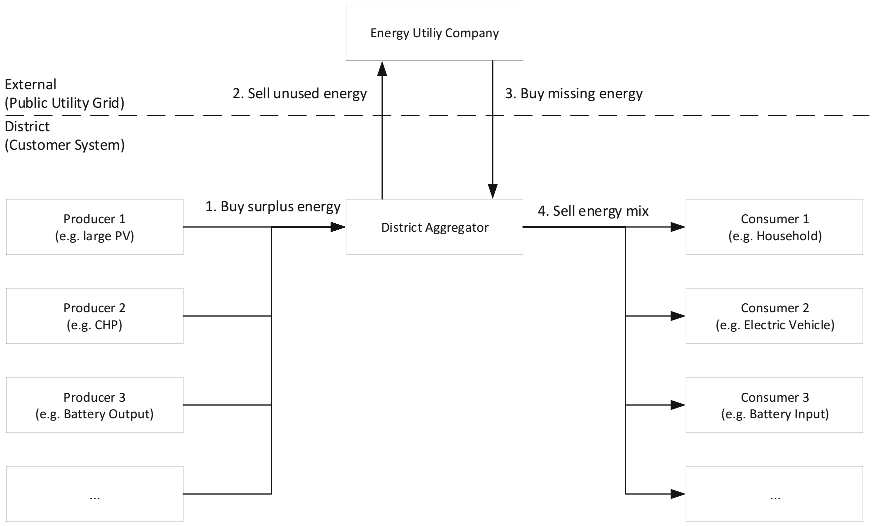

Fig. 8 Presentation of the stakeholders involved in energy trading and their interaction within and outside the neighborhood

4.5 Designing the Local Energy Market

If an energy exchange is to take place between neighbors, the first question that arises is how it is to be organized, i.e. how suppliers and consumers are to interact. The aim is to create a market that is as efficient and fair as possible with as little effort as possible for all involved stakeholders.

The simplest approach for the district aggregator to bring supply and demand together is to have fixed, long-term contracts, in which a purchase and a sale price is agreed with all participants in the marketplace. The agreed price is a matter for negotiation between the stakeholders and is therefore linked to prices on external, national markets, but offer a bonus incentive to participate. The advantage of this approach lies in the very simple implementation and comprehensibility for the participants, who hardly need to change over compared to the otherwise existing energy system, but still benefit from the low prices and the good climate change mitigation of district energy. However, this approach has little to do with a real energy market among neighbors, as they have hardly any influence and market power. It is also questionable from a macroeconomic point of view, as it does not provide any incentives to change behavior in the interests of the energy system. Nevertheless, this approach is very common. This is mainly due to the fact that the generation facilities of a district are often owned by only one legal entity, so no real marketplace is necessary. In Germany, such an approach is frequently found in state-subsidized tenant energy projects.[13] The diverse structure of actors as found in the *ENaQ* project then requires rethinking.

In contrast to this approach, an auction-based approach is often discussed, especially in the scientific literature (Majumder et al., 2014; Ampatzis et al., 2014). Energy trading can be organized as a Double Sided Auction (DSA). At its core, an order book is set up in which every market player can place transactions, i.e. either offer or buy electricity. Such an order book is created for defined trading periods, e.g. 15-min intervals. Each bid contains a tradable amount of electricity (either sell or buy) and a specific energy price (so-called limit). The sell orders are then sorted in ascending price order, the buy orders in descending price order. After that, the first bids are matched until either offer or demand is exhausted or becomes unrealizable because the purchase price becomes lower than the selling price. The price for this trading period can then be settled, for example, as the weighted average of all matched contracts (uniform-pricing) or individually depending on the bid (pay-as-bid) (Faqiry & Das, 2016; Ilic et al., 2012). This shows the high complexity and high effort of the DSA approach. Both can be improved by an automated agent system. Each participant in the marketplace would authorize an agent to interact in the marketplace according to their own ideas (e.g. bidding behavior, preferences) (Ghorani et al., 2019; Rashedi et al., 2016). The development and maintenance effort of the agents could then be offered as a service.

[13]Mieterstromprojekte in acc. to § 21 Abs. 3 EEG.

In contrast to classic DSA approaches, the legal problems described in Sect. 4.3 and their solution by the consumer system and implementation of the district aggregator mean that the energy producers cannot decide whether their electricity is supplied to the residents or not, as they are physically wired. In fact, due to the mandatory metering concept, the allocation of the individual energy quantities from different sources to the consumers is also predetermined and cannot be influenced.

Therefore, a hybrid model of the two solutions presented must be applied in which the district aggregator is the central point (Katic, 2020): It holds fixed purchase contracts with the operators of non-controllable systems (mostly PV) and places these energy quantities in its own order book. In a second order book, the operators of controllable generators (CHP or battery) have the possibility to ask for a price based on their possible production and on this basis decide on their own whether to produce or not. The electricity is then transferred to the aggregator and offered by it on a second order book. The residents indicate, for example in a mobile app, what price they want to bid per order book and what kind of electricity they want to get if they do not get a contract. Matching is then carried out in the same way as in the classic DSA approaches, except that the missing energy of one order book is first stocked up from the second and only then electricity is procured externally. The consumer's preferences can be set once, but can also be easily and individually adjusted, e.g. to changing life situations.

4.6 Section Summary

To summarize, a strong interdisciplinarity and dependence on local conditions can be observed for the establishment of a local energy market. The participation of various stakeholders from civil society, industry, research, and administration in diverse formats and intensities is therefore essential for the success of the project, but the results might be heavily dependent on regional differences. Only the first steps toward full implementation are presented here, which primarily deal with the basic desires of the future neighborhood residents, the legal and regulatory feasibility, the required business models and the organization of the marketplace. However, further co-creation elements between the district aggregator and the potential residents are necessary and will be taking place. For example, questions regarding the medium for the residents to interact with the local energy market (e.g., smartphone app, voice assistant, ...), the creation of bidding-agents, detailed pricing, or the reasonable amount of time required for interaction must be clarified in order to further develop the business model of the district aggregator. Another major challenge is the processing of the huge data volume of such a Smart Energy Quarter and the implementation of the methodology designed here in the form of a digital platform. This platform will be discussed in more detail in the next section.

5 A Digital Local Energy System

The market design discussed in the previous section combines considerations to the German legal framework, new technology, and both inward and outward participation in different layers, in order to implement a local energy supply and trading system. An important aspect of such an energy supply system is that the effort to take part, as a consumer, prosumer, or as a district aggregator, is as low as possible. A digital system has the potential to support the district aggregator while allowing citizens to take part in the energy supply system. In the following, we present parts of a digital energy management system for smaller districts. Its aim is to ease running a local energy system and market with diverse and partly volatile energy generators possibly from different owners. The system shall reduce the effort for the aggregator to reach the KPIs (see Sect. 1 for the energy supply KPIs) and also reduce the effort for the market participants making it more user-friendly.

5.1 *Digital Support for the Local Energy Market*

As described in Sect. 4, the aggregator runs the local energy market for the urban neighborhood. Such a market in a small area has limited amounts of traded energy and therefore limited possibilities to run a profitable business on the margin. Therefore, an aggregator will probably run multiple of such small energy markets. Additionally, the effort prosumers have to take to participate in the market should be as low as possible to make the participation more attractive. To reduce the effort for the participants and the costs for the aggregator, automatization, which will be described next, is an essential aspect.

System Automatization

The systems involved in a local energy market can be automated with the help of digitalization. On the one hand, the trading aspect needs to be automated to reduce the effort for both the consumers and producers as well as the aggregator. This can be achieved with agent-based trading algorithms (Yasir et al., 2014; Mengelkamp et al., 2017) and automated measurement of the energy consumption and generation (Römer et al., 2012).

Technically, the availability of measurement data is becoming possible with smart meters at the household level. These could be either a custom metering system or certified Smart Meter Gateways (SMGWs). As of mid 2020, the rollout of these systems in Germany is in the starting phase (Kroener et al., 2020). These certified smart meters have a gateway and a software infrastructure so that an External Market Participant (EMP) can technically access the measurements (Bundesamt für Sicherheit in der Informationstechnik, 2019).

On the other hand, the control of the energy systems needs to be automated. This includes the control of energy devices such as a district battery or CHP plant to execute the power generation which was determined by the local market.

In the *ENaQ* project this is done by the so-called Quarter Energy Management System (QEMS). An important aspect of QEMS is the transferability to other urban neighborhoods with a local energy market and district aggregator. The system aims to help to transfer the idea to more urban neighborhoods.

In the QEMS, data from various internal and external sources is collected, on the basis of which automated decisions for the energy system are made. This includes weather forecasts and the generation forecasts derived from them, the development of national energy markets, but also historical and current system statuses and information on the contractual and legal framework conditions. The central processing instance is then a model of the entire energy system as described by Schmeling et al. (2020) and Wehkamp et al. (2020).

Visualization for the District Aggregator

Seeing the district aggregator's responsibility to guarantee the energy supply, an overview of the local market and of the energy systems to control if the supply is working correctly is necessary. For example, the aggregator needs to know if the KPIs are reached. As it may run multiple local energy markets in different neighborhoods, the amount of work to control a single market should be as low as possible.

Therefore, specific visualizations for the aggregator have been developed in an inward co-production process, in which usability experts, system developers, project stakeholders, and the future district aggregator in the *ENaQ* project participated. Seeing the district aggregator's responsibility to guarantee the energy supply, an overview of the local market and of the energy systems to control if the supply is working correctly is necessary. Figure 9 shows one of those visualizations. The glyphs with the three blue bars show the three main KPIs: costs, CO_2 emissions, and own consumption percentage. With these glyphs, it is simple to recognize patterns, i.e., typical situations that can appear in the districts. For example, low costs and emissions with a high percentage of own consumption could show a period of high PV generation. These patterns can even be recognized in retrospective for the last 24 h, for example. This helps the aggregator to spend less time with one district, because the system operator only needs to look at the overview once a day. The design process has been described in-depth in Herdel et al. (2020).

5.2 *Incentivization for the Consumers*

In addition to the technical hurdles in the control of the plant technology and the implementation of energy trading, it is also important to involve the residents in

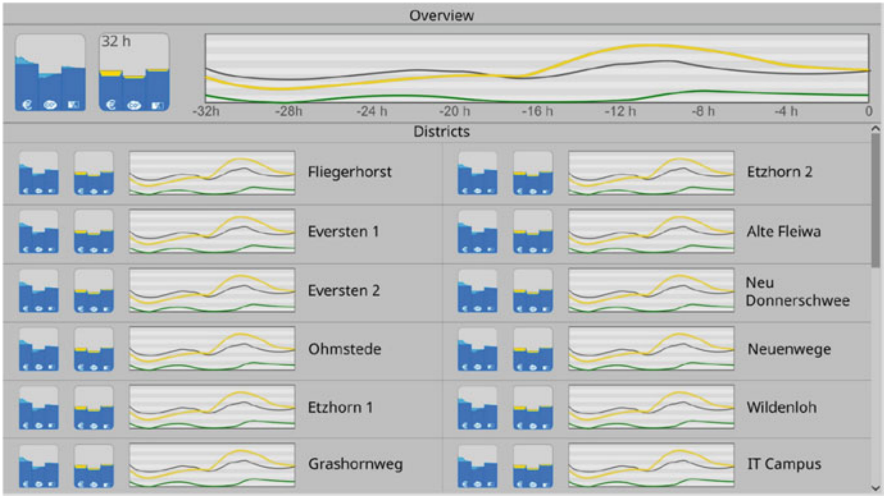

Fig. 9 An overview for the aggregator of multiple districts with a local energy system (Herdel et al., 2020)

the ongoing operation of the energy system and to raise awareness of the limited sustainable energy resources available in the neighborhood.

Following the goal to include the residents in the local market, the KPIs shall be achieved together with the district's residents in different participation opportunities, from information to co-creation. It is also important to include incentivization elements to promote the use of local energy during the time periods when it is available, since, as seen in Fig. 7, survey participants responded that direct feedback would possibly motivate them to change their behavior.

In the following, two examples of how such a direct feedback can be given to the user are presented. One option does not require the individual consumption information of the residents while the other one is based on such information. Both examples have also been part of the continuous inward participation processes, in which several partners have been involved in the co-design and even co-production processes, and also of outward participation as they have been discussed with interested citizens in different workshops.

Energy Signal Light

For many reasons residents might decide to not share their live energy usage, particularly in terms of data privacy. Therefore, an incentivization tool without the need to know the residents actual energy usage is in development. The Energy Signal Light is a small LED device that can be installed in flats or hallways, making it visible casually without the need to open an application or in any other sense

Fig. 10 Photo of an Energy Signal Light prototype. It uses a simple hint to let the user know if the usage of energy at the current moment would benefit the KPIs. The device could be installed in a wall

thinking about the energy consumption. A possible implementation of such a signal light can be seen in Fig. 10.

The light has a limited number of colors, similar to a traffic light. The colors could indicate if the consumption of energy at the current time would, for example, lower the CO_2 consumption, benefiting the KPIs. This way, the awareness of the best times to consume energy could be increased. This method only needs to know the data from the energy generators in the city district but not the consumption data from the individual residents.

Energy Bonus Points

In cases in which the residents are willing to share their energy consumption data, by using the aforementioned SMGWs, the incentivization elements can be adapted to the individual households. An incentivization system that is designed for this case uses a pareto-optimal consumption curve. This curve weights the KPIs against each other and calculates a consumption curve that would benefit the KPIs the most. Knowing the exact consumption over time from the residents, some kind of bonus points could be given to the residents if their consumption is close to the calculated optimal curve. Other gamification instruments, as for example friendly competitions could be implemented to motivate a behavioral change going further than just the visibility aspect. At this point the project partners want to continue with the outward participation, seeing that it is important to know how the actual behavior of real participants would be, also to find unintended changes in behavior. For example, following the calculated curve could lead to a higher energy consumption at a certain point in time to increase the usage of local low-CO_2 energy. Nevertheless, it should not lead to a higher consumption in the long term, e.g., in a month. Moving now into outward participation to develop these first ideas further together with citizens and further stakeholders is an elemental part of what ENaQ is aiming for.

5.3 Section Summary

In summary, the digital platform is developed to support an efficient local energy market by helping the aggregator to overview the KPIs of the market and the energy generation devices as well as allowing the prosumers to participate in the market. Moreover, with the use of incentivization applications and the digital platform, it would be possible to reach the collective energy KPIs. When transferring this concept to other projects, the software needs to be adapted to the individual circumstances. The district aggregator's information, i.e., size, number, and type of the energy plants in the district, needs to be updated. The incentivization functionality needs to be adapted to the wishes and needs of the citizens as well as the KPIs for the energy supply.

6 Living Labs and Resilient Cities

The organization of a local energy market and the digital local energy system as seen in Sects. 4 and 5, are solutions that could be transferred to other districts. This would contribute solutions to the question of how cities must be shaped and structured in order to reduce their hunger for resources and energy, and how to become drivers of positive development (Dawson, 2011), hence further encouraging resilience in cities and urban transformation.

Resilience can be seen as a holistic design and problem-solving approach for socially constructed systems. Gößling-Reisemann et al. (2016) summarize the concept of resilience as follows:

"Resilience describes the ability of a society to maintain the (infrastructure) services necessary for its needs and survival even under stress and in turbulent environments and against the backdrop of long-term changes." (translated from German)

A societal perspective is consciously chosen, which implies that the resilience of a socially constructed system (e.g. a neighborhood, an energy system, or an economic regime) depends primarily on the design of these systems and the ability of the actors involved to develop resilience within them. In the context of resilience, robustness, the ability to adapt, and the ability to transform are of central importance (Walker et al., 2003; Gößling-Reisemann et al., 2016). Resilient cities can deal with short-term disruptive events and long-term changing conditions both proactively and reactively (Fekkak et al., 2016). This applies not only to the design of technical infrastructures (such as energy or local supply systems) but also to the design of space (e.g. creating incentives for resource-saving lifestyles) and social structures (neighborhoods, relationship to politics and administration, regulatory framework, etc.) (Gößling-Reisemann et al., 2016). The resilience of a city thus results from the interaction of interdependent system components. Resilience has to do with a critical reflection of the existing systems and the way they are handled against the backdrop of expected and unforeseeable changes and developments (Fekkak et al., 2016; Gößling-Reisemann et al., 2016). Thus, for example, climate change mitigation and the associated need to redesign the energy system as described in Sect. 2.2 is already a possible adaptation in the sense of resilience (Kegler, 2014). Nevertheless, existing path dependencies often determine the strategies chosen to deal with climate change. These in turn lead to an underestimation of the true need for adaptation and transformation, which results in transformation gaps at various system levels and thus influences resilience in a negative sense (Schäfer & Scheele, 2017). It is therefore generally agreed that the development of resilient cities can only be realized within the framework of interdisciplinary and transdisciplinary, collaborative processes.

The design of resilient cities must be able to overcome not only existing technological regimes, but also cognitive, normative, and regulatory behavior patterns that have negative consequences and prevent positive development. Living lab projects, such as *ENaQ* offer the necessary framework for establishing resilient structures in cities. Here, not only individual system components are developed and left to themselves, but all relevant levels of urban design and urban life are taken into consideration (Sect. 3). The city or neighborhood is seen as a coherent, interdependent system whose future development depends not only on renewable energies or local energy production but also on the corresponding regulatory framework (Sect. 4), the design of the neighborhood and its areas, and on the behavior patterns of people living in the neighborhood (Sect. 5).

In this sense, the *ENaQ* project and its future results contribute to the building of resilience, not only in Helleheide but also in further urban neighborhoods where *ENaQ's* learnings are transferred and adapted. One important factor has become clear in this chapter: Resilience cannot be obtained by mere technical developments but only through the synergy of technical components and participative processes in which different stakeholders are involved at different levels of participation. In this way, cross-organizational and cross-topic networks and cooperation between politics, administration, citizens, scientists, and entrepreneurs are created and contribute to a resilient neighborhood design.

7 Future Work

Thinking energy supply systems as a topic for smaller communities such as neighborhoods is an evolving field. In the fields that this chapter covers, namely co-creation and participation in a living lab, local energy market design, and digital systems to run local energy supply and incentivize citizens, important research remains open for future work.

When working in living labs, a generic framework on how to implement a co-creation process for energy or more generic infrastructure focused projects is missing. Such a framework could help to simplify the work in living labs and to get better results when working with stakeholders. In the field of participation, the active integration of citizens in topics with complex technical questions where some previous knowledge is necessary is another area to be further researched as well as how complex questions can be integrated into a participation process. Taking into consideration which formats work best and which do not, depending on the topic, audience, and other circumstances, is also something to further examine. In the *ENaQ* project, these questions could be part of future research.

With regard to local energy markets, there are many theoretical approaches as to how these could be organized on paper, but the energy law aspect is often missing in the considerations and also the acceptance of the users has hardly been researched due to the difficult implementation. Solutions tested in real context that could reduce the hurdles that energy communities such as the Helleheide neighborhood face when building up a local energy system would ease the growth of this idea, its application, and a subsequent urban transformation.

Digital systems are an enabler to actively include consumers and prosumers into a local energy system. Research is necessary to find suitable algorithms to control local and volatile energy systems to fulfill the energy demand, especially in very small systems such as single neighborhoods. Additionally, connecting the energy devices in a digital system to control multiple smaller energy systems is not trivial and needs further research in algorithms, data management and processing, and user interface design. The inclusion of consumers and prosumers with incentivization methods, such as the energy signal light, is another topic for future work, including which positive and which rebound effects these systems can have and what users expect from these systems.

7.1 Next Steps in ENaQ

For other living lab or energy-related projects, the concrete next steps in *ENaQ* could be a useful guidance. Therefore, we present the current state and future work within the project in the following.

Currently, the district is prepared for the first construction works to start. Hence, the majority of the research project takes place before the citizens move into the area. Nevertheless, the evaluation is planned to be done at the end of the project together with the people who then live there.

During the construction, the optimum sizing and operation strategy for the energy supply system is determined using a simulation software developed in the project (Schmeling et al., 2020). The market role of the district aggregator is further clarified, including legal questions, and the market design, including the necessary contractual basis between the stakeholders directly involved in energy exchange, will be further developed. The results are meant to be an example for other neighborhoods, where a similar energy system, including a district aggregator, can be implemented.

Before the neighborhood is constructed and the energy systems are available, the digital platform is tested with the energy systems in another building, which includes a CHP and a solar system. Next to the benefits when developing the digital system, using an additional living lab, the transferability to other environments can be evaluated. This is a first indicator if the platform can also be used in other city districts.

The technical development is accompanied by the participation process. An important part is the outreach-based participation to directly approach people in their everyday environment. With such activities, for instance in pedestrian areas, a more diverse population can be reached. Another format which has been launched recently is a permanent citizen workshop in which local residents, interested in the *ENaQ* project, meet regularly in co-design and co-production workshops, allowing a more persistent interaction and citizen involvement. Within the framework of the workshop, the way in which the Helleheide residents will be able to take part in the local energy market shall be discussed. One aspect is to determine how to involve the residents in the complex trading system, how much effort and complexity is possible, and likewise how much simplicity is necessary.

7.2 Evaluation of Living Lab Projects

The results' evaluation in a living lab is a promising but also complex task. Given the technical as well as the participatory aspects, the evaluation needs to take this differentiation into consideration.

The technical evaluation focuses on the measurement of the KPIs. During an evaluation period, data about the energy systems and the local energy market will be measured and analyzed to continuously assess the KPIs. The energy system needs to be fully reliable during the evaluations. This is why the energy system will have backup systems that can prevent outages in case the evaluated algorithm causes errors in the energy system. This is a huge challenge and a clear difference from a pure lab-based evaluation.

In terms of the evaluation of participation processes, we apply the criteria from Goldschmidt (2014) that have been pointed out in the introduction: competence development, fairness, legitimacy, transparency, efficiency, and effectiveness. In this case, questionnaires are distributed among participants after workshops. Based on the mentioned criteria, participants have the chance, for instance, to evaluate the transparency by agreeing or disagreeing to statements like "The assigned tasks were clear to me." or "How the results will be used later and which effects can be achieved is clear to me." Each criteria will be covered by one to two statements which can be agreed on, partly agreed on, partly disagreed on, or fully disagreed on.

A generic evaluation framework for living labs that can be customized for a certain project is open for future work.

8 Final Considerations

This chapter aimed at answering the question, how can a local energy market be co-designed by the stakeholders in an urban living lab promoting transformation of urban structures and hence building more resilient neighborhoods. The development of a local energy market with the goal of developing a greener, more local energy supply that is accepted and used by the residents was the example used.

To answer the question, we have described the general framework of participation in a living lab project. This setup is then used for a participative process, from information to co-design, to develop a local energy market, as well as a supporting digital platform. The main goal to show the co-creation process in the example of the local energy market is the development of a local and climate-friendly energy supply. The design of such a market begins with the (future) residents of such a city district. As described in Sect. 3 the design process starts with the local citizens, researching what they think about local energy supply. These ideas and opinions are the foundation for the design process of the real energy supply system for the new city district. Designing such a market includes technical, business model, and legal considerations. The market design and legal considerations have been described in Sect. 4. Section 5 takes the realization of the local energy supply system one step further and discusses the digital system to monitor energy devices and KPIs as well as including the residents in the urban transformation process toward a more climate-friendly energy supply.

From the participation activities, the main findings so far are that people are willing to participate in a local energy market if they can save money and reduce emissions, and that direct feedback would possibly help them best to change their behavior to reach that goal. For the legal and business point of view, the main findings are that the role of an aggregator for a local energy district is key to design a local energy market that is compatible with a liberalized national energy market. The aggregator model can be used to allow energy exchange between consumers, producers, and prosumers participating actively while keeping the effort for all participants low.

Making such a market possible includes the availability of a digital system that allows participation with less effort. Additionally, digital services provide useful information to the market participants for them to improve their energy consumption and thereby improving the KPIs for the local energy market. Such incentivization methods can be, for example, a low-barrier offer for the residents to lower their climate impact with their energy consumption.

The participative approach to this project has limitations too. The complex technical and regulatory considerations are difficult to discuss with participants who are not used to these domains, therefore in many phases only inward participation has been possible. Additionally, it is not always possible to reach a representative group of interested residents. The outward participation in the next phase will cover this limitation by making it possible to test the business model and parts of the digital platform. Nevertheless, the more different stakeholders and people are taking part in the participation process in many different formats, the more difficult it gets to bring together the different interests. It is a large effort to use the plurality of inputs to achieve better results.

Another major limitation when it comes to using the described co-creation process and methods in other projects is that this research does not describe a generic framework, but a concrete project example. The examples shown can be used as ideas and guidance for other projects, but have to be adapted for the certain use-case.

The market design and digital platform research described in this chapter comes with limitations too. The local market design is limited by the national market rules and legal framework in Germany and Europe. Even within Germany it is difficult to directly copy it for other urban quarters, as the basic parameters such as generation technology or energy demand creates tight boundaries. A model that would work in the whole European market is even more difficult. Nevertheless, research such as this shows how legal frameworks can be further improved to support local energy usage. The digital platform is not simply usable for other urban areas either. The software needs tight integration with the technical energy and information systems in the respective area and hence needs to be adapted. A generic software platform and common standards for connected energy devices could improve this situation.

In conclusion, we see that a participation process in a project such as *ENaQ*, and particularly in the examples presented in this chapter, has a multitude of possibilities. We also confirmed that it is important to have different intensities, forms, and dimensions in which the stakeholders participate, as it is not always possible or even useful for all stakeholders to take part in one activity at the same time. Finally, we believe that projects like this, in which the technological developments are achieved through the interaction of many stakeholders in an interdisciplinary and transdisciplinary participative process further contribute to more resilient cities, hence fostering urban transformation.

Acronym

CHP Combined Heat and Power Plant
DSA Double Sided Auction
EMP External Market Participant
IAPP International Association of Public Participation
IoT Internet of Things
KPI Key Performance Indicator
LL Living lab
OECD Organization of Economic Co-operation and Development
P2P peer-to-peer
PV Photovoltaic
QEMS Quarter Energy Management System
SMGW Smart Meter Gateway
ULL Urban living lab

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How to Measure Safety Risks for Cyclists at Intersections?

Johannes Schering, Jorge Marx Gómez, Steven Soetens, Kim Verbeek, and Amritpal Singh

1 Introduction

Many municipalities in Europe and the rest of the world realized that the promotion of cycling is an attractive and cost efficient solution for traffic and environmental problems (European Commission, 2020). To confirm more people to cycle more often an attractive bicycle infrastructure is a key factor. That means that the quality of bicycle paths (e.g. surfaces, connections), the degree of traffic safety (e.g. risks at intersections) or travel times (e.g. waiting times at traffic lights) has to be improved. It is a big problem at this point that there is no or only too little suitable data on bicycle traffic available that could be used by traffic or city planners for the further expansion and the adjustment of the infrastructure to the concrete needs of cyclists (Monheim et al., 2016). Therefore, more and more cities or regions and research institutions started data driven initiatives to learn more about cyclists' behaviours and demands to actively find solutions to that problem (Fahrradportal, 2017). This leads to bicycle data which is collected by diverse sensor systems—so-called *Intelligent Transport Systems* (ITS). Bicycle counting, intelligent bicycle parking, bike2work campaigns based on bicycle apps, smart camera systems to detect (near) accidents, sensor systems to measure air quality or other solutions are

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already used in cities all around Europe and the rest of the world. The challenge here is that most of these applications are not aligned to each other in neither the national nor the European context. This makes an evaluation of the potentials of existing (and forthcoming) ITS solutions in the field of cycling very difficult or nearly impossible. Countries and even cities are not comparable in their efforts of cycling promotion (e.g. traffic safety, amount of cyclists). The effect and the potential of these local based solutions on mobility transition in cities remain unclear as there are diverse approaches how to count or detect cyclists not only in one country but in nearly every city working on data driven solutions for cyclists (European Commission, 2020). As a result, standards on open bicycle data for a common understanding do not exist so far.

The EU funded project *BITS (Bicycles and Intelligent Transport Systems)*[1] is working on solutions to the challenges mentioned above. One of the central goals of the project is to make cycling data from different European countries available in a comparable format and structure. This target will be delivered by an open data platform, the so-called *CyclingDataHub* (CDH)[2] which is hosted by the Province of Antwerp (Belgium). The platform gives all interested stakeholders open access to external data sets with focus on ITS applications in the cycling domain. Facing more and more digitalized societies, the idea is to increase the amount of available cycling data by external stakeholders as municipalities, businesses and researchers working on data driven cycling solutions. Interested external partners as the Province of Utrecht or the Region of Hannover are also contributing to the CDH by supplying their specific data sets. The digital platform as result of the BITS project will be a step forward to a common understanding of cycling data and makes *SmartCycling* more visible in the European and the transcultural context.

Initial cycling data sets will be delivered by the pilot regions of the BITS project through the implementation of already existing and totally new ITS as camera detection of near interactions (e.g. Province of Antwerp), bicycle counting (e.g. East Riding of Yorkshire), digital bicycle parking (e.g. City of Bruges) or air quality sensor systems (e.g. City of Zwolle) in the whole North Sea region (Netherlands, Belgium, Denmark, Germany, United Kingdom). The implementations will be evaluated in terms of its potential to attract more people for bike usage and to make cycling more safe and smart. One of the key ideas of the Interreg funded project is that regions which promote cycling for a very long time (Netherlands, Belgium, Denmark) exchange ideas with less experienced regions (Germany, UK) to identify the best solutions and new approaches. Therefore, the smartest solutions will be transferred, tested and evaluated to other partner regions as part of the project.

[1] https://northsearegion.eu/bits/

[2] www.cyclingdatahub.eu

1.1 Cycling Safety and Relevance of near Interactions

The promotion of cycling becomes more and more attractive for cities and regions. As mentioned above, an improvement of traffic safety for cyclists contributes to a more frequent bicycle use. A bicycle infrastructure with a high level of safety feeling is an important factor whether people decide to cycle more often or not (Fahrradportal, 2019). One important indicator regarding the safety level is the number of bicycle accidents in the whole city area (or at certain problem points as intersections or streets without bike lanes). If the number of accidents is decreasing parallel to an increasing degree of bicycle use, it can be assumed that a) cycling is more recognized by other traffic participants and / or b) that infrastructure improvements successfully led to more traffic safety (Keller, 1988). While sales quantities and the availability of pedelecs (*pedal electric cycle*) are increasing (Zweirad-Industrie-Verband, 2020), the number of bicycle accidents is growing. Although the number of people died in traffic accidents in Germany using all means of transport decreased, the number of killed cyclists as consequence of bicycle accidents is increasing year by year (Süddeutsche Zeitung, 2019). In total, the amount of cyclists involved in an accident in Germany increased up to 30 percent between 2000 and 2018 while the number of other traffic participants involved in an accident has decreased for more than 30 percent at the same time (Ortlepp, 2019). Because of the strongly growing during the Corona pandemic when many switched from public transport to more individual means of transport as the bicycle or the car to keep distance, experts assume that the number of killed and severely injured cyclists will grow even further (RP Online, 2020).

Especially the traffic safety situation at intersections needs to be improved. Earlier statistics from the late 1980s revealed that during that time already more than 50 percent of the bicycle accidents in inner cities were happening at intersections with an increased risk at night and in the early morning because of reduced lightning conditions (Heuser, 1987). More recently published statistics (e.g. German Bicycle Club ADFC, City of Muenster, Germany) show that nowadays more than 60 percent of the inner city bicycle accidents are happening at intersections (Ortlepp, 2019; Korn & Thiemann Linden, 2012). The danger potential arises if cyclists do not follow traffic regulations when turning especially to the left, running red lights, cycling on the wrong (and prohibited) side of the road or cycling directly on the automobile road instead on the separated bicycle path. To increase the safety level of cyclists at intersections, the bicycle traffic guidance needs to be clearly visible for all traffic participants, priority rules need to be precise, cyclists have to be separated by motorized traffic in a sufficient degree and the sight view of the cyclists should not be restricted (Ortlepp, 2019; Stock, 1980). Other factors of the intersection as the average daily volume of motorized traffic and bicycles, the width of the side walk and the existence of traffic islands may have an influence on the frequency of critical situations (Kim et al., 2012).

A big problem that is not solved so far is that many dangerous situations at intersections are not registered. At least a high number of accidents with severe injured or killed cyclists are reported to the police. Nonetheless, many accidents are not documented. About 42 percent of the accidents with severe injured and 25 percent of the accidents with light injured will not be part of the statistics (Keller, 1988). According to a research of Hautzinger the estimated number of unreported cases is very high. Nearly 99 percent of all single-bicycle accidents, about 97 percent of all accidents between cyclists and pedestrians and about 82 percent of all accidents between cyclists and cars are not part of official accident statistics (Hautzinger et al., 1993). When it comes to near accidents or interactions the reporting rate becomes more and more uncertain. According to the results of a survey among cyclists in Freiburg, Germany, about one-third of the respondents stated to be involved in a cycling accident in the past few years. More than three out of four people indicated that they were involved in at least one near accident (Fuchs & Pfeiffer, 2009). That many cyclists are experienced with near interactions is validated by another study from Brazil. Over a duration of 17 months 1.133 bicycle commuters were screened (e.g. by telephone interviews). According to this study 9 percent of the respondents were involved in a bicycle accident, while 88 percent stated to be involved in at least one near accident (Bacchieri et al., 2010). A survey by the German Traffic Safety Council (Deutscher Verkehrssicherheitsrat DVR) among 1.000 adult cyclists revealed that nearly 50 percent of the responding cyclists were involved in at least one near accident with a suddenly opening car door ("dooring" situation) (Deutscher Verkehrssicherheitsrat, 2019). Factors which are part of registered bicycle accidents are quite well known. Especially seniors and children are endangered. Male cyclists are much more often killed in traffic accidents (Auto Club Europe, 2011). However, safety statistics do only cover situations which were reported to the police. As mentioned above, in the field of cycling these are mainly accidents with severe consequences (killed or seriously injured cyclists) (Statistisches Bundesamt, 2019). As most of the near accidents are not reported to the police, the frequency of near accidents or near interactions between cyclists and other traffic participants was observed mainly by surveys (e.g. Freiburg, Brazil) but not by camera measurements. That means that the available data on near interactions is mainly based on the subjective perspective of the cyclists. As it is not clearly defined what near interaction or near accident does mean, the existing results are not or at least only hardly comparable. The objective perspective (e.g. by sensor systems) of near interactions was not detected so far.

The numbers mentioned above make clear that there is a huge demand on data about conflict situations which do not result in an accident. Therefore, the first main research question of this paper is how to detect near interactions between cyclists at intersections by ITS (in this case camera systems). The detection of near interactions at intersections could contribute to a higher degree of safety and comfort for cyclists on the mid and long term as new conflict points in the bicycle infrastructure could be identified. The prerequisite for more safety is that the knowledge collected is integrated in forthcoming infrastructure improvements. As the newly generated data should not only contribute to the improvement of the traffic situation at one certain intersection the data need to be opened to a broader audience. That leads to the second research question of this contribution. In the following it will be answered based on the specific example from Antwerp what steps are necessary to take to make the resulting data publishable in a high quality for interested stakeholders on open data portals as the CyclingDataHub. Finally, it will be discussed how to evaluate the regarding traffic safety. One existing approach to measure a collision risk of specific traffic situations is the Surrogate Safety Measure (SSM) that is based on traffic parameters as speed, acceleration, time and space headway. The term *surrogate* stands for identifying safety critical events (or near accidents) in traffic, which can be used as an alternative to accident records (Johnsson, 2020). The Time-to-Collision (TTC) estimates the expected time when two traffic participants collide and is often used to judge the degree of danger of a certain conflict situation. Based on that different driving assistance systems with focus on motorized traffic and different types of driver behaviours (e.g. sensor, V2V communication based) have been developed (Tak et al., 2018).

2 Measurement of near Interactions with 3D Camera Technology

The first discussion point of this publication is how to detect near interactions between cyclists at intersections by ITS. As part of the European project *BITS (Bicycles and Intelligent Transport Systems)* which is funded by the North Sea Region (NSR) programme and is aiming at the improvement of the availability of open bicycle data regarding road safety, convenience and comfort for cyclists, the Province of Antwerp tested a 3D camera technology by Viscando from Sweden to detect near interactions between cyclists, vehicles and pedestrians at a dangerous intersection in late September 2019. Facing the challenges mentioned above, the topic of near accidents seems to be quite relevant as local police reports reveal that the number of bicycle accidents in Antwerp has increased between 2014 and 2018 year by year (Wang et al., 2019). The observed intersection is located in the municipality of Bornem which has about 20.000 inhabitants and belongs to the arrondissement Mechelen in the southwestern part of the Province of Antwerp. At the Puursesteenweg a cycle highway is interrupted by a traffic lane and railway tracks.

The images of the 3D camera are automatically processed what means that no images or video files are recorded. The traffic participants are divided into different categories as cyclists, pedestrians and vehicles (cars and trucks). The trajectory of every road user is registered with a time stamp. A conflict situation is detected when two traffic participants are crossing one another's trajectory and do pass this crossing point in a time interval below 1 s (dT, time difference between the arrival of the two objects at the conflict point CrossPtX, CrossPtY). This time difference is often referred as Post Encroachment Time (PET) in literature (Paul, 2019). For the localization the intersection was divided into a coordinate system (Fig. 1). The conflicts are detected with an accuracy of about 15 centimetres. To enable

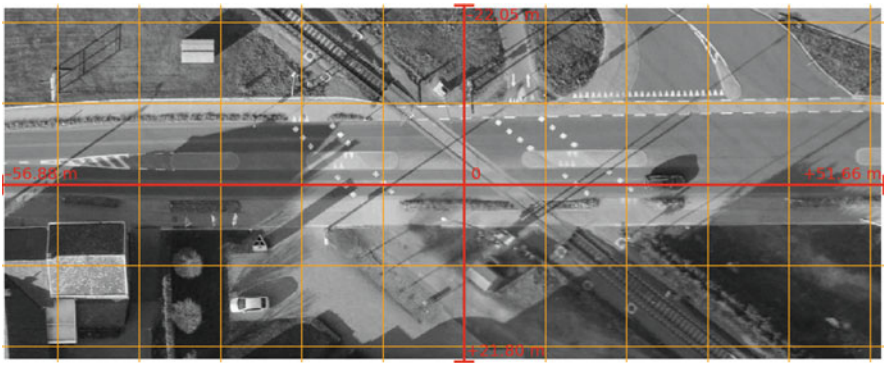

Fig. 1 Coordinate system at the intersection in Bornem / Antwerp. Source: Viscando, Province of Antwerp

a localization each conflict situation contains an x and y coordinate (CrossPtX, CrossPtY on the ground plane of the point of intersection between the trajectories of the tracks that participate in a conflict). In total, 114 near interactions between cyclists were detected during 5 days of measurement (Monday, the 23rd until Friday, the 27th of September 2019). It has to be mentioned that the near interactions between cyclists and vehicles or pedestrians will not be further discussed in detail in this publication.

3 Evaluation

One of the main deliverables of the BITS project is the realization of a European open data portal with focus on bicycle data. The approach of the so-called *Cycling-DataHub* is to make cycling data from all over Europe available and accessible for external stakeholders. Municipalities, research projects and other interest groups can publish their cycling data in categories as Cycle Use, Cycle Infrastructure, Safety, Environment and Emissions and Bicycle Business Performance. Therefore, the second research question which needs to be discussed in the following is what problems need to be solved to make the resulting data publishable in a high quality for interested stakeholders on open data portals.

As part of the pre-processing phase third parties and stakeholders which are interested to work with this kind of open data need to be enabled to localize the intersection and the conflict points. Therefore, the x and y coordinates given need to be converted into geocoordinates (longitude and latitude format, see 3.1). In addition to the missing localization, it was not clear which of the near interactions measured are more conflictful or even dangerous than others. Although the degree of severity and of relevance regarding the risk estimation was not calculated in detail for each near interaction point so far, first ideas on how to evaluate the near interactions on safety issues were collected. This leads to the third research question of this research paper how to evaluate the resulting data regarding to safety issues. As we may learn by Surrogate Safety Measure, a study of speed levels, the time-to-collision and cycling directions could contribute to assess specific risks at intersections. Regarding the time dimension the conflict situations were filtered into different times of the day (morning, noon, afternoon) to understand the distribution of the near interactions over the whole day (see 3.2). Based on the vx and vy coordinates of cyclists and other traffic participants (e.g. vehicles) the average speed levels were calculated. These were not only divided into different times of the day but also geographically to the different parts of the intersection. In the last step cycling directions were determined (see 3.3). Contrasting directions could mean a higher potential risk at a certain point and could be more relevant for a later risk assessment (see conclusions and future work 4.).

3.1 Geocoordinates

The conflict points in the raw data set were only provided with x and y coordinates on the intersection in the coordinate system by Viscando (see Fig. 1). To enable external people who are interested to work with the data set to locate the intersection and the conflict points, the University converted the x and y coordinates into geoinformation in the longitude and latitude format. The geocoordinates of the zero point (Fig. 1, point of intersection of the red lines) are 51.085709, 4.263511.

$$\text{Conversion formula longitude}: dx/\left(111300 * \mathrm{COS}(51.085703)\right) + 4.263511),$$

$$\text{Conversion formula latitude}: (-(dy/111300) + 51.085703)$$

$$dx \text{ in metres} = \text{Distance x coordinate from the zero point}$$

$$dy \text{ in metres} = \text{Distance y coordinate from the zero point}$$

$$111,300 \text{ in metres} = \text{Distance of latitude (constant)}$$

$$\mathrm{COS}(51.085709) = \text{Correction factor of longitude}$$

3.2 Filtering into Different Times of the Day

The 114 conflict situations at the intersection all contain a number dT between 0 and 1 which indicates the time to conflict point in seconds (time difference between the arrival of the two objects at the conflict point). These were filtered into conflict situations of above 0.2 (39 situations), between 0.1 and 0.2 (17 situations) and below 0.1 (56 situations). In a next step the conflict situations were filtered into different times of the day (morning, noon, afternoon). The average mean time of a near interaction over the day is 32 minutes. The peak time can be identified in the morning hours (7 h–9 h) with one near interaction each 17 minutes. The mean time at the afternoon (16 h–18 h, 24 minutes) is also higher compared to the average level but lower compared to the morning. Monday is the day with the shortest mean time of near interactions over the day (25 minutes).

The calculated mean times can be validated by the numbers of bicycles counted during the 5 days of the 3D camera measurement. As mentioned above, the daily traffic volume (e.g. motorized traffic, bicycles) may have an influence on the frequency of critical situations. This can be proven by other statistical values of the Province of Antwerp. Besides the measurement of near interactions at intersections, the Province is counting bicycles at different locations on a regular basis. Two counting stations are located at the municipality of Bornem (FMN GV 04 A Bornem and FMN GV 04 B Bornem) close to the intersection. The hourly values of these two stations during the last working week in September 2019 reveal that there were two peaks in the amount of counted bicycles between 7 h and 9 h in the morning and 16 h and 18 h in the afternoon (Fig. 2). That confirms the assumption that the frequency of near interactions increases when the amount of counted cyclists is growing. Taking the bicycle counting data into account, this effect seems to be stronger in the morning as the total number of counted bicycles in the afternoon is slightly higher compared to the morning hours.

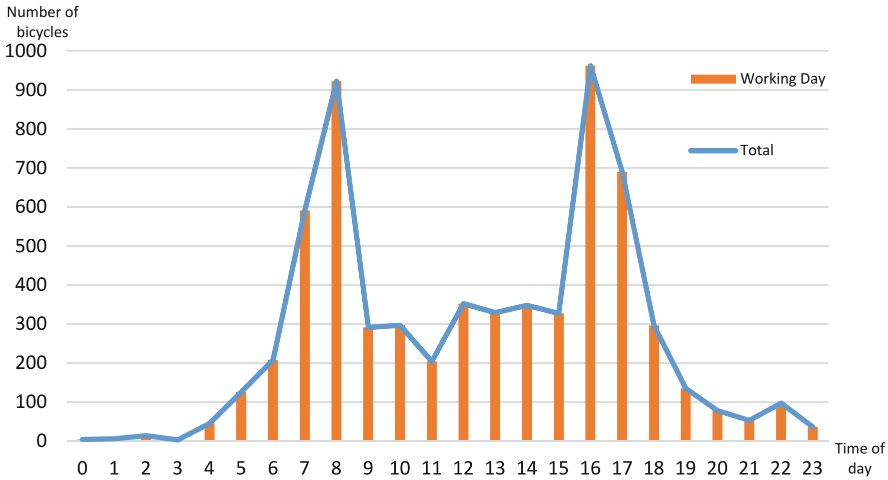

Fig. 2 Number of counted bicycles per hour in Bornem, 23rd to 27th of September 2019 (University of Oldenburg)

After all it can be summarized that according to the calculated mean times the probability to be involved in a near interaction with another cyclist is much higher in the morning compared to other times of the day. The frequency of conflict situations in the afternoon is lower than in the but higher as the rest of the day. These results are confirmed by the statistics of bicycle accidents in European cycling cities. According to statistics of the City of Erlangen / Germany, most cycling accidents are registered between Monday and Friday in the morning time (7–9 h). In addition, there are also many cycling accidents registered between Monday and Thursday in the afternoon (16–18 h) (City of Erlangen, 2017).

3.3 Speed Levels and Directions

Beside the mean times the speed levels, the average speed and the speed distribution in kilometres per hour (km/h) of all conflict situations were calculated as other potential relevant key performance indicators (KPIs). The speed levels can be calculated by the vx and vy coordinates given by each vehicle or traffic participant (x and y components in metres per second of the velocity vector for the tracks participating in the conflict at the point CrossPtX, CrossPtY).

Speed level in km/h:

$$\varDelta \mathrm{V} = \sqrt{\left(\varDelta \mathrm{vx\hat{}2} + \varDelta \mathrm{vy\hat{}2}\right)} * 3.6$$

The average speed of all near interactions is 11.270 km/h, the top average speed of one interaction is 22.296 km/h. As another step of the data preprocessing outliers had to be removed as motorcycles, scooters, mopeds, bicycles and speed pedelecs were not divided. One alleged bicycle crossed the intersection with a speed level of 80 km/h, another one with 45 km/h, two other ones with more than 30 km/h.

Not only the mean times but also the speed levels reflect that the risk to be involved in a near interaction could be higher in the morning compared to other times of the day. Between 7 h and 9 h when many commuters cycling to work or school what is confirmed by the bicycle countings (Fig. 2) the near interactions with the highest average speed levels can be identified (12.962 km/h). The speed levels in the afternoon (16–18 h) are close to the average speed levels (11.086 km/h) (Table 1).

When discussing about potential risks and speed levels it also has to be mentioned that quite a lot of near interactions with very low speed levels were measured. More than one-third of all situations (39) with an average speed level below 10 km/h were detected (see distribution of average speed levels in Fig. 3). A very low risk of these near interactions as part of a later risk assessment process (see 4. conclusions and future work) can be assumed.

Table 1 Average speed levels of all near interventions (University of Oldenburg)

	Average in km/h	7 h–9 h	12 h–14 h	16 h–18 h
All days	11.270	**12.962**	9.530	11.086

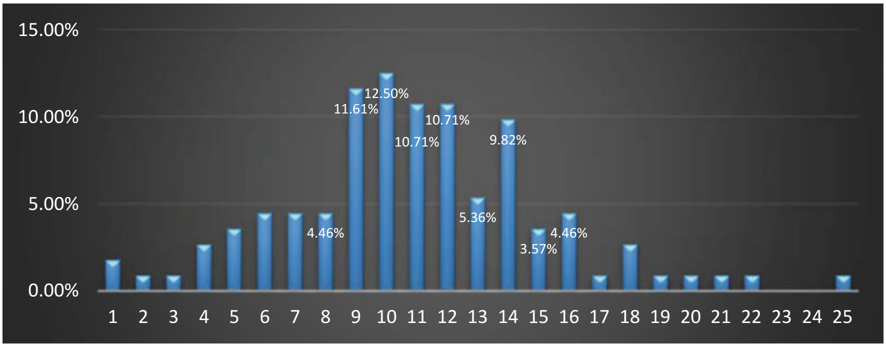

Fig. 3 Distribution of average speed levels (University of Oldenburg)

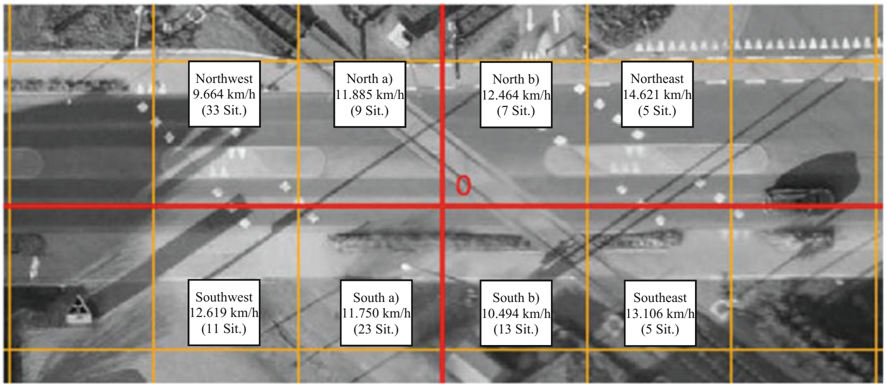

Fig. 4 Geographical distribution of all speed levels (grid by Viscando, values by University of Oldenburg)

It can be assumed that a supposed bicycle that passes the intersection with a speed level faster than 35 km/h is not a bicycle but could be a motorcycle. Therefore, this small number of high speed bicycles was filtered out of the data set to make the results more accurate.

As a next step, the speed levels were not only investigated in the time but also in the geographical dimension to learn more about risks at different parts of the intersection (Fig. 4.). A higher degree of risk in the southern part over the whole day could be assumed as the average speed levels in the southern part of the intersection are higher than the general average speed level. In the field south a) where the cycling path is interrupted, 23 near interactions were detected. It is remarkable that in the northwestern part of the intersection many interactions (33) with a quite low

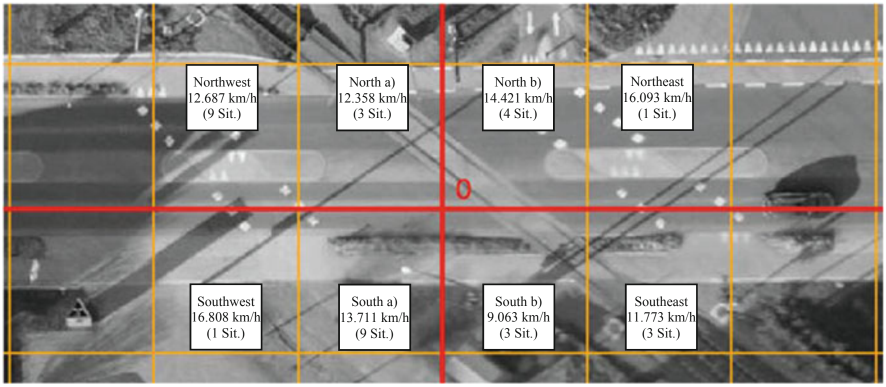

Fig. 5 Geographical distribution of speed levels in the morning time 7–9 h (grid by Viscando, values by University of Oldenburg)

average of speed levels were detected (9.664 km/h). The highest speed levels were detected in the northeast (14.621 km/h) and in the southeast part (13.106 km/h). The number of near interactions detected in the north (54 situations) and the south (52 situations) is nearly equal.

That the morning time is the most conflictful time of the day is also proven by the geographical distribution of the speed levels between 7 h and 9 h (Fig. 5.). In the northern part of the intersection a remarkable increase of the average speed levels could be perceived (13.237 km/h). Especially in the northwestern part the increase is obvious (12.687 km/h). The increase of the average speed levels in the southern part is less remarkable (12.670 km/h) and lower compared to the northern part. Therefore, taking into account the speed levels a higher risk in the northern part during the morning hours could be assumed.

3.4 *Preferred Routes and Directions of the Cyclists*

The analysis regarding preferred routes and cycling directions by Viscando has shown the following results. When crossing the railway line, as well as when crossing the Puursesteenweg, the cyclists tend to show different preferences of the route they choose depending on the directions they are cycling to. When crossing the railway from the western side, the bicyclists are almost equally likely to choose the northern pavement, the southern pavement or the automobile road, with a slight preference for the latter. When crossing the railway from the east, the cyclists use the northern pavement more often than the southern one. In both cases, between 37 and 39 percent of the cyclists tend to cross the railway at the level crossing for vehicle traffic. When crossing the Puursesteenweg from the north, the cyclists do prefer the eastern crossing slightly more often. When crossing the Puursesteenweg

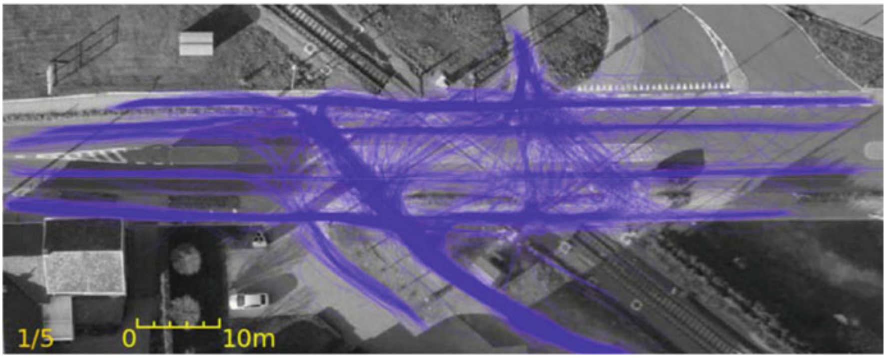

Fig. 6 Heatmap of Bicycle trips. Source: Viscando, Province of Antwerp

from the south, the cyclists show a strong preference for the western crossing. In both cases, there is a significant share of cyclists who tend to shorten their way and cross both the railway line and the Puursesteenweg at the level crossing for vehicle traffic. This tendency is more significant for the bicyclists coming from the cycling path in the northern part of the intersection (see Heatmap Fig. 6).

In addition to the speed levels, the cycling directions could also be a relevant factor to determine the degree of risk of a critical situation. Contrasting cycling directions (combined with differing speed levels of the two cyclists involved) could lead to an increased risk of collision. The cycling directions can be abbreviated by the vx and vy coordinates given of every traffic participant. As an example, cyclist 1 has the coordinates −1.89 (x) and − 3.15 (y). A negative x coordinate means that the cyclist is approaching the intersection from east cycling to the western direction. It has to be mentioned here that the algebraic sign of the y axis (+ and -) is reversed. That means that a negative y coordinate indicates that the cyclist is moving from the southern to the northern direction. At all, cyclist 1 is approaching the intersection from the south and is cycling to the northwestern direction with a speed level of 13.22 km/h. Cyclist 2 with the coordinates 6.91 and 1.37 is cycling to the southeastern direction with 25.35 km/h. It can be deduced that this conflict situation which happened in the central southern part of the intersection had a very high risk of collision because the cyclists moved (a) with a high average speed level of 19.29 km/h, (b) with differing speed levels (13.22 km/h vs. 25.35 km/h) and (c) to conflicting directions (northwestern vs. southeastern direction). Fig. 7 shows some of the most conflictful situations because of high speed cyclists, significant speed level differences and contrasting directions.

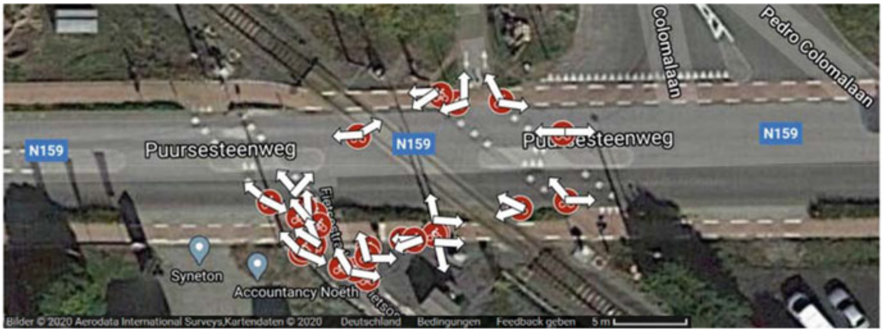

Fig. 7 Some of the most conflictful near interactions regarding speed level differences and contrasting cycling directions. Source: GoogleMyMaps (University of Oldenburg)

4 Conclusions and Future Work

Several research questions were discussed and answered in this research paper. The first question was how to detect near interactions between cyclists at intersections by ITS. The solution which was discussed is the 3D camera system of Viscando that detected 114 near interactions among cyclists during five days in late September 2019. The measurement shows where are problem points at the intersection with an increased number of conflict points. The second research question of this paper was which steps are necessary to make the resulting data publishable in a high quality for interested stakeholders on open data portals. The x and y coordinates of the traffic participants (vx, vy) and the near interactions were transformed into geoinformation to enable the localization of the intersection and the conflict points. It seems to be that not each conflict point has the same relevance in terms of traffic safety what leads to the third research question how to evaluate the resulting data regarding to safety issues. To further understand the degree of risk of a near interaction the speed levels and the directions of the cyclists were further investigated. Especially in the morning hours (7–9 h) many near interactions with increased speed levels were detected. Taking the number of counted bicycles in Bornem into account, it can be assumed that there is a connection between the number of near accidents and the number of cyclists passing the intersection. The average speed levels in general tend to be higher in the southern part of the intersection but are higher in the northern part in the morning hours. The cycling directions reveal further conflict potential as contrasting directions of two cyclists could be more dangerous than equal directions.

The preprocessed and refined data set of the near interactions including geoinformation and speed levels will be provided and make public accessible in the *CyclingDataHub* and other open data portals in a suitable raw data format. The quality standards defining the quality of open data according to the 5-star open data model by Berners Lee will be considered. That includes an open license, a structured data set in a machine readable format (e.g. CSV or JSON but no PDF file), open standard formats, usage of Uniform Resource Identifiers and linkage to other similar data sets in a common structure and format (Oyama et al., 2016). Based on the results of the detection of the near interactions the Province of Antwerp is actually planning construction measures to improve the traffic safety situation at the intersection in the municipality of Bornem. The idea is to repeat the detection of near interactions by the 3D camera system after realizing the measures to evaluate whether the level of safety has increased.

Generally applicable factors on the safety assessment of cyclists' safety at intersections could be deduced by the results of the study of the near interactions in Antwerp which were discussed in this paper. Based on the results of the University, the Province of Antwerp and Viscando are now working together on a methodology to measure risk levels for cyclists at intersections. As can be understood from the results above and existing methodologies as the Surrogate Safety Measure, differences and distributions of speed levels and cycling directions seem to be important indicators to measure the degree of risk of a certain near interaction.

To learn more about cycling safety at intersections the Antwerp case need to be compared to measurements at more intersections. A remaining question which will be part of future research is how intersections in different countries and cities could be compared regarding traffic safety. As part of the BITS project near interactions between cyclists and vehicles at two intersections in the Province of Friesland and another two in the City Zwolle were detected in the Netherlands. The camera system which was tested in these implementations is different compared to the Viscando technology. The speed levels of the vehicles and the time difference to collision (value between zero and 5 s) were measured. The four Dutch cases will be compared to the Antwerp case where 32 near interactions between cyclists and vehicles were detected. Although the conflicts between cyclists and car drivers or trucks were not discussed in detail in this publication, it can be mentioned that the average speed levels of the vehicles in Antwerp tend to be higher (23 km/h) compared to the other intersections. Therefore, a higher risk compared to the Dutch cases could be assumed. Nonetheless, further research which will be part of future publications is necessary at this point.

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Part IV
Resilience Through the Smart Use of Resources

Geographic Information System for Forecast and Control of Soil Erosion. Case Study: *Marmanelo* and *Caminhos de Ferro de Moçambique* Neighbourhoods in the City of Mocuba

Mahomed S. J. Mia and Urânio S. Mahanjane

1 Contextualization and Motivation

Mozambique experienced an armed conflict, which lasted roughly 16 years. This conflict began in 1976 and ended with the signing of the General Peace Agreement in 1992. According to Jafar (2014), it was one of the most devastating conflicts in southern sub-Saharan Africa, which left the country destroyed, extremely poor, highly indebted and more dependent. The external debt increased by around 500% and more than 60% of the foreign investment was cancelled. And yet as one of the direct consequences of this conflict, were the human victims (more than 100,000 deaths).

During the period of conflict, populations living in the interior districts that were most affected by the war migrated to safer places. The district of Mocuba has a military barrack, which was responsible for security in the interior region of the province of Zambézia. Due to the factor of relative security, the district and the city revealed themselves as alternative place for the populations more inland. In this way, the peripheral neighbourhoods of the city of Mocuba were being occupied in a disorderly manner by this group of people who left the most affected districts, looking for security. This unordered occupation brought environmental problems (such as erosion).

Soil erosion in some peripheral neighbourhoods of the city is a consequence of the mentioned problem, since some of them did not and do not have suitable living conditions and the population was removing the vegetation cover that protected the

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Fig. 1 Access roads destroyed by erosion

soil for the construction of housing. Today, this problem has affected the population (destruction of houses, loss of human lives, rivers became cloudy in the rainy season due to the transport of large amounts of sediment, among others). In the place under study, there is a high level of erosion occurrence due to intense urbanization and the lack of territorial planning.

According to data provided by the Conselho Municipal da Cidade de Mocuba (n.d.-a, n.d.-b)[1] during the exploratory study, about 191 houses were affected by erosion in the neighbourhoods of the municipality. Of these 191 houses, 91 were completely destroyed and 100 were partially affected. Regarding the road network, the city of Mocuba has about 16.38 km of impassable roads. The two neighbourhoods, Caminhos de Ferro de Moçambique (CFM) and Marmanelo, have more than half of impassable roads, with about 8.28 km. These data clearly show that the CFM and Marmanelo neighbourhoods are the most affected by erosion in the city of Mocuba. Figure 1 illustrates some access roads with transitability problems due to the effects of erosion.

The absence of a geographic information system makes the problem even worse, since there is no control, data (database) and information on the evolution of environmental problems (mainly erosion), affected populations, destroyed areas, among other aspects. The lack of a geographic information system is not the cause of the occurrence of erosion in the city, but it complicates the management of the problem and consequently calls into question the development of the city itself from an economic, social and environmental point of view.

In this order of problems, the following question arose that guided the research: could the use of a geographic information system contribute to the forecast and control of erosion in the Marmanelo and CFM neighbourhoods in the city of Mocuba?

[1]Concelho Municipal da Cidade de Mocuba/Municipality of the City of Mocuba.

Thus, to direct the research and create the barriers, other questions were risen such as:

- What is the situation of erosion in the neighbourhoods of Marmanelo and CFM in the city of Mocuba?
- What is the behaviour of the parameters that influence soil erosion in the city of Mocuba?
- What is the level of vulnerability for the occurrence of erosion in the neighbourhoods in question? and
- How to model the Geographic Information System for the forecast and control of erosion in the neighbourhoods of Marmanelo and CFM?

Urbanization is a concept that represents the development of cities, where houses, sewers, avenues, schools, hospitals, among other infrastructures are built. Urban development is also followed by population growth, and this (urban development) results mainly from the migration of people from rural to urban areas. However, when there is no urban planning, social problems (such as the case of sanitation and housing) multiply in cities and especially in places of informal settlements that are created spontaneously without the planning of space, or without a territorial order.

The unordered occupation of land as well as the improper exploitation of natural resources is lasting for many years and has intensified in recent decades. The problem causes deforestation of native vegetation, which increases susceptibility to erosion process as it also sustains (Brito, 2012).

There is a great environmental impact caused by the increase of the population in some points of the geographic space, either in cities or in peripheries. Geographical concentration implies for itself environmental issues that do not arise when the population is dispersed in rural areas.

Agenda 21 further proposes that governments, at the appropriate level, with the support of the relevant international and regional organizations, should take actions to prevent soil erosion and promote activities aimed at controlling erosion in all sectors.

The problem of erosion in the Marmanelo and Caminhos de Ferro de Moçambique (CFM) neighbourhoods is the result of unplanned urbanization, as the population coming from rural areas has no financial or economic resources and they come to the city looking for better living conditions. This lack of resources does not allow them to purchase housing in planned and orderly areas, and they settle in neighbourhoods on the periphery and in inappropriate places.

The use of an instrument such as the geographic information system (mainly with regard to the use of urban soils) is an added value, not only to plan and manage the land to be used, but also to make a control on the environmental situation in occupied areas. The use of this instrument with the aid of ARCGIS 10.2.2 becomes important because it will map critical areas, areas of intervention and areas to be preserved. This system is shown to be an important element in assisting the land planning and occupation process.

Territorial planning can be an alternative, and it is even the most correct solution to this problem, since it may create the restructuring of the urban and suburban space altered by human action, minimizing the effect of the man–nature relationship. It is important to mention that an intervention of this level will imply high costs, which in most of the cases our municipalities cannot afford. In this order of ideas, monitoring the evolution of the problem, the execution of alternative and specific actions may prove to be effective solutions in combating and minimizing this problem.

This research provides technological tools for erosion forecast and control. With the use of this system by the authorities and the population, a sustainable technological contribution is expected to minimize this problem of erosion in the Marmanelo and CFM neighbourhoods in the city of Mocuba, as well as for other regions of Mozambique and of the world.

The general objective of this study is to design a geographic information system for the forecast and control of erosion in the Marmanelo and CFM neighbourhoods in the Municipality of Mocuba.

2 Methods and Materials

The research was carried out in two (2) neighbourhoods in the municipality of Mocuba, namely Marmanelo and Caminhos de Ferro de Moçambique (CFM). These neighbourhoods are the most affected by erosion. This qualitative and quantitative research made an evolutionary analysis of the problem in question (verified the evolution of land occupation / use and the problem of erosion between March 2005 and December 2015) and finally conceived a geographic information system for the forecast and erosion control. The procedure methods used were as follows:

a. *Ecological method*, this method helped in the analysis of the erosion situation in the neighbourhoods in question and allowed to establish the relations between man (population and his activities) and the environment according to (Corrêa, 2012);
b. *Comparative Method,* this method enabled the comparative study between individuals and the comparison of data collected on the parameters that influence the occurrence of erosion in the study neighbourhoods;
c. *Statistical method*, this method allowed the study of the correlations between the various environmental phenomena, thus allowing to verify the vulnerability to the occurrence of erosion in neighbourhoods.

The research was based on the following data collection techniques:

a. *Bibliographic and Documentary Review*—these techniques were used to collect information through bibliographic works and documents in the institutions (Municipal Council, Government, among others) that are relevant to the work;
b. *Experimentation*, using a computer to model and develop a Geographic Information System capable of helping to control and forecast erosion in the neighbourhoods in question;

c. *Direct and indirect observation* was used to make a direct observation of the phenomenon and by indirect observation (using satellite images), two elements were analysed, the vegetation cover and the urbanized area. For data collection, an observation guide (direct) was developed; and
d. *Interview*, it was used to obtain information from employees of some institutions related to the urbanization of the city and the structures of the neighbourhoods. Based on interview guides, detailed information was collected from municipal authorities, community leaders and the population of the two neighbourhoods concerned, the provincial directorate of land, environment and rural development (DPTADER) and the National Institute of Meteorology (INAM)—Quelimane.

For data collection, ArcGIS was used to map and analyse the places with the highest declivity and not proper for housing; NetBeans was used for the design of the geographic information system. This allows for rapid application development. GPS, to accurately georeference locations with erosion problems (critical, vulnerable locations, among others); and Google earth, which helped in the extraction of satellite images, that allowed the analysis of the evolution in the occupation of spaces; based on these images, it was possible to verify the expansion and population density and the reduction of vegetation cover in the study area.

Thereby, the data collected for the study and used for the analysis (on ArcGIS) was Digital Elevation Model. Through the use of LANDSAT satellite with the 90 $\times$ 90 m resolution the acquisition of DEM images of the study area was possible, thus allowing to do the analysis of the rainwater flow and the vulnerable areas. Maps were also elaborated (mainly for the eroded areas) using the digitalization of the analogue sources.

3 Results and Discussion

The study area, the Marmanelo and Caminhos de Ferro de Moçambique (CFM) neighbourhoods, are located in a region where the predominant relief is the plateau. The problem of erosion in the Marmanelo and CFM neighbourhoods is linked to the process of unplanned urbanization (lack of spatial planning), since the population coming from the rural area is devoid of financial or economic resources, and come to the city looking for better life conditions.

Due to these scarce financial resources, it does not allow them to acquire spaces for housing construction in planned and ordered areas, thus creating conditions for their settlement in these peripheral neighbourhoods and in incompatible locations.

The weakness of the Municipal Council of the City of Mocuba (CMCM) with regard to inspection and urban planning instruments coupled with the scarce financial resources of the population, conditions the settlement of the population in inappropriate areas, thus increasing the occurrence of erosion. It should be noted that territorial planning would be the best solution, but an intervention of this level will be very costly, which the municipality cannot afford to pay. However, the implementation of alternative and specific solutions can prove to be effective in minimizing and combating this problem.

3.1 Urban Planning and Infrastructure Adaptation in the City of Mocuba

The concentration of people in a limited space creates a series of challenges that must be faced in order for these populations to fulfil their multiple needs of housing, food, work, recreation, transport, communication, interaction, spirituality, amongst others. In the cities, these needs are attended by a series of urban infrastructures that interact to create the complex system that a city is (Schick, 2014).

The growth of the cities not always follows an established plan, this is the example of the city of Mocuba and most of other cities in the developing countries, which present (besides the central zone) many areas of informal settlements, which resulted of the spontaneous fixation of the most underprivileged population.

In order to face this situation, the governments have been taking a set of measures related to urban planning. The implementation of urban planning is of extreme importance to minimize the various problems related to the cities.

The land use planning law (19/2007 of 18 July 2007) enunciates as objectives the guaranty of soil occupation to people and local communities, and the requalification of urban areas and the preservation of the ecological balance and the built and natural heritage, as well as to optimize the natural resources and manage conflicts of interest.

At light of this law, it is determined the people responsible for the ordering process. For the municipalities/autarchies, the law define three (3) main instruments: the structure plans, urbanization plans and detail plans.

Making use of the structure plan, it is possible to verify (see map in Fig. 2) the areas of intervention in the urban requalification and reordering. Although this is an important measure, it involves a high operational cost, and is not at local authorities level, but central, which may take a long time for its implementation.

Due to the high operational cost of the urban planning measures, not all city areas are benefited by this process. So, it is possible to verify on the map above that the area of study did not benefit of this process.

The implementation of urban planning is the right measure to be applied to minimize the impact of various urban problems. But, due to the economic-financial situation of most of the population and also of the municipality authorities, other measures can become a viable alternative.

Other alternative measure to face this problem would be the introduction of infrastructure adapts to this reality. This measure like the previous (urban reordering and requalification) has the fragility in what concerns the operational costs. Taking into account that the erosion has been affecting mainly the disadvantaged population and looking at the fragility of the housing policy of the country, this measure proves ineffective.

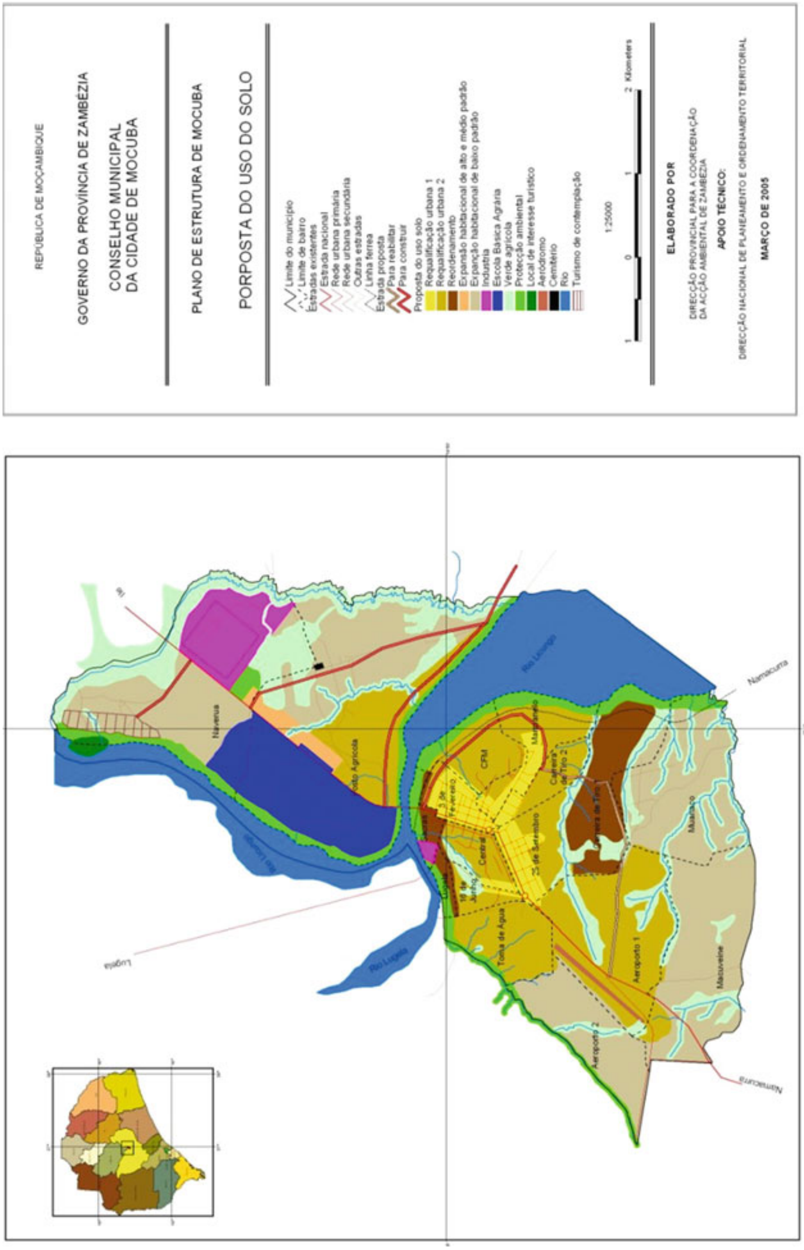

Fig. 2 Map of land use in the city of Mocuba. Source: CMCM (2017)

3.2 Factors that Condition the Soil Erosion Process

For the specific case of Mocuba city peripheral neighborhoods (and of the study area) we note the combined influence of the main factors that influence soil erosion, namely the climate (precipitation, wind and temperature), relief, soils, vegetation cover and human action, according to (Brito, Brito, 2012). The study area has a tropical climate (with precipitation being the most important factor).

According to observations made, it was found that Marmanelo and CFM neighbourhoods lack drainage systems, it was also found that old rainwater runoff beds, which have soils vulnerable to erosion, were occupied. According to MAE (2005), the soils in the study area are clayey and sandy soils, which due to their characteristics, are even more vulnerable to erosion.

The study area despite having some vegetation cover, a large part of it was removed during cleaning for construction or for opening small agricultural fields, leaving the soil vulnerable (see the Fig. 3).

According to the above images, there was the removal of the vegetation cover with purpose of opening cultivation areas in risk areas and the failure to observe the cultivation rules for sloping areas. Still in this context, in addition to the removal of the vegetation cover, there is excavation and removal of soil for the purpose of making bricks for housing construction.

These activities show the influence of human action on the environment, revealing itself as the main driver of erosion processes. This results mainly from unordered occupation and the removal of vegetation cover. For Bittar et al. *apud* Brito (2012), the main causes of the emergence of urban erosion are the precariousness of the rainwater drainage system and the rapid and uncontrolled urban expansion. The study area is a consequence of this rapid and uncontrolled expansion, where the disadvantaged population was occupying marginal areas and without conditions for housing.

Fig. 3 Corn and sugar cane fields in sloping areas

The study area has not only a few small water trajectories, areas of marked declivity, but is also located on the banks of the Licungo River. These factors combined with the high population density, harmful practices to the environment (such as the removal of vegetation cover, construction in sloping places) make this area vulnerable to the occurrence of erosion.

For the calculation of soil loss through erosion, the universal soil loss equation was used. The formula for calculating soil loss involves some important factors, notably: rain erosivity (*R*), soil erodibility (*K*), topographic factor (LS), use and management (*C*), conservation practices (*P*) (Schick, 2014).

$$\mathrm{A} = \mathrm{R} \times \mathrm{K} \times \mathrm{L} \times \mathrm{S} \times \mathrm{C} \times \mathrm{P}$$

The Rain erosivity (factor R) is the ability of rain to cause or induce erosion, and erosivity is proportional to the kinetic energy generated by the maximum intensity in 30 min of precipitation. Due to the lack of data on the intensity of precipitation, Lombardi Neto and Moldenhauer (1992) propose the use of the erosion index (EI), considering only the average monthly precipitation and the average annual precipitation. Thus, the following formula was used:

$$\mathrm{EI} = 67,355\left(r^2/P\right)^{0.85}$$

And for the calculation of the *R* factor, the sum of the monthly erosion index is added, as illustrated in the formula below:

$$R = \Sigma\mathrm{EI}$$

Using the formulas described above, it was found that the factor *R*, or rain erosivity (mean value of 11 years) is about 8472,411 MJ mm ha year. The soil erodibility (factor K) is the vulnerability it has to erosion. This erodibility is influenced by its characteristics/properties, which influence the infiltration capacity and the permeability of rainwater.

According to Borges (2012), the values of soil erodibility can be synthesized according to its characteristics, as shown in the Table 1.

Table 1 Value of factor K for each type of soil. Source: Chaves (1994) cited by Borges (2012)

Soil type	Factor K
Alluvial soils	0.047
Sandy soils	0.0078
Cambisols	0.06
Yellow latosol	0.028
Red latosol—yellow	0.02
Red latosol—dark	0.013
Red—yellow podzolics	0.0293
Litolic soils	0.035

Table 2 Mean values of the LS factor. Source: DOMINGOS (2006)

Declivity	Values of the LS factor
Plan (0–3%)	0.863
Low wavy (3–8%)	2882
Wavy (8–20%)	5400
Strongly wavy (20–45%)	8322
Mountainous (45–75%)	11,611
Cliff (more than 75%)	16,318

The study area has sandy soils, which suggests that its erodibility is around 0.0078.

Relief plays a role in soil erosion, it determines the speed of erosion processes. This factor is composed of the length of the ramp and the slope. The average values of the LS factor (ramp length and slope) are described in the Table 2.

The study area has a slope that varies between 6 and 12%, and looking at the Table 2, it can be framed in a wavy slope and the LS factor value of 5400.

The use and management of the soil are pointed out as a factor for the calculation of soil loss. The activities carried out can contribute to soil conservation and or exposure to atmospheric and/or erosive agents. According to Artins (2005) cited by Domingos (2006), for exposed areas, the average value of this factor is 1 (one). Due to the existence of some vegetation in the study area, mainly undergrowth, and the soil is not fully exposed, the value adopted in this research for the respective calculation was 0.6.

The last factor necessary for the calculation of soil loss is the Conservationist Practice, which according to Domingos (2006), is the relationship between the intensity of soil loss with a given conservationist practice and the losses when the crop is planted in the direction of the slope. For this research, factor $P = 1$ was adopted as a constant, representing the worst situation of soil loss taking into account its conservation activities. The factor $P = 1$ (which represents maximum values) indicates the absence of conservationist practices, which is the case verified in the study area.

Thus, the equation presented for the calculation of soil loss is as follows:

$$\text{A (ton/ha.year)} = \text{R} \times \text{K} \times \text{L} \times \text{S} \times \text{C} \times \text{P}$$

Thus, from this equation, the following can be obtained:

$$\text{A (ton/ha.year)} = \text{R} \times \text{K} \times \text{L} \times \text{S} \times \text{C} \times \text{P}s$$

$$\text{A (ton/ha.year)} = 8472,411 \times 0.0078 \times 5400 \times 0.6 \times 1$$

$$\text{A (ton/ha year)} = 214,115$$

According to the calculations made, the study area loses an average of about 214,115 ton/ha year. This amount is later deposited in watercourses, causing silting and consequent flooding.

Soil wear can have several consequences (environmental, social and economic). From an environmental point of view, soil wear reduces productivity and increases the amount of sediment deposited in other areas, such as water courses and drainage canes. From a socio-economic point of view, this wear creates the destruction of infrastructure and can even cause people's death.

The lack of administrative and technical actions to minimize this problem can cause an increase in this amount annually, since it also increases the eroded areas.

In order to minimize the erosion problem, corrective actions are taken in most cases to the detriment of preventive actions. Corrective actions are not always effective, as the problem has already started. The implementation of these corrective actions also involves many financial and material costs. Preventive actions aim not only to minimize the cost of amounts with corrections, but also to minimize the effects that this problem can bring to society.

According to observations made within the study area, there were no actions implemented or to be implemented by the CMCM, only rehabilitation of the main roads connecting the neighbourhoods is carried out in an unsustainable way.

3.3 Conception of Geographic Information System for the Study Area

Modelling of Geographic Information System for the Study Area

The modelling consisted of building a model that represents the relationships between the activities, people, data and the objects involved in the production of a specific product, in this case geographic information system, according to Brito (2012) *apud* Costa (2009). In this context, the activity diagram (see Fig. 4) shows the actors and the levels of execution of activities within the system. This geographic information system has three actors, which are the population, the technicians and the administrator.

This diagram shows that the population views the information, that is, it has the right to consult the various informations that will be made available by the CMCM. The population can still view and download the provided images and maps. The technician in turn makes the registration of maps, the calculation of soil loss and visualizes the news. The system administrator performs not only the functions that the population and technicians do, but also manages users and news.

The sequence diagram is presented to show the interaction between the different objects and their collaboration in carrying out the activities (see Fig. 5). Thus, it appears that there is interaction between these objects that make up the system. The objects that compose this system are: the population, the technician and administrator, the graphical interface and the database.

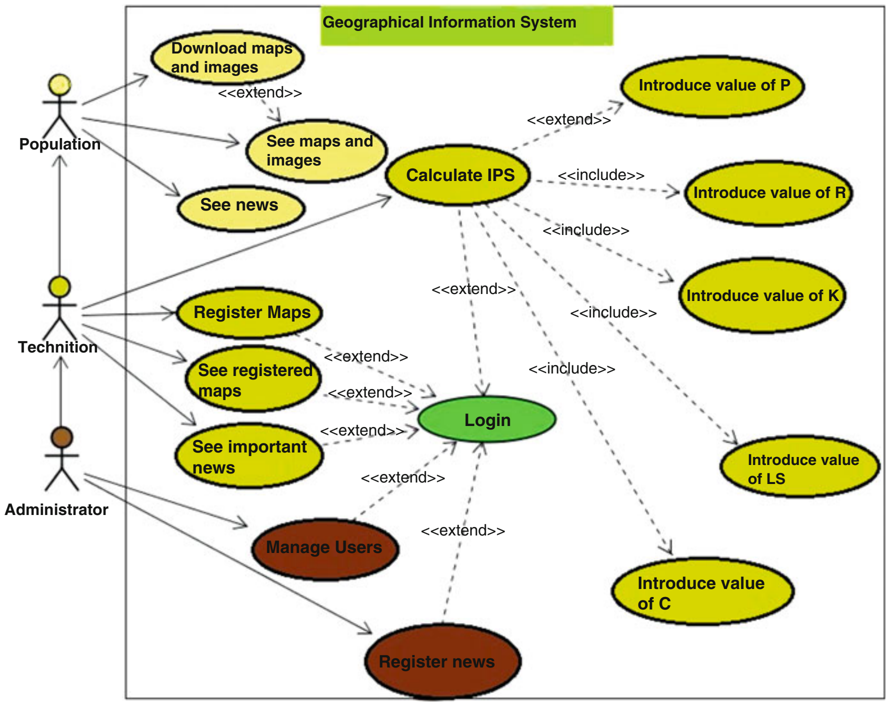

Fig. 4 Use-case diagram

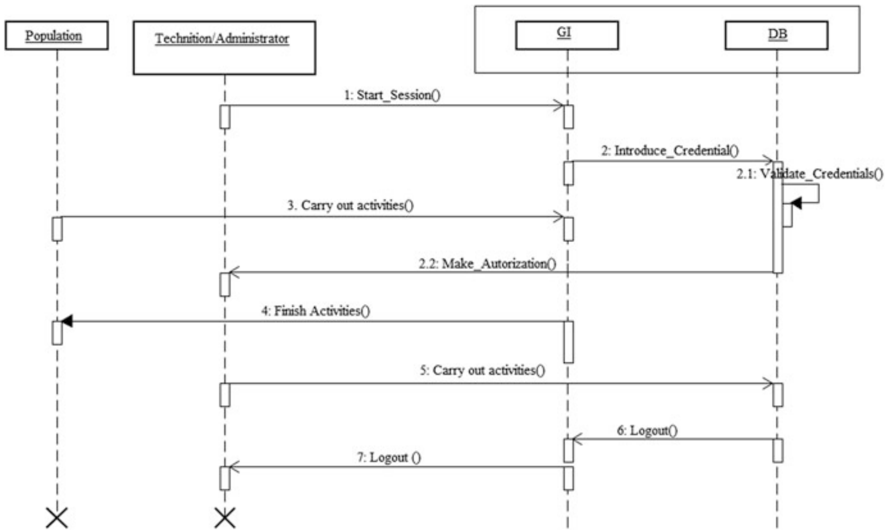

Fig. 5 Sequence diagram

Analysing the diagram, it is possible to see a constant interaction between these objects to carry out the planned or commanded activity. There is interaction between the graphical interface and the database for the execution and response of commands made by the population, technicians and system administrators.

Activity diagrams capture actions and their results. They focus on the work performed on the implementation of an operation (method), and its activities on an instance of an object. An activity diagram is an alternative way of showing interactions, with the possibility of expressing how actions are performed, what they do (changes in the states of objects), when they are performed (sequence of actions), and where they happen.

For this paper we present as an example the activity diagram of map registration (see Fig. 6). This diagram is intended to show the procedure used to register the

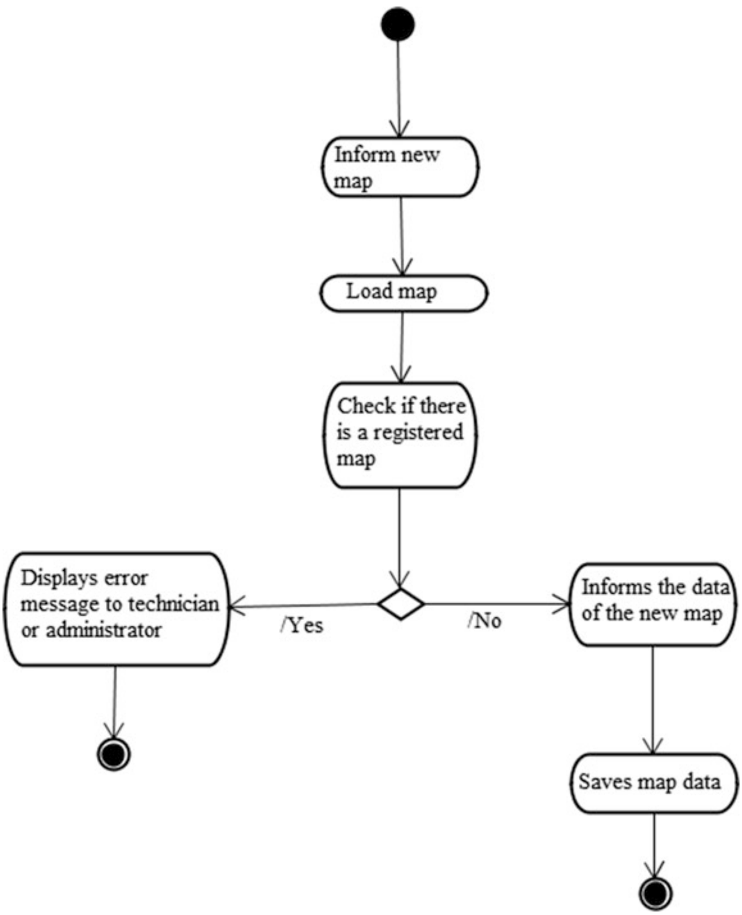

Fig. 6 Activity diagram—map registration

maps. Maps are a fundamental element of this system. These maps will help to control the various areas affected by erosion.

When trying to register a map, the system itself generates a set of information that the technician must satisfy, if the technician does not satisfy, the system will present error information to the technician or administrator. When registering the map, the system will check if the desired map exists, if not, it shows an error to the technician. In case everything is correct, the system will inform the existence of new maps and will save this map in the database.

This interaction and the processes presented in the diagrams above show how the system works, that is, how the system will work to respond to the commands of the various actors involved or that are part of this system.

Development of the Geographic Information System for the Prevention and Control of Erosion in the Study Area

After modelling, the geographic information system was developed. This system has different graphical interfaces (the main screen, the soil loss calculation screen and the map record) and with different levels of use (population, technician and administrator), each of the actors in this system has different activities. (See Figs. 7, 8, and 9).

On the main screen are available the news that CMCM intends to disseminate to the population, a photo gallery (where they show or evidence public and private infrastructures destroyed by erosion) and maps of various physical and geographic aspects are also available.

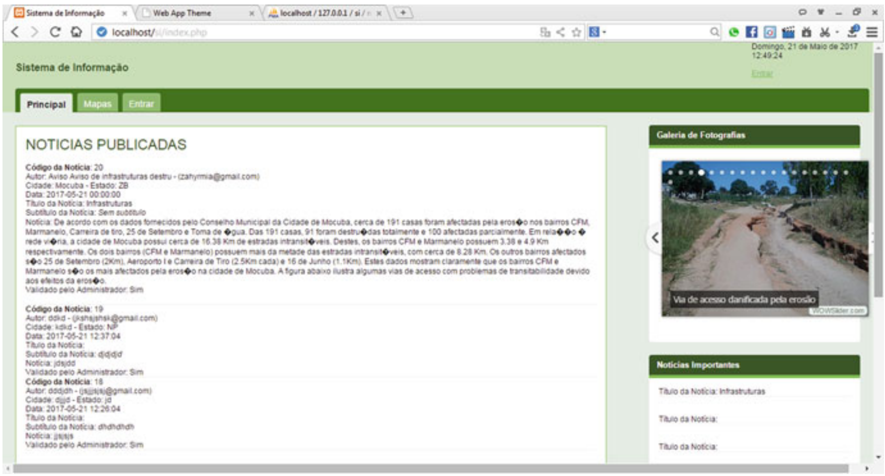

Fig. 7 Interface—main screen

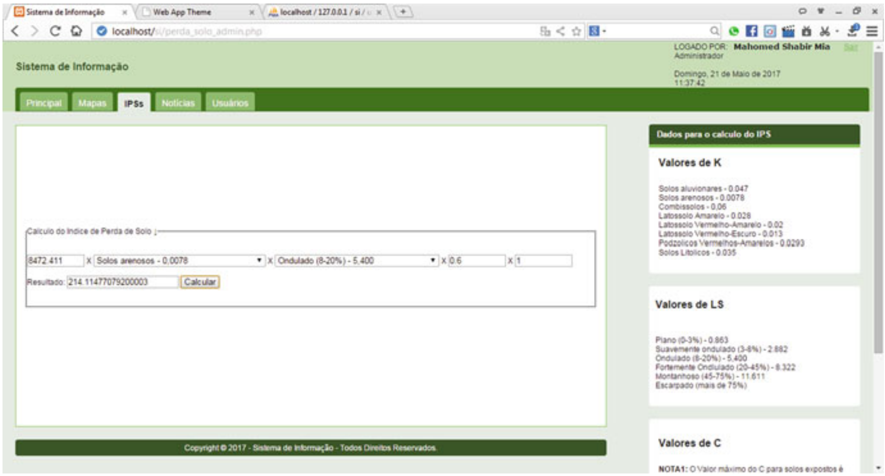

Fig. 8 Interface—calculation of soil loss

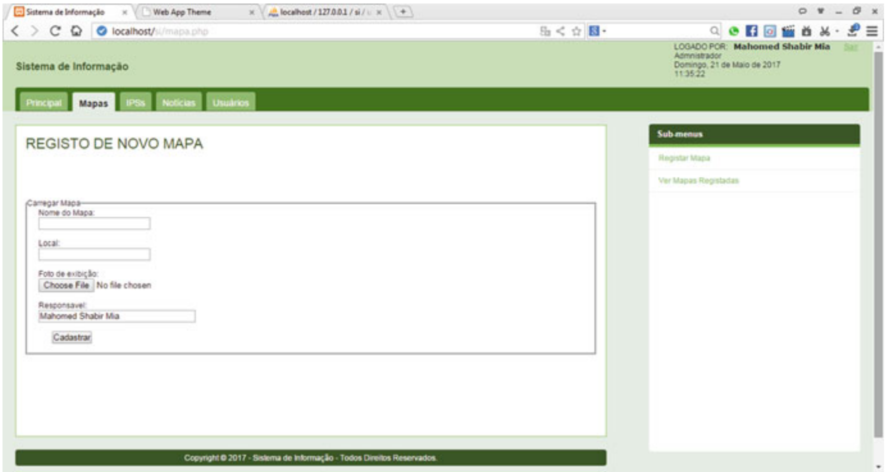

Fig. 9 Interface—map registration

This interface shows only the field for calculating soil loss. This is an important fact, since it helps to check the amount of soil that a region loses or may lose over a year. Thus, with the calculation of soil loss, the urbanization technician can suggest actions to be taken to minimize it.

In the interface on the map registration are the fields to be filled in on the map identification. The technician registers the map and uploads it. In this field any map can be loaded and it will be available for viewing on the main screen and other interfaces. These are maps that will help to control erosion not only in the study area but also in the city in general.

3.4 Utility of the System Created and Its Social Importance

Studies that involve environmental planning and management require a good diagnosis of the area of interest, of which must cover the physiographic, biologic and human characterization of the local or region, as well as the interrelationships between these factors, enabling the understanding of its dynamic. The amount of necessary information is great in order to reach such diagnosis, as well as it is also difficult to manipulate if one does not have an organized system and, preferably, computerized, that will assist in this task (Cruz and Campos n.d.)

According to Raia (2000) the use of the tools of a geographic information system is of fundamental importance, because it allows handling, altering or addition of other information, or still work with part of the data quickly and flexibly.

Thereby, the system created and proposed is of vital importance in the planning and developing of the city. This system can and will help in decision making about the proper and improper location for certain types of construction infrastructures and measures to be taken in the act of building in order to reduce the risks and impacts of erosion.

According to Sérgio Mustafa, head of the Planning and Registration section of CMCM, the system will bring added value to the control of erosion in the city, since it can be used by everyone (administrator, technician and the population), which constitutes an advantage compared to others more complex.

The easy handling of the system by different users allows the information to circulate more efficiently and effectively, contributing for everyone engagement in the control of the erosion, thus facilitating the taking of different measures for its minimization.

4 Conclusion

The problem of erosion has affected a large number of individuals, not only in the city of Mocuba, but in the country in general. This problem, despite having natural causes, is exacerbated mainly by human activities.

After conducting the research, it was concluded that the study area and consequently the city of Mocuba have been suffering from the effects of erosion. Despite the natural factors that make the study area prone to erosion, human activities have aggravated this problem.

It is still concluded that the stage of erosion in the study area is intermediate, but due to its natural characteristics (soil, relief, climate, vegetation) it can pass to an advanced stage, as a result of human activities, such as the increase in population density in these neighbourhoods, which will create more pressure on the environment.

The change in precipitation patterns recorded in the city over the past 11 years shows that in addition to the activities carried out by the local population, this region also suffers the consequences of human activities in general. Precipitations are irregular in the study area, and although their cumulative values are identical, the monthly values have changed and as a result, the rains have been falling very intensely. However, the wind has been regular.

The vulnerability to the occurrence of erosion is medium-high. The combination of erodibility factors showed that this region is vulnerable to the occurrence of erosion, but even more serious is the vulnerability to which the resident population is facing the consequences of this problem. The population's concern is mainly focused on locating in high places regardless of its slope, thus preventing the effects of floods and being vulnerable to the effects of erosion.

There are several actions that can be taken to minimize this problem, from preventive to corrective. However, due to the lack of resources and funds, preventive actions are shown to be more effective solution to this problem.

With the modelling it was possible to show the functionalities of the system. This modelling of the system also showed the relationships established between the various components of the system, allowing an easy construction of the system.

The use of this system by the authorities and the population results in a sustainable technological contribution to minimize the problem of erosion in the Marmanelo and CFM neighbourhoods in the city of Mocuba, but also for other regions of Mozambique and the world. If the system proves to be efficient for minimizing erosion, it can be transferred to other regions that present the same problem.

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Digitalization of Groundwater Monitoring Points Using LoRaWAN

Marius Wybrands, Andreas Saum, and Jorge Marx Gómez

1 Introduction

Groundwater is an essential part of the water cycle and the primary resource of drinking water in Germany (NLWKN, 2018). Chemical and microbial contamination and decreasing groundwater levels (NLWKN, 2018) threaten the availability of drinking water. By the EU Water Framework Directive, systematic and large-scale monitoring of groundwater monitoring points is mandatory. There are more than 14,000 groundwater monitoring points in Germany, of which 6000 are monitoring the quantitative status. The individual federal states are responsible for monitoring (Umweltbundesamt, 2017).

To ensure a quantitative good groundwater level, the average rate of extraction should not exceed the average recharge (European Parliamen, 2000). The frequency of measurements needs to be in a way that both short-term and long-term fluctuations can be detected. Measurements must be carried out more frequently for those groundwater monitoring points which do not achieve the goals set by the EU Water Directive Framework. Likewise, measurements with short-term intervals are required while testing new production wells.

There are various methods to measure the groundwater level. For low-frequency measurements, a manual electronic water level indicator is applicable. Other methods apply to higher frequented measures. These include automatic recording methods with data loggers (Striggow et al., 2013). If the monitoring point provides GSM/GPRS or UMTS/HSPA+, a central system stores the data. Despite the possibility of automatic recording, many regions still use a manual electronic water level indicator or data logger without connectivity to a central system. The

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reasons for this are high acquisition costs, lack of mobile phone networks, and data transmission problems.

Companies that are responsible for measurements will benefit from the potential of digitalization. Technology is needed, which enables communication via wireless. Also, groundwater monitoring points that are outside the mobile phone network have to be concerned. The LoRaWAN (Long Range Wide Area Network) technology can cover these requirements (Haxhibeqiri et al., 2018).

The communication protocol LoRaWAN belongs to the Low Power Wide Area Networks (LPWAN) and offers a power-saving communication (Adelantado et al., 2017). LoRaWAN offers the possibility to create a private communication network with simple network structures (Adelantado et al., 2017). The bidirectional protocol allows communication of 2–5 km in urban and up to 15 km in rural areas (Adelantado et al., 2017).

With the successful connection of groundwater monitoring points to the Internet, companies can drastically reduce the time needed for measurements and, have completely new possibilities to investigate the groundwater data through a higher monitoring frequency.

The chapter is structured as follows: In Sect. 1.1, relevant publications are listed, which compare LPWAN technologies and worked out criteria to compare technologies. In Sect. 1.2, groundwater measurements are described. In Sect. 2, the use case is explained in detail. This project was carried out in cooperation with the water utility Oldenburgisch-Ostfriesischer Wasserverband (OOWV). The prototype is described in Sect. 3. Subsequently, LoRaWAN measurements carried out in Bremen and at the water supply plant in Nethen. Finally, the results are discussed in Sect. 4, and a conclusion is given in Sect. 5.

1.1 LPWAN and LoRaWAN

In the field of LPWAN and LoRaWAN, publications are dealing with different aspects of the technologies. The focus of this chapter is on publications evaluating LPWAN and LoRaWAN criteria.

Mekki et al. (2019) examined NB-IoT, Sigfox, and LoRaWAN and Muteba et al. (2019) NB-IoT and LoRaWAN. The comparison parameters and results were similar in both publications. Both used the criteria quality of service, battery life, latency, scalability, network coverage, deployment, and cost. For the eighth parameter, Mekki et al. (2019) used the payload length, and Muteba et al. (2019) used the data rate.

Haxhibeqiri et al. (2018) providing a comprehensive overview of the technical details of LoRaWAN. They presented a SWOT analysis for the technology. The quadrants of weaknesses show a need for research in the area of security and adaptive data rate (Haxhibeqiri et al., 2018).

Adelantado et al. (2017) deal with limits and research gaps of LoRaWAN. The authors consider the network load and the current duty cycle to be critical. Due to this, LoRaWAN is not feasible for every use case. They also pointed out that the packet loss rate increases with a larger number of end devices per gateway. As a third aspect, they highlight the topic of Connectivity as a Service. With this approach, users utilize an existing network server and already installed gateways. The individual use cases have different requirements that are not fully covered by a standard base station.

1.2 Groundwater Monitoring

Groundwater is only moved freely by gravity in the subsurface. It does not matter which origin the water has (e.g., precipitation) (Hölting & Coldewey, 2013). In Germany, the groundwater resources are extensive, and 6.279 liters of water per inhabitant could be consumed daily in order not to endanger the groundwater level (Umweltbundesamt, 2017). The amount of groundwater extracted is also stagnating strongly. In 1991 25% of the water supply was used, and in 2013 it was only 13.3% (Umweltbundesamt, 2017).

The method to extract groundwater and other issues are regulated nationally (Groundwater Ordinance) and EU-wide (Groundwater Directives) (Umweltbundesamt, 2017). The individual municipalities are responsible for observing these regulations. The municipalities can carry out the activities themselves, establish associations, or hire a private company to ensure the correct execution (Umweltbundesamt, 2017).

The Groundwater directives regulate the criteria that must be archived for the respective groundwater level to have a defined good status (European Parliamen, 2000). Groundwater monitoring points are necessary to enable both quantitative and chemical monitoring of the groundwater (European Parliamen, 2000). Monitoring for all groundwater bodies is required. To this end, the EU Member States must collect data to identify short- and long-term fluctuations (European Parliamen, 2000).

Depending on the monitoring results, the frequency of measurements at individual groundwater monitoring points must be adjusted. These measurements allow the assessment of a total of 1.253 groundwater bodies (Umweltbundesamt, 2017). In 2016 a total of 95.8% were in quantitative good status (Umweltbundesamt, 2017).

There are different opportunities to carry out the measurements. The most common is to use the manual electronic water level indicator. With the manual electronic water level indicator, an employee lowers a tape measure into the monitoring point, and when it touches the water surface, a light signal switch on. Further possibilities are to use a floater or a pressure probe to take measurements. Within the scope of digitalization, there are already various automated measuring methods. In some regions, data loggers are already in use, which allows higher sampling frequencies.

In the case of data loggers without a mobile network connection, the data must be transferred manually.

The increased frequency of monitoring does not directly improve the resilience of the socio-ecological system, but it does contribute to it indirectly. Due to the possibility of continuous monitoring and better data collection, disturbances and exceptional situations can be detected and traced more easily. The improved data availability results in new possibilities for data analysis and a better understanding of the system. Especially for groundwater monitoring points that are influenced by waterworks and for pumping tests, the digitization of groundwater monitoring points indirectly contributes to the improved resilience of the region.

Anumalla et al. (2005) define six requirements for real-time systems in groundwater monitoring. Firstly, the costs for the individual components and integration must be low, since the number of monitoring stations is very high. The transmitter units must be compact enough to fit into the measuring pipe. The sensors are energy efficient and with long battery life. The individual components (data acquisition, data transmission, data analysis) are modular. The fifth requirement is reliable wireless communication. The last requirement is that the sensors can also cover other applications or values in the environmental sector (Anumalla et al., 2005).

2 Use Case

Water supply utilities have an interest in digitalizing their groundwater monitoring points. Especially in the area of water supply plants, there are many groundwater monitoring points. The Oldenburg Ostfriesische Wasserverband (OOWV) is one of the ten largest water supply utilities in the German water industry and the largest area supplier of drinking water (OOWV, 2019). The OOWV supplies an area of 7832 square kilometers (OOWV, 2019). Within this area, the OOWV has to measure several monitoring points per month. The OOWV measures the groundwater level and the quality of the groundwater (OOWV, 2019).

The OOWV needs the data because they have a long-term obligation to provide evidence about the groundwater levels and document the quality and quantity in detail. Up to now, most of the measurements are carried out by car over several days a month. An employee manually enters the data into a system. To optimize this process, the OOWV has already taken several steps.

On the one hand, 182 groundwater monitoring points have data loggers that collect the data over a more extended period. It has the advantage that employees do not need to drive to the groundwater monitoring points frequently, but there is a small risk of critical long-term data gaps, if the data logger fails. On the other hand, the OOWV has equipped some monitoring points with sim cards, and the data is transferred to a server. The problem is that there is a complex administration and high costs. Also, the solution via the mobile network is not practical for all water supply plants. Many of the monitoring points are in areas where there is no mobile network coverage (white patches).

Table 1 Technical aspects

Technical aspects	Description
Message size	Since the monitoring of the groundwater level transmits a maximum of 2–3 sensor values, the message size is sufficient
Latency	Latency in the range of seconds is acceptable, since this application Is more about traceability of the data and real-time operations are not relevant
Data rate	The data rate plays a minor part
Bandwidth	Like latency and data rate
Coverage	Assuming that it is possible to cover between 5 and 15 km, the range is sufficient
Transmission direction	Data must only be sent from the end device to the gateway
Transmission frequency	The fastest transmission frequency is 10 s. Usually the measuring frequency will be in the hour range

Table 2 Additional restrictions

Restriction	Description
Private gateways	Many groundwater monitoring points are located in very rural areas. It is therefore a great advantage to install private gateways. In some areas no mobile network is available
Providers	It would be better if there was a nationwide coverage of LoRaWAN to save costs. However, since there is no nationwide coverage in Germany, it is not an exclusion criterion
Maturity	LPWAN technologies have not tested in the long-term
Hardware providers	Wide variety of suppliers available
Message confirmation	As long as at least one data record per month arrives the legal requirements are achieved

The OOWV hopes to save time by digitizing the groundwater monitoring points and reducing the monthly trips to the monitoring points. With more frequent measurements, new analytical approaches are possible. Furthermore, the OOWV hopes for a complete data stock and a system for monitoring data. A further goal is to measure all monitoring points precisely on the time.

To examine how far the use case maps the technical possibilities and especially restrictions of LoRaWAN, see Tables 1 and 2. Table 1 lists the technical aspects, and Table 2 lists further restrictions that are not directly related to the technical specifications of LoRaWAN.

3 Prototype

The theoretical considerations show that LoRaWAN is suitable for the digitization of groundwater monitoring points. Theoretical considerations are validated with a software prototype in a field test. The focus was on the core aspects (Pomberger et al., 1992). The idea, process, and essential functions are tested. The primary tasks in creating a LoRaWAN prototype include installing the hardware, providing a network server, and the further processing the operating data.

The prototype is explained in the following using the Internet of Things reference model (CISCO, 2014) (see Fig. 1). Within the prototype, five of the seven layers of the reference model are essential. Because of the small amount of data, a pre-compaction and normalize the data was not necessary (layer 3 and 5).

3.1 Physical Devices and Controllers

Hardware provisioning is divided into the transmitter and receiver side. There are different options for both. On the transmitter side, there are development kits like Dragino (Dragino Technology Co., LTD., 2020) or ALSO (AllThingsTalk, 2020). On the other hand, there are production ready LoRaWAN solutions (The Things Industries, 2020a). On the receiver side, the Dragino Dev Kit offers a single channel gateway. The Dragino Dev Kit works with only one frequency and one spreading factor. If productive solutions are tested, a multi-channel gateway is therefore recommended (e.g., (Wifx Sàrl, 2020), (The Things Industries, 2020b)).

A network server is required to build a LoRaWAN solution. The fastest solution is to use the existing network server of The Things Network and register the

Level	Description
7 Collaboration & Processes	Using all features of Grafhana and CONTACT Elements for IoT like sharing data, individual conditions, event trigger and workflows.
6 Application	Grafhana and CONTACT Elements of IoT platform
5 Data Abstraction	-
4 Data Accumulation	Node-Red, MQTT, InfluxDB
3 Edge (Fog) Computing	-
2 Connectivity	LoRix One Gateway with ChirpStack network server
1 Physical Devices and Controllers	Arduino Uno with a LoRa Shield, temperature and humidity sensor (DHT11),

Fig. 1 Architecture description with hardware and software components using the Internet of Things reference model (CISCO, 2014)

hardware there. On the other hand, it is also possible to set up a private network server via ChirpStack. Depending on the requirements, these steps are sufficient to demonstrate the functionality of LoRaWAN. If the data visualization is in the foreground, both The Things Network and ChirpStack's network server can work with the MQTT interface. The data are transferred to any MySQL database. Openness to all IoT platforms or visualization tools is given.

An Arduino Uno with a LoRa Shield was part of the prototype. The shield is designed for the European area (868 MHz) and has an SX1276 from Semtech installed. A temperature and humidity sensor (DHT11) are connected to the Arduino. To evaluate the use case, the range and reliability of the technology plays the most significant role, and the type of sensor technology is secondary. With the help of the OOWV, an attempt was made to provide a production ready sensor for the groundwater monitoring points. However, the procurement was a challenge.

For the implementation, the library LMIC was used. This library supports class A and B devices and is designed for the SEMTECH chips SX1272 and SX1276. Besides LMIC, the library DHT was used for the temperature and humidity sensor, and the library CayenneLPP for the data transfer. This library provides a comfortable possibility to send sensor data via LoRaWAN. For the registration, OTAA was used. For the registration and assignment to the terminal device, the DEVEUI and the APPKEY were implemented. When sending the data, the sensor data is retrieved, converted into the Cayenne format, and sent. In addition to the sensor data, signal-to-noise ratio, RSSI, the data rate and frequency are transmitted.

3.2 Connectivity

In order to receive the data, various steps had to be taken in the connectivity layer. Firstly, a LoRix One gateway was installed. The ChirpStack Gateway OS image was installed, and the host address of the network server was added. The network server was set up at ChirpStack. For this purpose, the gateway bridge, the network server, and the application server were installed on a Debian system. The gateway bridge is responsible for converting incoming packets to JSON. The network server is responsible for authentication, removal of duplicates, communication with the application server, and acts as MAC layer in the LoRaWAN network. With the help of the application server, gateways and end devices can be managed, and data can be forwarded via an MQTT interface. Different objects have been created in the application server to receive data:

- A gateway was created, and the ID is assigned. The position and height of the gateway can also be set.
- A service profile can be used to set data rates. All devices transmit with a spreading factor of 7, or variability of the spreading factor is possible.
- A device profile is created. The LoRaWAN MAC version (1.0.3), the device class (class A), and the registration (OTAA) are selected.

- When an application is created, the service profile is selected. The application is used to configure how the data is decoded (Cayenne LPP).
- The devices are created within the application. For this purpose, a device EUI is created, and the device profile is assigned.
- The application can also be assigned to the extent which data is processed (InfluxDB).

3.3 Data Accumulation

After data processing by the network server, the data is further processed for storage. A pipeline was created, using the development tool Node-Red. The data assigned to the application on the network server is subscribed via MQTT, and the relevant data is extracted. This data is stored in two different ways. Firstly, the data is stored in an InfluxDB and secondly in an IoT platform. InfluxDB is a time-series database that is designed to store many sensor data. CONTACT Elements for IoT were used as an IoT platform. The platform allows the creation of digital twins for individual devices like groundwater monitoring points.

3.4 Application

A Grafana instance was used to accesses the sensor data in the InfluxDB. Grafana is an open-source tool, which can connect different data sources. Within the dashboard (see Fig. 2), technical information like frequency, RSSI, and SNR are visualized in addition to the sensor information. Also, metadata such as the Dev EUI or the Gateway ID are displayed.

More information can be accessed in the digital twin of Elements for IoT platform. Besides the sensor data, the measurement processes, the location, as well as metadata, like documents and images, can be visualized. The digital twin is arbitrarily expandable and can display all desired information. In addition to the visualization of a single device, the so-called fleets can also be created. A fleet is a collection of several devices. Thus, a fleet can be created for each water supply plant, and all groundwater monitoring points can be assigned. In Fig. 3 an example of a digital twin can be seen. It shows sensor information, the last six measuring processes, and the groundwater monitoring point.

The fleet (see Fig. 4) shows an example of all groundwater monitoring points of the water supply plant in Nethen. In a productive solution the map is used to show the time and value of last measurement.

Fig. 2 Grafana dashboard

3.5 Collaboration and Processes

The collaboration level is very closely linked to the application level. Both Grafana and Elements for IoT offer functionalities. With Grafana, conditions can be defined (e.g., temperature average higher than 25 degrees within the last 30 minutes) and send messages when the condition occurs. The IoT platform offers more possibilities at this point. Also, individual conditions as python code can be implemented. When the conditions are met, various events trigger. These include e-mails, starting work sequences, or creating actions.

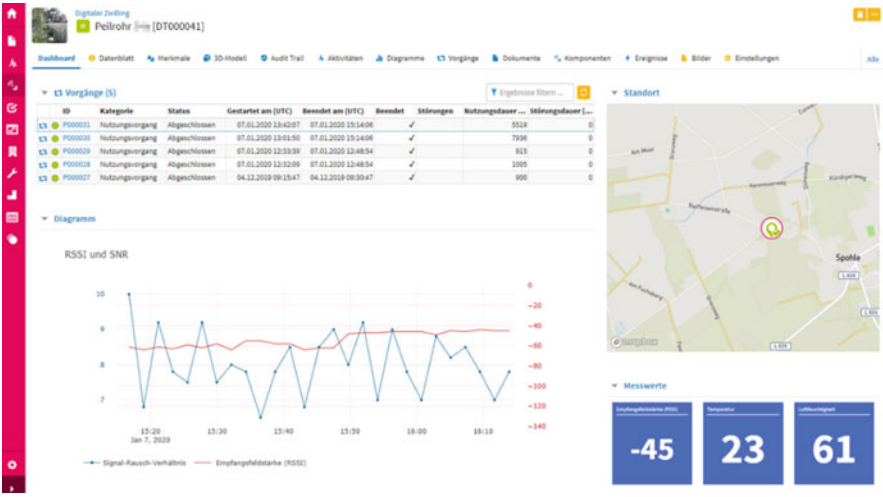

Fig. 3 Digital Twin of a groundwater monitoring point

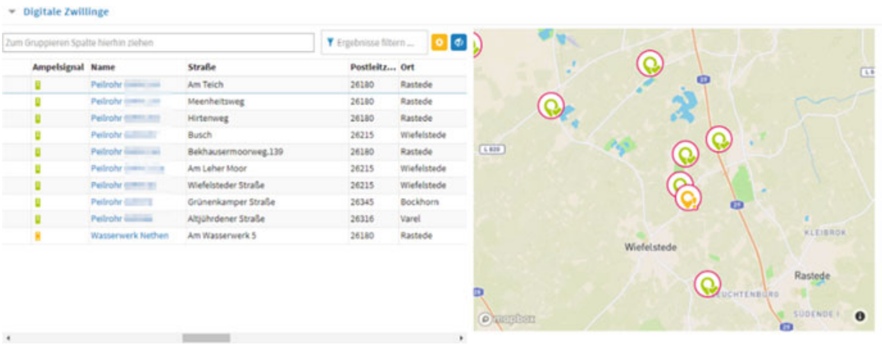

Fig. 4 Fleet of groundwater monitoring points at the water supply plant in Nethen

3.6 *Pilot Measurements City Center Bremen*

In the initial measurement series, the gateway was installed on a balcony on the seventh floor and the device was installed at a height of approximately 1 m. Different distances were tested at a spreading factor of 12. Up to a distance of 1 km, data was successfully transmitted to the gateway. There were buildings and trees between the transmitter and receiver (citizen's park Bremen). The packet loss rate was 0.6%. In the next step, the device was installed on a balcony on the third floor and worked with a spreading factor 12. The distance between the gateway and the terminal was 2.5 km. Between transmitter and receiver were large houses (Universum Bremen, Atlantic Hotel Bremen) and citizen's park Bremen. The packet loss rate was 10.1%. The same measurement was carried out again with a spreading factor 7. In this measurement, the parcel loss rate was 12.8%. This measurement was carried out over 5 days.

3.7 Measurements at the Water Supply Plant in Nethen

At the water supply plant in Nethen measurements were carried out to evaluate the application. For this purpose, the gateway was installed on the roof of the water supply plant, and a first successful test measurement was carried out on the roof. The gateway was oriented that it was free of objects on all sides and thus had 360-degree coverage.

After the test measurement, different monitoring points were approached, and measurements were taken. The device was placed directly next to the groundwater monitoring point (antenna height approx. 20 cm), to obtain realistic measuring conditions. The first monitoring point was approximately 530 m away from the gateway. These measurements were successful, and data were delivered at a spreading factor of 7. At the following monitoring points (distance between 1.4 and 4.0 km) were not delivered for either SF7 or SF12. Between these monitoring points and the gateway was a forest area, and because of the large number of trees, the signal could not reach the gateway. At the end of the measurement, the first monitoring point was successfully rechecked. The following chapters will deal with this problem in more detail.

4 Discussion

The implementation and measurements at the water supply plant have shown that groundwater monitoring points cannot be digitalized only with LoRaWAN. The lack of digitalization is because of the low antenna height. The signal is too weak to bridge several kilometers. The test measurements in Bremen have shown that with the same hardware, the distance is possible with massive buildings. Most of the groundwater monitoring points are in rural areas. In Lower Saxony, many of these areas are forested. Due to a large number of trees, data can only be transmitted over very short distances. In combination with the low antenna height, distances of up to 1 km are more likely possible.

Yim et al. (2018) investigated the performance of LoRaWAN within a tree farm. The results show that the range is also worse than described in theory. The antenna height plays a significant role. At the height of zero meters, the reliability was 21.66%. At the height of 1 km, the reliability already increased to 85.33%. 100% reliability was achieved at an antenna height of 3 m. The experiments were performed at a range of 200 m, and a single channel gateway was used. Iova et al. (2017) tested LoRa in different environments. The range decreased significantly in a forest area from a maximum of 550 m to a maximum of 90 m. Furthermore, the authors found out that an existing connection in a forest area has a constant packet loss rate.

In a field test, it was examined to what extent groundwater monitoring sites in the forest area can be digitized. These also prove lower ranges in forest areas and a high path loss in dense forests. The ranges were estimated at 750–1500 m (SmartMarkers, 2019). By installing a gateway at a height of more than ten meters and installing the transmitters at a height of more than 30 centimeters, it might be possible to overcome the distance.

A solution is shown by Park et al. (2018), which also confirms the low range. With the drone's help, they have developed a mobile gateway that collects data from the end devices. The only problems they see are the drone's low battery life and the weather sensitivity (precipitation, temperature) of the gateway (Park et al., 2018).

5 Conclusion

The feasibility of a use case from the water industry was examined. For this purpose, the requirements were taken up by the water supply company OOWV from Germany. By implementing a prototype, the suitability of LoRaWAN to digitize groundwater monitoring points was evaluated. The results must be interpreted in two ways: In theory, it is possible to implement the use case with LoRaWAN. All exclusion criteria are not fulfilled, and by evaluating the results using various criteria taken from the literature, LoRaWAN is suitable. However, the implemented prototype shows that a distance of more than 1 km is not possible due to the low antenna height and the forested measurement area. Various other publications confirm the results.

The contribution in this paper shows the potentials and restrictions of LoRaWAN for the application groundwater monitoring points. Further research is needed in the area of groundwater monitoring points. It should be investigated to evaluate to what degree hybrid solutions of LoRaWAN, NB-IoT, 3G, 4G are useful and whether there is a possibility to increase the antenna height at the transmitters for better results. Also, a further critical examination of the use case will be necessary for the coming years when the new 5G standard will be available.

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Developing an Environmental Information Portal for Various User Groups

Ali Akyol, Raphaela Helbig, Sven von Höveling, Hadi Ghorashi, and Andreas Solsbach

1 Introduction

The provision of environmental information is becoming increasingly important against the background of growing social awareness of environmental and climate protection issues, as is currently reflected by the introduction of mandatory non-financial reporting in Germany since 2017 (Deutscher Bundestag, 2017) or the Fridays for Future movement in 2018 started by Greta Thunberg in Sweden (Sommer et al., 2019).

Companies are therefore called upon to maintain extensive corporate environmental information to meet the ever-increasing demands of politics and the public. At the same time, municipalities are increasingly informing their inhabitants and visitors about current developments in their (natural) environment.

However, it is largely unclear to both businesses and local authorities whether the information provided is of interest to citizens. The challenge that companies must face is to identify the need for environmental information. To identify the environmental information need and to provide a solution using an environmental information portal is the aim of the project "Portal for a demand-oriented provision of environmental information by companies and municipalities under citizen participation" further referred to with the acronym PUUK (from the German project title) (Carl von Ossietzky Universität Oldenburg, 2020) which started in April 2020

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as a research project funded by the German Federal Environmental Foundation. In discussions with several companies, which are located in Lower Saxony in Germany, the University of Oldenburg found out that the companies had little or no information on who is using the environmental information provided in open data portals, company websites, or sustainability reports.

Currently, three main stakeholder groups are identified: companies, municipalities, and citizens. The ongoing research is aiming to identify further stakeholders and to subdivide these three stakeholder groups by interests, requirements, and state of knowledge. The state of knowledge is important for the PUUK project since this kind of information influences the requirements analysis for the environmental information portal especially in the section of support applications. What kind of support is needed for the stakeholder to understand the environmental information, to handle the information research in the portal or further applications?

As the laws and regulations for the provision of environmental data became increasingly strict, especially larger German corporations (Deutscher Bundestag, 2017), the need for easy submission of standardized data increased. Therefore, the PUUK project enables a time-efficient method for organizations to report environmental data to externals. Further, the creation of PUUK enables practical benefits for municipalities and citizens. The portal aims to bring a strategic fit between citizen information needs and municipality data supply. The user-centric development approach of the project can therefore improve communication between the separate shareholder groups while providing citizens with their individual information needs.

Regarding the scientific relevance of the PUUK project, this paper shows the overall approach of the project, starting with the concept (section 2) that includes the derivation of a research gap, a description of the Citizen Science approach, a breakdown of the different user groups as well as the environmental data sources and classification of the presented project. In Section 3, the planned functionalities are described, and in Section 4, a potential domain-oriented architecture, as well as a technical, is presented. In Section 5, a conclusion is given, and finally, in Section 6, an outlook gives an idea of the next steps and expected results.

2 Towards a Concept for an Innovative Environmental Information Portal

The project aims to develop a "portal for a demand-oriented provision of environmental information by companies and municipalities under citizen participation" (PUUK) that is a special form of an Environmental Information Portal (EIP) which combines both existing databases for environmental information and innovative visual presentation. Moreover, the new PUUK/EIP (in the following used as synonyms) will be accessible for everyone by fulfilling the individual information needs of citizens, communes, authorities, and companies. This task will be addressed in several analytical steps. First, we describe existing information systems providing environmental information (Section 2.1). Second, we introduce the Citizen Science approach (Section 2.2). Then, we give an overview of various user types (Section 2.3) and various environmental data (Section 2.4) that might be related to the EIP. We conclude by classifying the integration task the research project faces (Section 2.5).

2.1 State of the Art: Environmental Information Disclosure and Environmental Information Systems

Disclosure of Authorities

Authorities of communes and cities of various countries make information available as Open Data for both public and further use worldwide. Access for the public is provided through a web portal and sometimes via the application programming interface. Two examples are the cities Stuttgart (Stadt Stuttgart, n.d.) and Dortmund (Stadt Dortmund, 2020), the latter also provides interfaces.

Disclosure of Companies

Companies disclose publicly environmental information as part of sustainability information—on a voluntary basis and due to regional reporting obligations, as Helbig and von Höveling (2019) summarize. In worldwide practice, companies most commonly use corporate sustainability reports and disclosure via CDP. Larger companies use a sustainability report to supplement their annual reports, some companies already publish both reports as an integrated report (KPMG, 2017). Moreover, large companies disclose environmental data regarding climate change, water, and forest via the online reporting platform of the Carbon Disclosure Project (CDP)—already more than 7000 companies disclose worldwide (CDP, 2019). Additionally, companies communicate via their own corporate channels such as websites and press releases.

Moreover, Helbig and von Höveling (2019) point out that corporate environmental information is stored in the registries of public authorities. These registries are a result of regional mandatory reporting, e.g. National Pollutant Inventory of the Australian government and Toxic Release Inventory of the US Environmental Protection Agency.

The research cooperation "eco4fin—enabling ESG interaction," a cooperation between the University of Oldenburg and Volkswagen AG, strives to create a prototype for an Environmental and ESG Communication Data Platform for the Financial Community. The research goal is to use new technologies in order to improve sustainability communication between a company and the stakeholder group of the financial community (Eco4fin Home, 2020). A process model shows various data storage and presents the potential to improve the existing sustainability communication between various participants and organizations (Helbig and Marx Gómez, 2019). Although the research focuses on a dedicated stakeholder group of companies, the researchers additionally consider providing Open Data access to ensure transparency and avoid greenwashing (Helbig and von Höveling, 2019).

Web-Portals Disclosing Integrated Data Pools

Several websites are providing combined access to various data pools. GovData is a Germany-wide integration platform providing data on communes and cities (GovData, 2020). In contrast, Open Corporates is a web-based Open Data integration platform combining corporate data (OpenCorpo-rates, 2020). The web portal OpenDataSoft provides access to over 2600 Open Data Portals worldwide (OpenDataSoft, 2020).

Another example of an integration platform is NUMIS (Niedersächsisches Ministerium für Umwelt, 2020). It enables access to many data sources with environmental-related data. To some extent, the portal implements legal requirements for authorities. However, it merely links and presents the data. Furthermore, there is no clear assignment to the needs of citizens.

Improving Information Transfer and Communication

Some research projects deal with the communication of data. The project with the German title "Zielgruppengerechte Risikokommunikation zum Thema Nahrungsergänzungsmittel" (project ended in 2013) is investigated, how to target different consumer groups in order to inform them about the risks and benefits of food supplements. The aim was to provide information according to the consumer's needs and to enable them to make independent decisions (Zielgruppengerechte Risikokommunikation zum Thema Nahrungsergänzung-smittel - BfR, 2020). Moreover, the German project "Beteiligung und Wirkung Zielgruppengerechte Methodik und Wirkungsmessung in der Umweltbildung" aimed to improve needs-based information transfer (Unabhängiges Institut für Umweltfragen, n.d.). As a result of this project, recommendations for actions regarding environmental education for target groups, especially for children, are stated.

2.2 Citizen Science Approach

There are different definitions of the term Citizen Science, which may differ depending on the scope of meaning and interpretation. The EU Commission defined in 2014 in a white paper "Citizen Science for Europe" the term Citizen Science with the following definition: "Citizen Science refers to the general public engagement in scientific research activities when citizen actively contributes to science either with their tools and resources" (Bunge, 2017).

This definition is open to different interpretations. However, this definition can be understood to mean that citizens actively participate in research with their resources. The Cambridge Dictionary defines the following under the term Citizen Science: "scientific work, for example, collecting information, that is done by ordinary people without special qualifications, in order to help the work of scientists" (Dictionary Cambridge, 2020).

The BMBF describes the term Citizen Science, as "a win-win situation for all," and thus describes the following. Both researchers and citizens benefit from the Citizen Science approach. Researchers can access knowledge that they cannot uncover on their own. Citizens can contribute to the creation of new knowledge through their commitment. Cooperation also breaks down the barriers between the world of science and the everyday world. Citizen Science also brings other benefits, as this approach enables citizens to learn how to work scientifically and researchers to explain their topics in a way that is understandable to everyone. Citizen Science can thus be understood as science communication that strengthens the citizens' sense of scientific responsibility. The Citizen Science approach has been used for a long time, but digitalization is creating new opportunities. Since 1900, the Citizen Science approach has been used annually in the USA, for example, researchers work together with citizens to record the bird population (BMBF-Internetredaktion, 2020).

In our work, the Citizen Science approach could take an important part. Within the opportunities of digitalization, the citizen can share their knowledge and their recorded data on the portal.

2.3 Various User Types

To develop an environmental information portal, the Citizen Science approach is a must. The Citizen Science approach, as described in the definitions, can be used in various ways. It is important for the research team to explain science simply and understandably so that citizens who have no connection to science can participate in the project. In order for the environmental information portal to be accessible to all groups of citizens and to be used sustainably, different user types are required.

- Citizen
- Companies
- Municipalities
- Roles for EIP management (e.g. administrator, operator).

Citizen

The main users of the portal are citizens. The portal will be developed for and with them. There are heterogeneous groups of citizens who all have different motivations to visit the portal. Citizens could be divided into heterogeneous groups, such as pupils, students, employees, environmentalists, environmental activists, pensioners, etc. Citizens can take on different roles in the portal. The first and simplest role of the citizen is to use the portal to obtain information. Furthermore, citizens should also be able to upload their environmental information on the portal, which is also the Citizen Science approach. With the help of digitalization, different devices can be used, such as smartphones and other tools. The third possibility is that citizens can discuss certain issues with each other.

Companies

Companies are the second role. Companies are obliged by the authorities to define environmental reports in different forms. Moreover, companies also voluntarily write sustainability reports out of a sense of responsibility for the environment and to present their environmentally friendly behavior. One knowledge gap is that companies do not know what information is relevant to citizens and write them at their own discretion. This is where the portal can help companies to better understand citizens' needs for environmental information and environmental reports. It can also create different added values for companies. They can communicate with citizens and exchange information. Companies can gain access to information that they would otherwise have had a lot of trouble obtaining. Another function that benefits companies is that they can also enter their own environmental information in the portal which simultaneously improves the ease to submit their mandatory environmental reports to their local authorities.

Municipalities

Municipalities also face the challenge of not knowing the needs of citizens for environmental information. Coming forward makes environmental information available to their citizens, just as companies know little about whether the environmental information provided meets the needs of citizens. Municipalities can use the portal to release environmental information that they collect via sensor stations to citizens in real-time. They would save themselves many processes and inquiries if the portal provided this frequently requested data. Furthermore, there is also the possibility of exchanging information with citizens. The communication with companies for environmental reports that are mandatory for the authorities is also to be improved by enabling the municipality to receive and process the mandatory reports via the portal. In this way, communication between municipalities and companies can be improved through the portal.

Roles for EIP Management (E.G. Administrator, Operator)

This role is assigned, e.g. administrative tasks within the portal. These can vary depending on the user's role and topic. For example, administrators are assigned the task of verifying companies and municipalities so that people cannot falsely impersonate them. Another task of administrators could be to exclude users or companies that do not follow the forum rules in the portal. If users of the portal misbehave, the moderator can admonish them and, after several admonitions, exclude the account from the portal. Furthermore, the administrators should have the possibility to remove inappropriate content published on the portal.

The users with inappropriate behavior, but also inappropriate contributions should be able to be reported by the citizens so that the administrators can find them faster and react to them.

2.4 Various Environmental Data

The portal will process different environmental data, which may vary according to source and type. Possible data types of environmental data are:

- Sensor data
- Citizen input (information and observations)
- Open Data Portals

Sensor Data

There are many different sensor stations that collect environmental information. Depending on the sensor and what environmental information is measured, the types of data vary. The sensor data should be importable into the portal by all user groups after a short verification of the users. Citizens as well as companies and municipalities should therefore be able to import environmental information directly via sensors into the portal.

Citizen Input (Information and Observations)

Citizens are particularly important when, for example, a certain bird species is to be counted. After all, the citizens form the largest number of users in the portal. Citizens could make entries in an input form. There is also a lot of knowledge that can only be uncovered with the support of the citizens. Therefore, the participation possibilities of the citizens are one of the core elements of the portal.

Open Data Portals

Open Data is “raw data” which is published and can be used by everyone without restrictions. This published data can also be integrated into internal business processes without restrictions (Open Data, 2020). Open Data is also assigned an important role in the portal. Through these portals, important information can be accessed without having to enter it yourself. This can have the advantage of saving costs and time. It becomes clear that there are heterogeneous environment data that are relevant to the design of an Environmental Information Portal. Combining this heterogeneous data presents a challenging task of data integration.

2.5 *Classification of the Integration Task*

The taxonomy in Fig. 1 describes four dimensions of integration and several characteristics for each dimension. It is based on Mertens et al. (2017) and Mertens (2013).

- System integration may involve data, functions, and processes. The main goal of system integration is to realize a continuous information flow to create efficiency and value. Mertens et al. (2017) describe integration-oriented application systems by referring to integration as eliminating the boundary of individual application systems that were not designed originally as overarching systems. While the original classification (Mertens et al., 2017) reflects only Enterprise Application Integration, we assign it to integration tasks within a broader scope—including information systems, data storage, and user groups from various backgrounds and affiliations.
- The direction of integration may be horizontal and vertical. Horizontal integration addresses process-oriented data, vertical integration focuses on data for high-level planning and controlling.

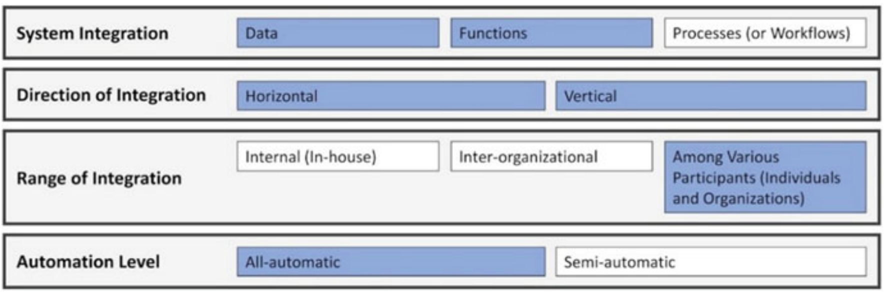

Fig. 1 Dimensions of integration using the taxonomy by Mertens et al. (2017) presented in a morphological box adapted version based on Fellmann et al. (2011, p. 254). The selection of characteristics for the design of the new EIP was conducted by the authors

- The range of integration may be internal (in-house within one organization), inter-organizational, or among various participants (individuals and organizations). The original classification (Mertens, 2013) describes the business context, while our classification concerns a broader scope.
- The integration's automation level of information transfer may be realized all-automatic or semi-automatic. For example, anomalies during the data collection would lead to different problem solving: An all-automatic integration would lead to diagnosis and therapy to be conducted by machines independently; a semi-automatic integration would rely on human–machine interaction (Mertens et al., 2017).

To define the integration task of the research, the authors conducted the selection of the characteristics for each dimension. An initial selection was done by reflecting the contextual situation. This was followed by a group discussion among the authors to ensure a clear understanding and avoid misinterpretation. The final selection has been highlighted in color in Fig. 1.

3 Possible Functionalities of the Portal

In order to use the portal, registration should not be necessary. All visitors to the portal should have free access to environmental information. The environmental information portal should be able to display personalized information based on the user logged in. The different user groups are described in Section 2.3. Different functionalities are required for these user groups. The basic functions are presented in the following.

3.1 Information Service

Information service is one of the main functions of the portal and should be available to all user groups without login or registration. In addition, it should also be possible for users to export and download the data. This would have the advantage that the users could also make the data available offline.

A useful function that can increase the community and the number of users is the share function. The users should have the possibility to share information, diagrams, or the whole site. This function could be realized with share buttons.

Since the users are not all on the same level of knowledge, environmental terms should be described to learn by using the portal. To allow users to choose whether they want to read an additional description for certain terms, there are different user views. These are divided into three categories: Users with little basic knowledge should expand their knowledge of environmental information by using the portal. To do this, the user can activate the view "all descriptions." Additional information is displayed for all possible terms so that the user can learn quickly and intuitively. If a user already knows the basic terms, he can activate the view “important descriptions.” A selection is made so that only terms that require some basic knowledge are displayed. With the last view, “environmental expert,” the user can set that no descriptions of environmental information are displayed.

If users have questions about certain information despite the descriptions, they can create their questions about an information or information topic in the forum. This allows the user to get help from other users who can discuss his question with him.

3.2 Registration Function

With this function, it can be ensured that a user is a real person and not a robot or a machine. This automatically creates a small barrier for robots and spam. Another important advantage of the registration function is that users can set their preferences, which are stored by the system. Thus, the personalized information can be obtained based on their profile.

3.3 Citizen Science Approaches

Citizen Science approaches are also to be realized through the portal. It should be mentioned that citizens should not only be involved in the information process but should also actively participate in the development process of the portal. It should become a portal developed with them. The definition of Citizen Science approaches is described in detail in Section 2.2.

A common example in Germany is “Mängelmelder” (notifier for defects), a reporting system for potholes, illegal trash, faulty streetlights, and other problems within the public infrastructure (leanact, 2020).

The citizen input through such a system enables faster communication with the government and therefore also a faster solution for the reported problem. Conversely, the reported data allows the city administration to identify hotspots which should preventively be more often controlled or certain areas which might need more attention in the future. To concretize this with another example, the oak processionary moth can deal severe damage to human health. Many municipalities are overwhelmed with the infestation through oak processionary moths and are unable to clean all trees due to the large amount. Through the citizen input the government can identify infested areas that are close to risk groups or well-visited public places such as kindergartens or schools.

Citizens are often motivated to participate in Citizen Science approaches through the urge to solve own problems. Furthermore, the communication with the city administration is much faster than through a common website. Moreover, people participate for ethical reasons.

4 Possible Architecture for the Integration Platform

During the conceptual development phase, the new Environmental Information Portal has been classified as an Integration Platform as a service (also known as Cloud Integration Platform), thus, it belongs to Cloud Computing. An Integration Platform as a Service combines the approach of an Integration Platform with the approach of a Service-oriented Application. An Integration Platform as a middleware (or combination of several middleware products) connects different information systems in a network and harmonizes their use via a central graphical user interface. In Service-oriented Applications, customers use the services of an information system. We define the Integration Platform as a service according to the state of research as “a suite of cloud services enabling development, execution and governance of integration flows connecting any combination of on-premises and cloud-based processes, services, applications and data within individual, or across multiple, organizations” (Pezzini and Lheureux, 2011).

In this early phase of the research project, a domain-oriented architectural model serves a structured explanation of the information system which is being worked on. In addition, an example of an IT architecture created for a structural element serves as a technical detail view. This is intended to ensure—even before implementation—that all those who are involved in the project can check the architecture concept regarding the fulfillment of requirements and relevant characteristics. The development of the domain-oriented architecture model followed the structured approach of Fellmann et al. (2011) which they originally used for an architecture model for technical customer services. The presented architecture accordingly serves as a reference for discussion. For this purpose, the documentation of the architecture is reduced and concise.

The definition of requirements (Section 4.1) is followed by the description of a concept of the architecture (Section 4.2). Finally, a possible technical architecture is presented for the IT level (Section 4.3).

4.1 Requirements for the Architecture

Based on the EIP’s aim and the insights of the contextual situation, there are several requirements the developer faces. By improving the information base, the EIP strives to balance information among different user groups and supports focused informed decision-making for all users. The following list summarizes all identified requirements for the integration task. The list will possibly be extended or modified during the project.

- Combine heterogeneous data sets and ensure that users have access to the same data sets.
- Combine heterogeneous applications within a unified graphical interface.
- Assign variable rights for users, e.g. open access and restricted access.
- Enable and aggregate feedback from citizens anytime.
- Extract need-oriented information for citizen.
- Extract information for informing policy decisions.
- Extract information for informing management decisions for businesses.
- Enable usage from anywhere and with different devices.
- Enable a consistent graphical user interface for users.

4.2 Domain-Oriented Concept for an Architecture

Figure 2 presents a concept consisting of three layers of an integration platform architecture that addresses the needs and challenges potential users face (as described in Section 1). The main elements of the integration platform were defined by systematically considering the identified requirements (Section 4.1).

The access level describes the areas of the portal. For better clarity, trivial pages or areas like an imprint, privacy, and licenses were omitted. Typically, the access level also determines which area can be accessed by which kind of user. This was waived in the figure. All areas except the admin area are accessible by every type

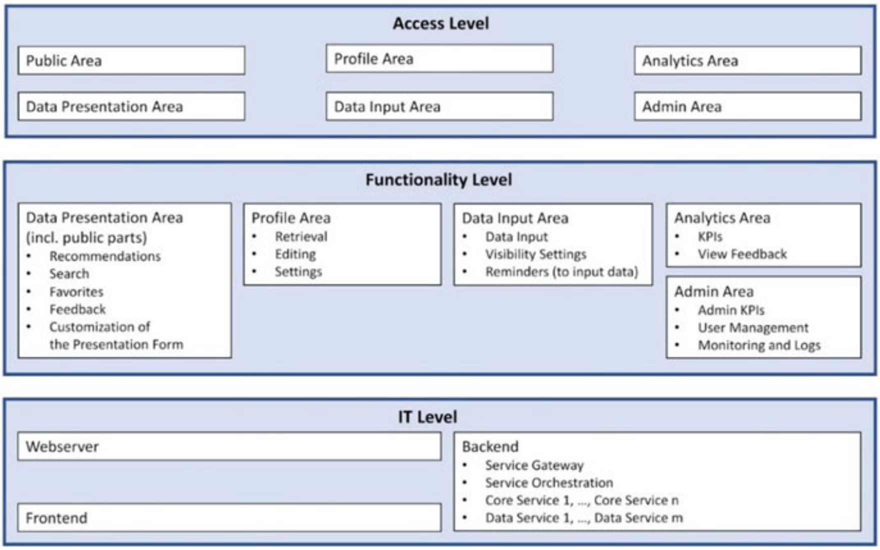

Fig. 2 Concept for the architecture and functions of an integration platform for providing environmental information via an innovative portal

of user. However, for the analytics and the input area, it is worth discussing whether citizens need the type of area. The functionality level describes the main functions of each area. The IT level gives a short overview of possible components used to develop the platform. On the current state of the requirements, a reasonable technical architecture for the backend is microservice architecture.

4.3 Architecture and Implications for Technologies of Backend, Frontend, and Services

Figure 3 shows a possible architecture for the EIP. The backend is realized by several services that are divided into two groups: core services and data services. Core services realize the main functions shown in Fig. 2. Data services enable the retrieval of data from external and internal data sources. External sources are open data sources, sources from companies, or (local) authorities. Data from companies or (local) authorities can be open or restricted. Internal sources are sources filled by the data input area of the platform. Services that need to save data have their own data storage, for example, a plain text file or a database illustrated with a database symbol.

A single standalone service (microservice) for each data service seems reasonable since it is more flexible for the different and possibly changing interfaces of the external sources. Moreover, companies or authorities might be better involved in developing a small microservice, partly because different technologies can be used.

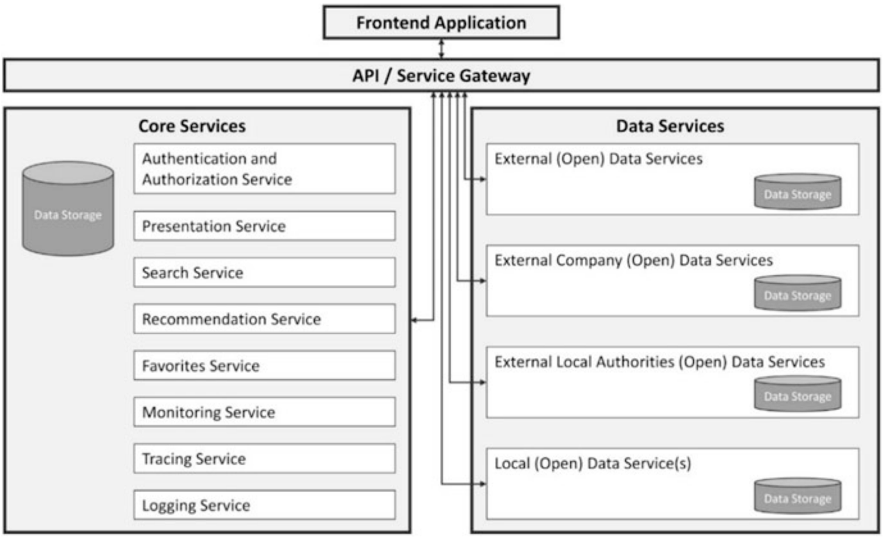

Fig. 3 Possible technical architecture for an innovative portal

A similar structure can be discussed for the core services. However, based on the current requirements, a single larger service that realizes all core services, as shown in the figure, seems to be reasonable.

The frontend communicates via a gateway with the services. The overall architecture can be implemented to run a classical server but is also predestined for running on a cloud infrastructure.

5 Discussion and Conclusion

In this paper the relevance of EIP and why it can solve current challenges were discussed in detail and why it can be a solution to current challenges. To be able to solve current problems, the concept of a EIP was elaborated in detail in Section 2. For the development of such a concept, a "state-of-the-art" analysis was carried out, considering different perspectives such as corporate disclosure. In addition, it was shown how different data pools such as OpenData and GovData can be integrated into the portal and can lead to an overall increase in the transparency of information and communication.

Furthermore, the approach of Citizen Science for the EIP was considered, which will play a major role in the portal in order to integrate citizens into scientific processes and to describe research in a citizen-oriented language. Through this approach, different added values could be shown that will benefit science, society, and finally the environment.

The motivation of data and information suppliers, especially of local authorities and companies, needs to be further discussed. While local authorities are in general rather likely to apply Open Data, companies are rather hesitant (Helbig and von Höveling, 2019). Moreover, further considerations might include possible legal and technical agreements.

The platform to be developed will have different user roles, which were also presented. In addition to the user roles, different data sources were presented that could be included in the portal. Furthermore, the classification of integrated tasks was elaborated in detail, which will be used in the technical implementation.

Moreover, the authors elaborated possible portal functions to be implemented. The technical structure for the realization of the functions was presented in detail. For users, the integration platform offers a variety of options for providing, retrieving, and visualizing all data and applications integrated from different subsystems and accessible via different end devices. The implementation of the planned integration platform places various non-functional demands on the developers, e.g. consistent data management, compatibility of the interfaces, integrity and security concept, cooperation between various operating systems, cooperation between programming languages, interconnection of all socio-technical elements. If implemented in the form of Open Data, this will contribute to the democratization of information. Challenging issues have been identified which influence the success of an implementation.

6 Outlook

The overall development of the PUUK project is scheduled for 24 months. For the next steps within the project, the researchers create multiple interviews with citizens, companies, and municipalities to identify the environmental needs of the various user groups. The online interviews are executed in a multi-layer design to constantly readjust the questionnaires' input based on earlier outcomes. The hereby gathered results will be used to match the shareholder needs to the technical requirements of the future portal in an initial pilot. During the next project stage, the technical pilot portal will be further developed and tested, with the final goal of achieving a fully functional EIP that can be implemented within the market.

Noteworthy, the research and implementation of the presented platform is part of a research project with its own financial means for this purpose. For a long-term continuation of the information system and the outlined social and technical goals, further financial means are essential, covering the operation and technical development. For this purpose, there are possible business models that can be classified as Integration Platform as a Service or Cloud Integration Platform. For example, it would be conceivable to provide free access for individual citizens and to charge companies only for actual value-added use (by guaranteed long-term basic use for free). However, the authors note that introducing paid services might lead to negative network effects and discourage the widespread use of the platform in the target region. Other alternative ways to finance a long-term operation and maintenance are, for example, crowdfunding or financing through public authorities.

While the PUUK project was prepared on excessive scientific research the further execution of upcoming steps will require additional input from both practice and literature. Therefore, the before described, existing environmental information systems should be further elaborated and extended in a market analysis of environmental information portals within the German market. The analysis will be especially focusing on different open data portals, their input sources, and their respective Application Programming Interface (API). Through that, the researchers aim to identify crucial characteristics and state-of-the-art technologies necessary to be implemented within PUUK.

Furthermore, the user-based approach of the project will require deeper insights into the environmental information needs of citizens. Therefore, the researchers plan on analyzing digital and innovative citizen participation methods to identify appropriate co-creation methods for the development of a shareholder that needs a focused platform.

At last, the by-law required submission of environmental data by larger companies will require the preparation of a matching database model. Therefore, close cooperation with existing and operating companies will be necessary to identify crucial key performance indicators and necessary submission structures.

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A Deep Learning Approach to Classifying Tyres Using Sidewall Images

Dean Gifford and Jean Greyling

1 Background and Introduction

Due to the large global tyre output, there is an overwhelming amount of End of Life Tyres (ELTs). These tyres have limited use and there is thus a need to recycle them. Recycling ELTs has challenges such as not being able to be added to landfills because of the typical shape of a tyre. The recycling of tyres is also not a profitable business opportunity. This can be addressed by improving the rewards from the recycling process and therefore making it more effective. Classification of tyres could assist with recycling, since the most rewarding recycling process can be selected, based on the compounds found in the ELT. The classification of ELTs is currently manual. A deep learning approach could assist in automating the classification of tyres. This study focused on finding a suitable deep learning model to accurately classify the tyres based on images of the tyre brand logo found on the tyre sidewall.

One of the reasons that tyre recycling is not a rapidly growing industry is due to its unprofitability. Waste tyres can contribute to material recovery or fuel recovery (ETRMA, 2011). Despite both of these by-products being advantageous to industry, the process needed to strip down the waste tyres and process the material is costly and complex. One of the main complexities is due to the variations in compounds that make up the different tyres. Different tyres will have more of certain compounds than others and it is not always guaranteed that a specific tyre will give the expected amount of by-product. The manual work associated with identification of the waste tyre categories is time-consuming, inefficient and has a high cost and error rate (Yu et al., 2013).

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Replacing the manual aspect of classifying tyres by images of their sidewalls with an automated process also has challenges. The classification of objects can be done using images, however, tyres introduce their own complexities. The information stored on the sidewall of tyres would follow the circular pattern of the tyre. Therefore, there is a complexity in retrieving the information in order to classify the tyres. Once the tyres can be classified, the category of each tyre can then be utilised to effectively improve the recycling initiative as highlighted by Dr. Crozier, Information Technology manager of the Recycling and Economic Development Initiative of South Africa (REDISA) (Crozier, 2016).

This paper has the following main research objective:

- To use deep learning to automate the classification of tyres.

The sub-objectives are the following:

- RO_1 Investigate the aspects which comprise neural networks.
- RO_2: Identify deep learning architecture which can be applied to classify tyres.
- RO_3: Compare various deep learning models and methods on their accuracy to classify tyres.

1.1 *Tyre Identifiers*

Tyres can be classified by a vast number of elements. The main ones described are the Department of Transportation (DOT) code, tread pattern, size and brand logo.

DOT Code

The DOT code specifies the manufacturer's details and more specifically the date a tyre was manufactured (Fig. 1). Wahdan et al. (1992) implemented the classification of tyres based on the DOT code by means of template matching and Optical Character Recognition (OCR).

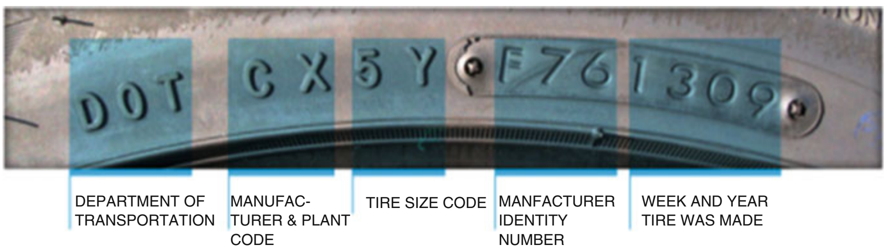

Fig. 1 Complete DOT tyre identification number (Toyo Tire U.S.A. Corp, 2016)

Tread Pattern

Tyres have different tread patterns based on their intended use, providing the ideal grip/rolling resistance of a tyre. Varying examples can be seen in Fig. 2. These patterns can be used to identify and inherently classify tyres. Classification by tread pattern using the following techniques was proven successful: k-nearest neighbour, linear classifier, decision tree and neural networks (Wahdan et al., 1992).

Size

The tyre size is the most well-known form of tyre classification due to the need of knowing this code when needing to purchase tyres. This code is multifaceted in the fact that it contains multiple sub-codes which too could be used for classification (Fig. 3). The size code has been successfully used to classify tyres automatically. OCR can be performed on each character of the code once it has been segmented. Complications arise with segmenting this code as it follows the radial arc of the tyre. Methods such as a radial projection method, sector scan method and a moment-based feature extraction can provide methods of accomplishing this task (Yu et al., 2012; Yu et al., 2013).

Fig. 2 Tyre tread examples (Domènecsh, 2013)

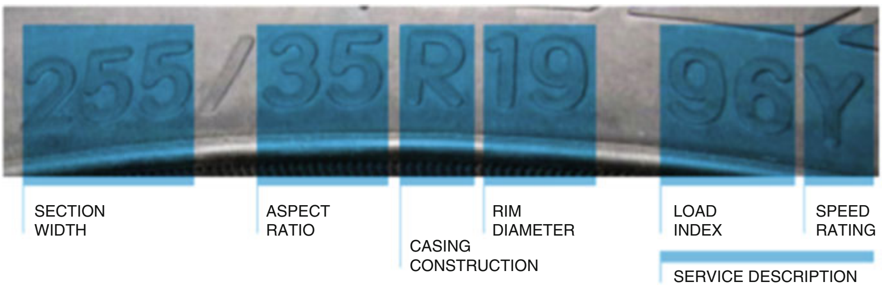

Fig. 3 Tyre size and service description (Toyo Tyre and Rubber Australia Limited, 2018)

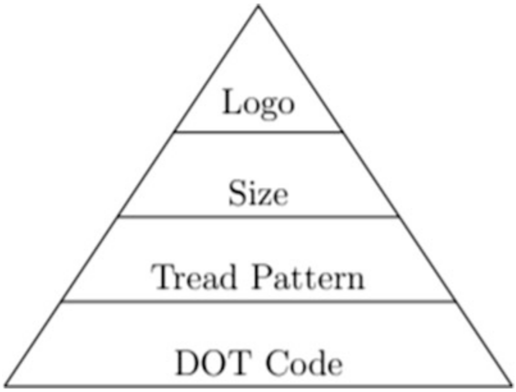

Fig. 4 Classification hierarchy

Logo

Since all tyres are produced by different manufacturers, they usually brand their tyre by means of their company logo. Due to the features on the sidewall being cast in the rubber, the logos can differ from the company logo in colour.

Taking the four classification elements into account, a hierarchy can be derived as seen in Fig. 4. This hierarchy can be explained in the sense that every manufacturer, with a specific logo, produces multiple tyres sizes. Each of these sizes could have multiple tread patterns for different intended uses. Every tyre of a specific tread pattern would have multiple DOT codes based on the date they were manufactured. Although there has been some success at classifying tyres, as mentioned in the sections above, none of the techniques used involved a deep learning approach.

After careful consideration of the purpose, relevance and objective of the research study, the main research objective was: *The use of deep learning to automate the classification of tyres*.

2 A Review of Related Literature

This section addresses the following research sub-objective:

- RO_1: Investigate the aspects which comprise neural networks.

Machine learning is a specific application of Artificial Intelligence (AI) whereby a system has the ability to learn from experience without being directly programmed. Artificial Neural Networks (ANNs) can be described as a computer system modelled on the human brain and nervous system and is one implementation of machine learning. The main aspect of machine learning is the ability for these networks to "learn".

There are two broad categories of machine learning (Goodfellow et al., 2016) namely:

- Unsupervised Learning makes use of a dataset containing many features and attempts to learn useful aspects of the structure of this dataset. This technique aims to find patterns in an unlabelled dataset with unknown features.
- Supervised Learning: makes use of a dataset which has various known features, as well as labels for each example in the dataset. It allows the machine learning algorithm to confirm whether it is learning the correct label for each example.

This study focussed on supervised learning as the research problem is aimed at classifying images of known features, in this case, the feature is the brand's logo.

2.1 Supervised Learning

There are two sub-categories of supervised learning, namely, *regression* and *classification*. Regression problems have the task of approximating a mapping from input variables to a continuous output variable. The output variable is a real value which is often a quantity such as size or amount. Classification problems have the task of approximating a mapping function from input variables to a discrete output variable. The output variable is either a label or a category and the model predicts which label best fits the current input.

In supervised learning, the training algorithm is provided with a *training set* Eq. (1), which is a set of examples of how the network should ideally behave.

$$T_s = \{x_1, t_1\}, \{x_2, t_2\}, \ldots, \{x_n, t_n\} : \quad 1 \leq n \leq N \tag{1}$$

where X_n is an input to the network and t_n is the corresponding correct output, known as the target output (Hagan et al., 2014).

The networks are then required to learn how to predict the target output. This is done by comparing the initial outputs to the target outputs. An error function is then used to modify the initial outputs. The error function, also referred to as the loss or cost function, calculates the difference between the output from the network and the target value. This provides an error, or loss measure, describing how well the model has performed on the given training set. The results of the error function are then pushed back through the network to adjust the biases and weights with the hope of improving the next iteration's outputs. This process is known as back propagation. Back propagation algorithm's goal is to modify the weights of the network in order to minimise the error function. There is also forward propagation which is the forward flow of data through the network.

The next section is an extension of supervised learning and neural networks to a sub-class of neural networks called Deep Neural Networks (DNNs). DNNs are neural networks which contain many hidden layers. When DNNs are implemented, it is known as deep learning. The specific category of implementations of deep learning that is focused on in this study is the Convolutional Neural Networks (CNNs or convnets).

2.2 Convolutional Neural Networks for Image Classification

Convolutional Neural Networks (CNNs) is a class of DNNs which was inspired by the visual cortex of the human brain. The neurons of the visual cortex only activate to a particular region of focus in the visual field, known as the receptive field (Saha, 2018). CNNs are similar in that they match only parts or features of the images and not the image as a whole. This can be compared to visually focussing on an object with the surrounding visual field blurred out. CNNs typically work with data with the following properties (Dumoulin & Visin, 2018):

- Data stored as multi-dimensional arrays.
- There exist one or more axes where ordering matters (e.g. width and height for images, time axis for a sound clip).
- An axis named the channel axis, which is used to access different views of the data (e.g. red, green and blue channels of an image or the left and right channels of a stereo audio track).

A CNN is made up of three types of layers. These are convolutional layers, pooling layers and fully connected layers (Brownlee, 2016).

Convolutional Layer

One of the main aspects of the convolutional layer is that of a kernel, also referred to as a filter or mask. The convolutional layer takes in an input, known as the input feature map, and "slides" the kernel over it, performing calculations to provide the resultant output feature map. Dumoulin and Visin (2018) explains the process below.

According to Goodfellow et al. (2016), there are three aspects of the convolution operation which help improve machine learning: sparse interaction, parameter sharing and equivariant representations. Furthermore, convolution allows for the inputs to be of varied sizes. In traditional neural networks, matrix multiplication is used, meaning that every output unit interacts with every input unit between the layers. Convolutional Neural Networks, however, have sparse interaction, which is accomplished by making the kernel smaller than the input.

Pooling Layer

The outputs from the convolution operation produce a number of linear activations. These linear activations are put through a non-linear activation function. This stage is known as the detector stage. This stage ensures that the data is normalised before it undergoes pooling. The pooling layers within a CNN aim to reduce the dimensionality of how the data is represented, further reducing the computational complexity of the model as wells as how many parameters need to be stored (O'Shea & Nash, 2015). The pooling layer effectively reduces the size of the feature maps by means of summarising sub regions using various functions such as the maximum value or by taking an average (Dumoulin & Visin, 2018).

Pooling works by sliding a window across the input feature map and passing the data found within the window through a pooling function. This is a similar process to that of the convolution operation, except that the linear combination described by the kernel is replaced by another function. These functions can include the maximum, minimum, average or even a weighted average function where the weights are based on the distance from the centre pixel (Goodfellow et al., 2016).

Fully Connected Layer

The previous layers described are used to learn a feature hierarchy from the data provided whereas a fully connected layer has the purpose of classification based on the learnt features (Stutz, 2014). The term fully connected refers to every neuron in the layer being connected to every activation within the previous layer. These layers can have a non-linear activation function or a softmax activation in order to produce the probabilities of the various classes the model is attempting to classify (Brownlee, 2016). The fully connected layers always appear after the combination of all the convolutional and pooling layers.

3 Experimental Design

This section, and following sections, address the following sub-objectives:

- RO_2: Identify deep learning architecture which can be applied to classify tyres
- RO_3: Compare various deep learning models and methods on their accuracy to classify tyres.

The methodologies surrounding machine learning research are highly experimental due to machine learning methods being complex and not following formal methods of analysis (Brownlee, 2018). For this study the following steps of the experiment are discussed in this section: data collection, data augmentation, experimental procedure, evaluation metrics, implementation and analysis of results.

3.1 Data Collection

In order to train a CNN to recognise the brand of a tyre, a data set consisting of the desired logos is needed. Unfortunately, there existed no data set consisting of logos from the sidewalls of tyres, therefore creating the need to collect the data manually. This study limited the number of tyre brands needing to be classified to three, namely, Continental, Dunlop and Sumitomo. These brands were chosen due to the following factors:

- Availability of large quantities at the various tyre depots.
- Uniqueness of the brand's logo.

Figure 5 displays the logos for the three brands as used in marketing as the representation of the brand. These defining logos are moulded in the rubber of the tyre sidewall in order to recognise the brand. In order to create the dataset needed, photographs of these logos on the sidewall were needed. Unfortunately, upon collection of the data, the logo for the Continental brand was very inconsistent among the various tyres or, in some cases, not present at all. However, the style used to write the brand name was consistent. It was decided to use the first two letters ("Co") of the brand name as it was very distinguishing.

The photographs taken were of high quality, having a resolution of 6000×4000. All images were taken using a Nikon D5300 Digital Single-Lens Reflex (DSLR) camera in order to provide high quality, clear photographs. Due to the time involved with collecting the data and the availability of tyres, only 300 sample images per category were collected. Therefore there were to be 300 different logos of the same brand as well as their corresponding sidewall image, providing a total of 1800 photographs needing to be taken. In order to minimise time spent on data collection, one tyre was used to collect two sample images, one from each sidewall. This would not compromise the integrity of the dataset due to the fact that each sidewall would have its own difference with regard to slight deformation, dirt particles as well as any wear from being stacked.

(a) (b) (c)

Fig. 5 Logos of three brands used

3.2 Data Augmentation

In order to use the data collected to train a model and make predictions, the data had to undergo some pre-processing before applying various data generation strategies used for the input data.

Pre-Processing

The images were initially taken as close-up segments of the tyre sidewall containing the logo. However, since the models needed to be trained on the logo only, the images needed to be manually cropped in order to remove all unwanted features from the logo images. The cropping of the images ensured that they were suitable for training and predicting. The last form of pre-processing needed was to split the data up into a number of bins (see Fig. 6). The data needed to be randomly and equally split amongst the bins, with each bin containing the same ratio of the three brands of tyres.

Algorithm 1 Bin Splitting Algorithm

```
parameters:
Conti ← List of cropped Continental images
Dunlop ← List of cropped Dunlop images
Sumi ← List of cropped Sumitomo images
Brands ← [Conti, Dunlop, Sumi]
binCount ← 5
classCount ← 3
dataPerClass ← 300

for x in range (0, numBrands) do
    imgCounter ← 0
    shuffle(Brands[x])
    for i in range (1, binCount + 1) do
        for j in range (1, (dataPerBrand/numBrands) + 1) do
            curImage ← Brands[x][imgCounter]
            Move curImage to Brand[x] subfolder in bin i
            imgCounter += 1
        end
    end
end
```

Fig. 6 Algorithm 1 used to split the images up into bins randomly and equally

Table 1 Data generation parameters

Parameter	Value
rotation_range	359
width_shift_range	0.1
height_shift_range	0.1
horizontal_flip	True
vertical_flip	True
shear_range	15
zoom_range	0.1
channel_shift_range	5
fill_mode	"Nearest"
Rescale	1./255

Data Generation

Due to the constraints on the data collection process, the dataset obtained is not very large according to machine learning standards. One strategy to help increase the size of the training set is the augmentation of the training set. Various parameters can be included, excluded or values adjusted for the data generation process. In order to decide which would be most applicable in the current context, a preliminary investigation was carried out. Each of the parameters were individually applied to a sample input image and the output was manually inspected in order to decide if it would be applicable to the current scenario. The final complete list of parameters and their corresponding values obtained from the informal investigation are displayed in Table 1.

Examples of the output from the data generation with the selected parameters and values can be seen in Fig. 7.

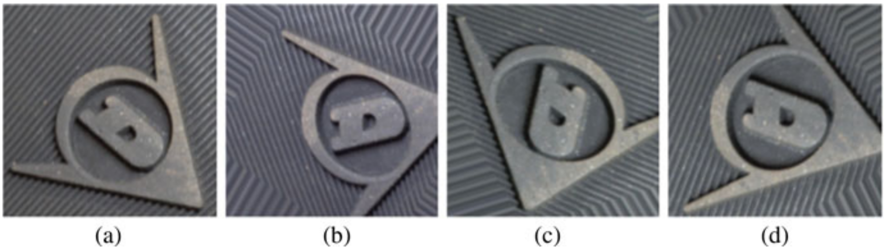

Fig. 7 Data generation visualisation (a) being the original image and (b), (c) and (d) the output of the data generation

3.3 Experimental Procedure

This section will explain the approach of the experimental procedure taken, highlighting the methods implemented (K-fold cross-validation and regularisation strategies implemented) as well as which models were evaluated (architectures to be evaluated) followed by a brief outline on the implementation tools used in the evaluation procedure (implementation tools).

Approach

The design of this approach helps to identify which aspects of machine learning and which architectures are best suited in order to classify tyre brands based on their logos. Each model will be trained using the close-up images of the logos, such as those seen in Fig. 8, which were collected and processed.

The training of the models contained two separate runs of experimentation. The first run trained the models from scratch on the training data provided, whereas the second run implemented models which are pre-trained on the *ImageNet* dataset and then fine-tuned for the input data set provided. This provided insight as to whether transferred learning is effective under the current context. The results will also allow for the comparison of training a model from scratch versus a pre-trained model.

K-Fold Cross-Validation

Due to the dataset obtained for the study being considered small for a machine learning task, it is important to be able to get the most use out of the data obtained as possible. K-fold cross-validation was applied, as a validation strategy to ensure that the data is utilised to its full potential. It provides a better overall representation of how a model performs. K-fold cross-validation is considered a gold standard in machine learning evaluation (Brownlee, 2016).

(a) (b) (c)

Fig. 8 Sample training logos

Regularisation Strategies Implemented

In order to increase the likelihood of achieving accurate results when predicting, a number of regularisation strategies were implemented. These are briefly discussed as to why they were included in the experiment as well as details given regarding their implementation. The data augmentation is a form a regularisation strategy whereby it allows the model to learn slight differentiations of the same image in order to increase the generalisation of the model. The following additional strategies were also implemented: validation set, early stopping and check-pointing.

A validation set was used in this study in order to measure the accuracy of the model during training. In order to obtain the validation set, a random selection of 60 images from the training set was set aside and used as the validation set. In order to ensure the model would not waste time training once an acceptable accuracy was obtained, early stopping was implemented. This strategy allows a minimum delta value and a patience value to be set whilst monitoring a particular variable in the training process. In order to ensure a well-trained model, the validation accuracy was monitored with a minimum delta value of 0.01 and a patience of 100. This means that the training process will continue until the validation accuracy does not increase (by any value more than 0.01) for 100 epochs. Although a patience value of 100 is quite high, the time taken to train the model was not a major concern or limiting factor, thus a high patience value was chosen to increase the chances of finding a better solution.

The last strategy implemented accompanies the early stopping. Due to the model essentially training past the point of the optimal solution (by 100 epochs), it is possible that the accuracy decreased. In order to save the weights of the model when the training of the model was optimal, check-pointing was implemented. This allowed for the correct weights of the model to be saved and then later loaded when doing the predictions.

Architectures to Be Evaluated

A number of models were implemented and evaluated. A select few were implemented using transferred learning (indicated by an asterisk) and this was due to the availability of the pre-trained networks in the Keras environment. These existing architectures were chosen due to their popularity in the image classification domain as well as success in the ImageNet Large Scale Visual Recognition Competition (ILSVRC). The models that were implemented are:

- LeNet-5 (LeCun et al., 1998): One of the pioneering and most well-known implementations of CNNs for object recognition. LeNet-5 was first applied to the recognition of handwritten digits.

- LeNet Modification (Chollet, 2016): This model contains a stack of 3 convolution layers and was implemented with the aim of building an accurate image classification model using very little data.
- AlexNet (Krizhevsky et al., 2012): The first deep architecture which won the ILSVRC 2012, outperforming all prior competitors. This network is similar to that of LeNet, but was deeper, had more filters per layer and had stacked convolutional layers.
- VGG16* (Simonyan & Zisserman, 2015): The runner up at the ILSVRC 2014, containing 16 weight layers.
- VGG19* (Simonyan & Zisserman, 2015): This model is the same as the VGG16 with the exception that it contains 19 weight layers instead of 16.
- ResNet50* (Wu et al., 2017): The ILSVRC 2015 winner. This residual neural network contains residual modules which can either be skipped or perform a set of functions.
- InceptionV3* (Szegedy et al., 2015): GoogleNet was the winner of ILSVRC 2014 and from this was derived InceptionNet.
- MobileNet* (Howard et al., 2017): This model is a result of attempting to produce small, yet efficient neural networks.

Implementation Tools

The implementation of the experimental procedure was written in the Python programming language. Python is considered the top programming language when it comes to machine learning tasks due to it being easily learnt and containing simple syntax. These factors allow for machine learning algorithms to be implemented with ease.

Python allows for additional, third-party, libraries to be added to a project in order to provide various added functionalities. One such library, Tensorflow, was developed by Google in order to provide functionality for machine learning applications. Tensorflow was installed with the CUDA extension (developed by Nvidia). The CUDA extension allows Tensorflow to run on multiple CPUs and GPUs. Running the machine learning algorithms on GPUs rapidly improves the computing performance of the programme.

Due to Tensorflow not being ideal for rapid development, a high-level API written in Python called Keras was implemented. Keras provides ease of implementation for neural networks by running on top of Tensorflow and focuses on being user-friendly, modular and extensible.

Python, Tensorflow with CUDA and Keras make up the main implementation framework for the experiment. Two additional libraries included in the study are:

- scikit-learn which was used in order to produce the confusion matrices, and,
- matplotlib is the library used to plot the graphs as a result of the training process.

This study made use of a dedicated machine learning computer with the following specifications:

- Operating System: Ubuntu
- CPU: RyzenTM ThreadripperTM 1920X Processor
- RAM: 16GB DDR4
- GPU: GeForce GTX 1080 Ti

Evaluation Metrics

In order to accurately compare the multiple models being implemented, meaningful metrics need to be collected, calculated and compared. In order to fully understand the evaluation metrics being discussed, the case of a binary classifier was investigated. Four terms help explain the metrics to follow and highlight their possible output cases which are possible with a binary classifier:

- True Positive: Predicted value and actual value is true.
- True Negative: Predicted value and actual value is false.
- False Positive: Predicted value is true whereas the actual value is false.
- False Negative: Predicated value is false whereas the actual value is true.

These possible outputs can be tabulated in a confusion matrix for a better representation as shown in Table 2. A confusion matrix contains information of the actual and predicted classifications output by a classifier.

This concept of the confusion matrix can be extended for a multi-class classifier (Table 3). From the values obtained in the confusion matrix, the following measures can be calculated and used to evaluate the performance of the model (Sokolova & Lapalme, 2009; Deng et al., 2016):

- The accuracy of a model provides the total number of predictions which were correct.
- The precision of a model is a measure of the accuracy provided that a specific class has been predicted. That is, for each class A_i the precision measures how many objects were labelled as class A_i which actually belongs to class A_i.

Table 2 Confusion matrix for a binary classifier

	Predicted positive	Predicted negative
Actual positive	TP	FN
Actual negative	FP	TN

Table 3 General confusion matrix

		Predicted Label		
		Continental	Dunlop	Sumitomo
Actual label	Continental	N_{11}	N_{12}	N_{13}
	Dunlop	N_{21}	N_{22}	N_{23}
	Sumitomo	N_{31}	N_{32}	N_{33}

- The recall is a measure of the effectiveness of a classifier to correctly assign to correct labels, taking into account the number of false negatives.
- Lastly, the F-score uses the precision and recall values in order to obtain a measure of accuracy, taking both false positives and false negatives into account.

For each of the models evaluated, five confusion matrices were compiled, one for each iteration of the k-fold method. To obtain a better representation of the model's performance, the corresponding values in the five confusion matrices were summed in order to obtain a total confusion matrix. This total confusion matrix was then used to calculate the required metrics as discussed above. These metrics will be compared in order to evaluate which model performs the best.

4 Experimental Results

The results are summarised for each model, by reporting on the performance metrics as stated in the evaluation metrics section. The performance measures provide an in-depth method of comparing how well this implementation performed compared to both training the same architecture from scratch as well as other architectures completely.

4.1 LeNet-5

The performance metrics for the LeNet-5 architecture (Table 4) indicated the importance of comparing all performance measures. The accuracy of each brand individually is above 70%, which would suggest that the model performed well. However, looking at the precision and recall values, it is notably not consistent, with the Continental and Sumitomo brands having lower precision than the Dunlop brand yet higher recall. The F1-scores provide a more accurate representation, with all brands getting a value between 54% and 60%. The average of the F1-scores, 58%, is a better representation of the performance of the LeNet-5 model as a whole and represents a value expected when looking back at the confusion matrix.

Table 4 Performance measures for LeNet-5

	Conti	Dunlop	Sumi	Average
Accuracy	0.706	0.754	0.707	0.722
Precision	0.546	0.709	0.554	0.603
Recall	0.687	0.447	0.617	0.583
F1-score	0.609	0.548	0.584	0.58

Table 5 Performance measures for LeNet-5 modification

	Conti	Dunlop	Sumi	Average
Accuracy	0.913	0.909	0.969	0.93
Precision	0.88	0.884	0.92	0.895
Recall	0.857	0.837	0.993	0.896
F1-score	0.868	0.86	0.955	0.894

Table 6 Performance measures for AlexNet

	Conti	Dunlop	Sumi	Average
Accuracy	0.711	0.6	0.667	0.659
Precision	0.561	0.438	0.5	0.499
Recall	0.617	0.703	0.147	0.489
F1-score	0.587	0.54	0.227	0.451

4.2 LeNet-5 Modification

The performance metrics for the LeNet-5 modification architecture (Table 5) indicated that the model performed uniformly across all three brands. The Sumitomo brand had higher valued performance metrics than the other two brands. The average values of the performance metrics indicate that with an accuracy of 93% and an F1-score of 89.4% the model performed well in recognising the three brands of tyres.

4.3 AlexNet

The performance measures for the AlexNet architecture (Table 6) indicated the model's inability to recognise the Sumitomo brand. Although the accuracy values for the brands seem uniform, the F1-score for the model, 45.1% indicates that the model's performance was inadequate for the task.

4.4 VGG16

The results for the VGG16 implementation when trained from scratch are presented followed by transferred learning, which reports on the results obtained from the transferred learning implementation of the architecture.

Trained from Scratch

The performance metrics in Table 7 highlights the bad performance of the VGG16 architecture when trained from scratch. The precision of the Continental brand indicates that when a logo belonging to Continental is being predicted, the model

Table 7 Performance measures for VGG16

	Conti	Dunlop	Sumi	Average
Accuracy	0.467	0.6	0.6	0.556
Precision	0.333	0.333	0.333	0.333
Recall	0.6	0.2	0.2	0.333
F1-score	0.429	0.25	0.25	0.31

Table 8 Performance measures for VGG16 (Transferred Learning)

	Conti	Dunlop	Sumi	Average
Accuracy	0.96	0.937	0.974	0.957
Precision	0.915	0.935	0.957	0.936
Recall	0.97	0.87	0.967	0.936
F1-score	0.942	0.902	0.962	0.935

will only get it correct 33.3% of the time. Likewise, the recall indicates that when the model is predicting a logo, it is 60% likely to predict it as the Continental brand. Particularly looking at the F1-score of the model, we can see only an average value of 31% was achieved, proving the model is inadequate to recognise tyre brands.

Transferred Learning

Table 8 indicates that the VGG16 architecture, with transferred learning, is uniformly accurate and does not bias towards certain brands. The high F1-score of 93.5%, as well as the other high average performance measures, prove that implementing the VGG16 architecture with transferred learning is well suited for recognising tyre brand logos.

4.5 VGG19

The results for the VGG19 implementation when trained from scratch are presented followed by transferred learning section, which reports on the results obtained from the transferred learning implementation of the architecture.

Trained from Scratch

The performance metrics in Table 9 confirms the bad performance of the VGG19 architecture when trained from scratch, with all average metrics for the model being low. Looking at the F1-score again, a low value of 32.6% is attained, suggesting that the VGG19 architecture when trained from scratch in inadequate.

Table 9 Performance measures for VGG19

	Conti	Dunlop	Sumi	Average
Accuracy	0.6	0.533	0.533	0.556
Precision	0.333	0.333	0.333	0.333
Recall	0.2	0.4	0.4	0.333
F1-score	0.25	0.364	0.364	0.326

Table 10 Performance measures for VGG19 (Transferred Learning)

	Conti	Dunlop	Sumi	Average
Accuracy	0.963	0.924	0.957	0.948
Precision	0.985	0.872	0.917	0.925
Recall	0.903	0.907	0.957	0.922
F1-score	0.943	0.889	0.936	0.923

Transferred Learning

Table 10 indicates that the VGG19 architecture, with transferred learning, is uniformly accurate and does not bias towards certain brands. The high F1-score of 92.3%, as well as the other high average performance measures, prove that implementing the VGG19 architecture with transferred learning is well suited for recognising tyre brand logos.

4.6 ResNet50

The results for the ResNet50 implementation when trained from scratch are presented then followed by the results obtained from the transferred learning implementation of the architecture.

Trained from Scratch

The ResNet50 architecture, when trained from scratch, performed uniformly accurate across all three brands as can be seen in Table 11. The model did seem to perform slightly better on the Sumitomo brand achieving above 94% for all of the performance measures, whereas the other two brands were above 82% for all of the performance measures. These high performance metrics and an average accuracy

Table 11 Performance measures for ResNet50

	Conti	Dunlop	Sumi	Average
Accuracy	0.889	0.901	0.966	0.919
Precision	0.842	0.837	0.956	0.878
Recall	0.82	0.873	0.94	0.878
F1-score	0.831	0.855	0.948	0.878

Table 12 Performance measures for ResNet50 (Transferred Learning)

	Conti	Dunlop	Sumi	Average
Accuracy	0.646	0.383	0.667	0.565
Precision	0.38	0.345	Nan	Nan
Recall	0.1	0.943	0.0	0.348
F1-score	0.158	0.505	Nan	Nan

of 91.9% alongside an F1-score of 87.8% indicate that the ResNet50 architecture, when trained from scratch, is capable of classifying tyre logos.

Transferred Learning

The performance measures are a strong confirmation along with the confusion matrix that the model did not train at all (Table 12). Since the Sumitomo brand's column contained only zeros, the true positive (TP) for the Sumitomo brand is 0 causing a divide by zero errors in calculating some of the performance measures. This is a clear indication that the ResNet50 architecture with transferred learning cannot be applied to the current task.

4.7 InceptionV3

The results for the InceptionV3 implementation when trained from scratch are presented here then followed by the results obtained from the transferred learning implementation of the architecture.

Trained from Scratch

Table 13 indicated that the InceptionV3 architecture, when trained from scratch, is uniformly accurate and does not bias towards certain brands. With an accuracy of 91% and an F1-score of 86.6%, the InceptionV3 architecture, when trained from scratch proves to be able to accurately classify tyre logos.

Table 13 Performance measures for InceptionV3

	Conti	Dunlop	Sumi	Average
Accuracy	0.893	0.913	0.924	0.91
Precision	0.817	0.899	0.887	0.868
Recall	0.877	0.833	0.887	0.866
F1-score	0.846	0.865	0.887	0.866

Table 14 Performance measures for InceptionV3 (Transferred Learning)

	Conti	Dunlop	Sumi	Average
Accuracy	0.972	0.927	0.943	0.947
Precision	0.931	0.857	0.992	0.927
Recall	0.99	0.937	0.837	0.921
F1-score	0.96	0.895	0.908	0.921

Transferred Learning

Table 14 indicates that the InceptionV3 architecture, with transferred learning, is uniformly accurate and does not bias towards certain brands. With all the performance metrics above 90%, the InceptionV3 architecture, with transferred learning, is well suited for classifying tyre logos.

4.8 MobileNet

The results for the MobileNet implementation when trained from scratch are presented then followed by the results obtained from the transferred learning implementation of the architecture.

Trained from Scratch

The MobileNet architecture, when trained from scratch, performed uniformly accurate across all three brands as can be seen in Table 15. The average performance measures for the MobileNet implementation indicate that the MobileNet architecture, when trained from scratch, performs extremely well in order to recognise tyre logos. The accuracy achieved by the model was 96.7% and the F-1 score equated to 0.95.

Transferred Learning

Table 16 indicates that the MobileNet architecture, with transferred learning, is uniformly accurate and does not bias towards certain brands. The high average

Table 15 Performance measures for MobileNet

	Conti	Dunlop	Sumi	Average
Accuracy	0.954	0.968	0.978	0.967
Precision	0.916	0.979	0.958	0.951
Recall	0.95	0.923	0.977	0.95
F1-score	0.933	0.95	0.967	0.95

Table 16 Performance measures for MobileNet (Transferred Learning)

	Conti	Dunlop	Sumi	Average
Accuracy	0.991	0.982	0.991	0.988
Precision	0.974	0.973	1.0	0.982
Recall	1.0	0.973	0.973	0.982
F1-score	0.987	0.973	0.986	0.982

Table 17 Summary of performance measures

		Accuracy	Precision	Recall	F1-Score
Trained from scratch	LeNet-5	0.722	0.603	0.583	0.58
	LeNet-5 modification	0.93	0.895	0.896	0.894
	AlexNet	0.659	0.499	0.489	0.451
	VGG16	*0.556*	*0.333*	*0.333*	*0.31*
	VGG19	*0.556*	*0.333*	*0.333*	0.326
	ResNet50	0.919	0.879	0.878	0.878
	InceptionV3	0.91	0.868	0.866	0.866
	MobileNet	**0.967**	**0.951**	**0.95**	**0.95**
Transferred learning	VGG16	0.957	0.936	0.936	0.935
	VGG19	0.948	0.925	0.922	0.923
	ResNet50	*0.565*	*Nan*	*0.348*	*Nan*
	InceptionV3	0.947	0.927	0.921	0.921
	MobileNet	**0.988**	**0.982**	**0.982**	**0.982**

performance metrics prove that implementing the MobileNet architecture with transferred learning is well suited for recognising tyre brand logos. The main advantage over using the transferred learning over training from scratch for the MobileNet architecture would be the number of epochs taken to train the model.

Table 17 provides an overview of all the evaluation metrics for models that were both trained from scratch as well as the models which implemented transferred learning. The values highlighted in each of the sections are indications as to which models performed the best (in bold) and which models performed the worst (in italic).

The MobileNet architecture outperformed all other models in both the training from scratch and transferred learning implementations. Both of which having the highest valued performance measures across all implemented architectures. Both implementations achieved an impressive accuracy with the transferred learning providing a slight increase in accuracy and a substantial decrease in the number of epochs taken to achieve said accuracy (Table 18). Although an increase of 3.2% in the F1-score might seem insignificant, taking into account the number of epochs taken to train the model at these high accuracies is important. The transferred learning implementation of the MobileNet architecture is almost instant, making it more favourable and the best suited for the task of classifying tyre logos.

It is important to note that although the MobileNet implementations were the most accurate, other models also performed well. The LeNet-5 Modification, ResNet50 and InceptionV3 all obtained an accuracy above 90% and an F1-score

Table 18 Comparison of MobileNet's performance measures

	Trained from Scratch	Transferred Learning	Difference
Accuracy	96.7%	98.8%2	↑2.1%
F1-score	95%	98.2%	↑3.2%
Average number of epochs	190	2	↓189

above 86% when trained from scratch. Therefore these implementations are also suitable for classifying tyre logos. When considering the transferred learning implementations of the ResNet50 and InceptionV3 architectures, it is expected that the performance measures would increase, as it did with the MobileNet architecture. This is true with the InceptionV3 architecture, gaining slight increases in the performance measure as well as a significant decrease in the average number of epochs, a decrease from an average of 200 epochs to an average of 19 epochs. However, when investigating the case for the ResNet50 architecture, it is seen that the transferred learning implementation completely diverges from the accuracy of the trained from scratch implementation. The transferred learning implementation for ResNet50 failed to train at all, causing it to be the worst performing model out of all the transferred learning architectures. This highlights the fact that transferred learning does not in all cases improve the accuracy of a model.

Consider both the VGG16 and VGG19 architectures, which behave in a similar fashion. It can be shown that transferred learning can improve the performance of a model. In this study transferred learning aided in transforming the models, which were trained from scratch and unable to learn or predict tyre logos into a state where the two models achieved above 90% across all performance metrics. These two, somewhat opposite cases provide valuable insight as to how transferred learning can improve the performance of a model, but does not mean that it will always do so. It is important to evaluate the differences on a case-by-case basis.

5 Conclusion and Discussion

End of Life Tyres (ELTs) take responsibility for the largest percentage of waste rubber, there is thus a need for the recycling of tyres (Forrest, 2014). Recycling could be made more profitable and appealing to businesses if the process was more profitable. In order to efficiently recycle tyres, it would be beneficial to know what compounds the tyre is made up of before deciding on the by-products to extract or recycling method to use. Being able to classify the tyres before entering the recycling facility, the most optimal recycling method can be chosen. This research investigated the automatic classification of tyres using a deep learning approach.

The focus was on classifying a tyre's brand as only the manufacturers of a tyre know what compounds make up their products. Using the classification by brand logo as a proof of concept, it can be taken further to then classify tyres by other identifying features such as size and DOT code.

The aim of this research was to use deep learning to automate the classification of tyres. This research proved that deep learning can be used to classify tyres successfully by means of comparing multiple deep learning architectures. The outcome of this research was multiple models which are trained to accurately classify logos from tyre sidewalls. A secondary output was that of a comparison of the models as well as a comparison of transferred learning and training CNNs from scratch.

The results obtained from the experimentation results was analysed and compared in order to deduce conclusions from the experiment. The results indicated that there were multiple models, whether transferred learning was implemented or not, that could classify tyre logos with high accuracy. The model which performed the best throughout the study was the MobileNet architecture, which achieved the highest evaluation metrics when trained from scratch as well as when transferred learning was implemented. Additionally to the individual results of the model, it was seen that transferred learning does not always improve the accuracy of the model, but in some cases, it can. The use of transferred learning should be investigated on a case-by-case basis.

It was concluded that by using a deep learning approach, the automation of tyre classification can be made less complex.

The most limiting factor of this research was the data. Although research has been done on tyres in both the machine learning field and other fields, no dataset existed that would meet the needs of identifying tyres. Logos of the tyre brands could have easily been collected by means of web-scraping and existing logo database, however, it was required that the images of logos in this study were from the actual sidewall of a tyre. The non-existence of this dataset contributed to the time spent manually building up the dataset by travelling to various tyre depots, gaining permission and access to their storage and then collecting the data in an environment that was not controlled. These factors lead to the dataset not being of a large size when considering machine learning applications as well as not being uniform in terms of lighting, angle and quality of the logo. Even though this was a limitation to the study, the results produced were still meaningful and accurate.

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A Backup Model: (QoS Guaranteed and Less Consumed Energy) for Cloud SDN Using Neural Networks

Ammar Alsous, Jorge Marx Gómez, and Manuel Mora

1 Introduction

Computer networking is an important component of the Information and Communication Technology (ICT), which is responsible for a significant amount of the consumed energy (electricity). In the last couple of years, a new networking technology has been used in data centers, i.e. Software Defined Networking (SDN) (Open Networking Foundation (ONF), 2013). This networking paradigm depends on the concept of decoupling data and control planes. That helps in utilizing the available networking resources more efficiently. In addition, it participates in Green Networking by reducing the consumed energy. SDN offers more management capabilities for that (Tuysuz et al., 2017). Moreover, minimizing the required energy (electricity) leads to less CO_2 emissions by power generation.

There are several disaster recovery methods for saving data from being lost. One of the common and significant methods is performing a backup. There is a need to do a backup at the data center level to another data center (in a different geographical place), to overcome any technical failures or geographical disasters. However, this operation could be costly in case of private connections. An efficient solution for such situations is to offer the backup as a service from a cloud provider. The cost could be shared between several users who need the service. When the backup is offered as a service, there is a need to specify the Quality of Service (QoS) level and to guarantee it.

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An extensive literature review showed that there is a lack of satisfactory backup solutions for cloud services, which use SDN in their networks and guarantee the QoS. Overall review on the state of the art of 49 studies from 2007 to 2017 was performed by Mendonca et al. (2019). It showed that the research area is still active with recent publications. Because disaster recovery services are important for data centers, the proposed approach presents a solution for cloud backup services. It addresses the problem of guaranteeing the QoS level during the backup, when the cloud provider uses SDN paradigm in the network infrastructure. This target has been achieved by proposing a routing selection model depending on AI methods (neural networks) to choose one of the accepted paths that could guarantee the QoS level for customers. There is a long procedure that should be applied once in the network establishment phase. After that, a relation between QoS criteria and backup duration is extracted and used for routes selection process.

The model performance was tested and the results were satisfying. There is a long procedure which should be applied once at the network establishing phase. However, the proposed model has shown a very high performance regarding the routing decision time using neural networks. Moreover, other AI techniques were tested and a detailed comparison was done to prove that neural networks are the best option for this research problem.

2 Software Defined Networking

Software Defined Networking (SDN) is a new computer networking paradigm that depends on decoupling the control plane and the data plane. As a result, the control plane (the controller) has a full view of the network. And the data plane represents physical network devices, which follow the control plane's commands. An SDN network is managed completely from the control plane (including routing algorithms). This paradigm helps effectively in utilizing the available network resources and reacting fast for any required changes. The third plane of SDN architecture is the application plane. Through the application plane, many applications can communicate directly with the network, which eases the network reconfiguration process (according to applications' requirements). Figure 1 shows the main architecture of an SDN network.

Separating data and control planes eases the administrator tasks and lets him administrate the network in a more flexible way (Nunes et al., 2014).

Centralizing the control plane can cause some drawbacks (e.g., single point of failure). One of the suggested solutions is to use multiple (redundant) controllers (for one control plane). The required network protocol is applied in the controller and then it will be sent to the data plane as abstracted commands. Each network device is not aware of the applied protocol in the network. It is just following its rules. That is why, it is important that network devices are able to interpret the controller's commands (support an SDN protocol) without the need to support routing protocols (routing protocols are not applied locally in network devices).

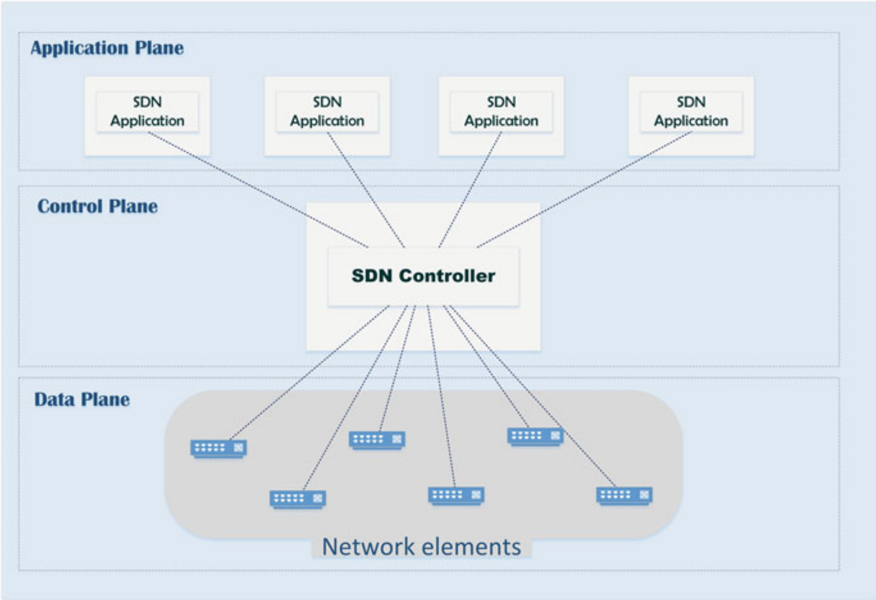


Fig. 1 SDN Architecture (Modified after AlSous & Marx Gómez, 2019)

Data plane could be called sometimes: Forward plane. That is because of its nature, which depends on forwarding network's packets without the awareness of the applied algorithm/protocol. Moreover, applying energy aware algorithms in SDN is easy and could save a significant amount of the consumed energy (especially in large-scale networks) (Tuysuz et al., 2017).

SDN principles (Open Networking Foundation (ONF), 2013):

1. Decoupling (separating) data and control planes:
   Separate the main functions in the network: control and forward. The controller (the control plane) is responsible for sending forwarding commands to network devices (data/forward plane), which follow them.
2. Central control and management:
   The whole view of the network is centralized in the network controller (control plane), which enhances the network management process. There is one logical controller in each network. To face the scalability problem, several physical controllers could be used.
3. The applications have the ability to control network resources:
   Some permissions on the network could be given by the control plane to specific applications (application plane). This eases the network configuration directly from the applications.

As mentioned before, data and control planes need an SDN protocol to communicate and transfer controller's commands. One of the most common SDN protocols is OpenFlow (McKeown et al., 2008). Data and control planes can use OpenFlow or other SDN protocol without the need to check the compatibility beforehand (no need for hardware check).

3 Green Networking and SDN

The electricity production process is responsible for a huge amount of CO_2 emissions. Day by day, the required energy to fulfill the consumer's need is increasing, which leads to a significant impact on the environment. One of the important electricity consumers is the Information and Communication Technology (ICT). Mainly, the ICT is composed of three sectors:

– End-user devices.
– Telecommunication networks.
– Data centers.

ICT was responsible for 4% of CO_2 emissions in the European Union (Nam et al., 2015). Network devices were responsible for 35% of the ICT power consumption (Lannoo, 2013). Legacy network devices consume electricity continuously because they are always in "on" mode (AlSous & Marx Gómez, 2016).

Many researches focus on reducing the power consumption at the server level by introducing cloud services and virtualization techniques, other new researches started to focus on the network and its power consumption. Software Defined Networking (SDN) brings the network virtualization concept to reality, which offers benefits to service providers and customers. A service provider could use virtualization techniques to increase the hardware utilization by sharing it between several users. On the other hand, a service customer could pay less for a virtualized service than for other services.

Green Networking refers to minimizing the consumed energy by networking. SDN could help effectively in reducing the consumed electricity in a network by: (1) turning off specific links, devices, or ports. (2) choose routing paths according to an energy aware algorithm. Moreover, SDN and by its ability to control and manage the network from the network controller offers advanced methods to minimize the consumed energy by turning network hardware "on" or "off" at many levels (device/port).

As Fig. 2 shows, ICT is expected to consume about 5% of the electricity production by 2020. Moreover, all ICT components require more electricity continuously.

The consumed electricity by ICT causes the mentioned amounts of CO_2 (Fig. 3). As presented, 3% of the global CO_2 emissions in 2030 are generated because of the ICT power consumption.

Other reports have shown different numbers through a European project. They showed that ICT consumed 920TWh, which is about 4.7% of the global energy consumption (19,500 TWh) in 2012 (The EINS Consortium, 2013; Van Heddeghem

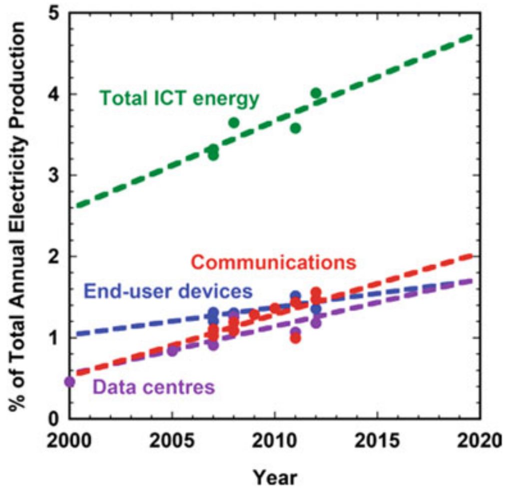


Fig. 2 ICT Total Energy Consumption (Gallagher, 2017; Initiative & others, 2012; Malmodin et al., 2010; Pickavet et al., 2008)

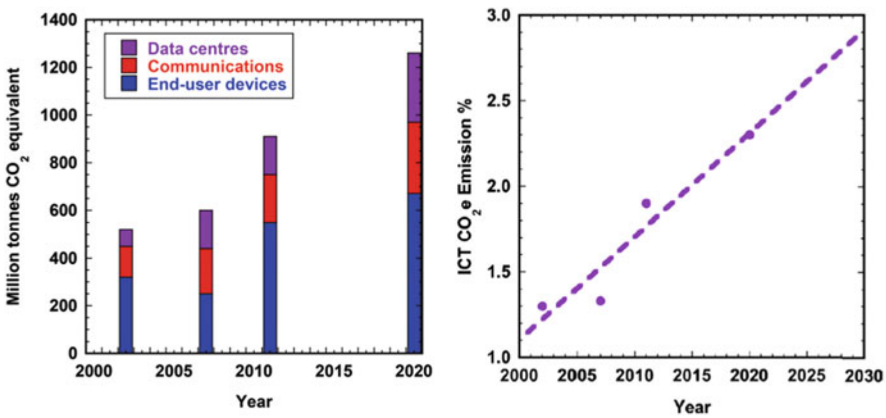


Fig. 3 CO_2 Emissions (ICT) (Gallagher, 2017; Initiative & others, 2012; Malmodin et al., 2010)

et al., 2014). This means, ICT was responsible for about 530 Mt. of CO_2 (around 1.7% of the global CO_2 emissions).

In order to face the environmental problems caused by energy generation, there are two main methods:

– Reduce the consumed power (by ICT).
– Use sustainable resources to generate the power.

"Green IT" is the used term to refer to reduce the negative environmental effects of IT operations (Gelenbe & Caseau, 2015). In order to measure the consumed power in ICT data centers, the Power Usage Effectiveness (PUE) is used. PUE represents the proportion of the consumed energy for computing to the total consumed energy in a data center (AlSous et al., 2019).

As mentioned before, SDN offers the ability to apply any routing algorithm in the controller and send the equivalent rules to the data plane (network devices). On the other hand, in traditional networks there is a need to apply routing algorithms locally in network devices and the used hardware should support the application of any algorithm/protocol. SDN requires that network elements support an SDN protocol (e.g., OpenFlow (McKeown et al., 2008)) to be able to communicate with the controller. In addition to routing algorithms, SDN offers the ability to apply energy aware algorithms (energy-saving algorithms) in the controller. These algorithms control the network flows and could spread them in the network to minimize the energy consumption rate in the network. Moreover, and according to the used hardware, energy aware algorithms could switch on/off network links/ports/devices to save energy (Markiewicz et al., 2014). Big companies have applied SDN in their networks (e.g., Google) and it is expected that 93% of mobile operators will use SDN in 2020 (Mavrakis, 2013).

SDN provides the ability for network virtualization, which is used significantly to reduce the consumed energy by using the resource sharing concept. However, there is a trade-off between network QoS and the consumed energy (Tuysuz et al., 2017). To guarantee the QoS in a network, there is normally a need for more computations (more energy consumption). Reducing the energy consumption rate could be achieved in two methods (it depends on the used hardware): (1) Lower data rate (less computational resources are required) and (2) Higher data rate (longer sleep-mode durations for network devices). Using SDN, energy-saving algorithms could be applied in the controller and act automatically. For example, they could be used to spread the network flows in the network instead of following shorted path algorithms. As mentioned before, energy-saving algorithms depend on the used hardware. In some cases, SDN can be used to switch on/off links, ports, or devices, which is important for the energy-saving process (Tuysuz et al., 2017) (AlSous et al., 2019).

Many researchers introduced energy efficient SDN approaches. The authors in Naudts et al. (2012) applied SDN paradigm with network virtualization. Applying these two concepts includes many advantages. It combines the advantages of using a programmable network (cheaper—more efficient network management) and virtualization (several network slices for several operators). According to the applied scenarios, the research showed that the SDN-based scenario reduced the consumed energy. Moreover, network maintenance costs have been reduced using SDN. The authors proposed the design of Green Abstraction Layer (GAL) in Bolla et al. (2013). In this model, network devices are able to exchange power consumption data, which should be processed in the controller that applies real-time control strategies in the network (to reduce the consumed energy). Based on the proposed GAL, a network management system was introduced in Bolla et al.

(2015). Using the network topology, resources, and network requests, it calculates available network routes and energy states of the used devices. The evaluation of the approach showed a promising results and a good accuracy. Several other energy aware SDN approaches were introduced: (Wang et al., 2014) and (Oda et al., 2014).

4 Network Quality of Service

In order to offer a service, there is a need to find a specific method to evaluate it. Network services require several criteria to check them, which is called Network Quality of Service (QoS). This means, the criteria to measure the performance characteristics of a network (Szigeti et al., 2013). On the other hand, network services without a guarantee use the "best effort" method (e.g., Internet). In this model there is no guarantee for the offered network service. The customer gets the best possible service without any guarantee. In the "best effort" model, the Round Trip Time (RTT) and the network bandwidth are not guaranteed for users or applications. The network service quality is determined by the current status of the network (Peuhkuri, 1999). Some service providers offer a guaranteed service for prioritized customers and "best effort" services for others. However, it is difficult to offer the two service types (prioritized and best effort) simultaneously (Goossens et al., 2002) (AlSous & Marx Gómez, 2019).

The essential network QoS criteria could be defined as the following (AlSous & Marx Gómez, 2017) (Sambanis, 2001):

- *Network bandwidth* (bits per second):
  The available data rate for carrying the data over the network.
- *Latency* (milliseconds):
  The needed duration to send a packet and receive it at the destination.
- *Jitter* (milliseconds):
  The differences in the latencies between the same source and destination. When network packets use different paths (e.g., packet switching networks), jitter could be caused. The out-of-order problem could be caused by the jitter, in which the packets arrive not in the same sending sequence. Several methods could be used to solve it (Frnda et al., 2013).
- *Packet Loss Ratio* (a percentage of the overall sent packets):
  The packets discarding/losing ratio. Many reasons could cause it (in network devices or physical links). According to the transmission protocol, lost packets could be resent or not.

4.1 How to Guarantee the QoS?

Regarding QoS requirements, network services differentiate from each other. The Service Level Agreement (SLA) between a service provider and a service customer specifies the service level (quality). Some services are very sensitive to data loss (e.g., send a file). In this situation, any lost packets should be resent to the receiver, which could degrade the whole service. On the other hand, other services can tolerate with a packet loss ratio (to a determined level) but they need a high bandwidth. As an example for that is the voice/video streaming. In streaming services, the bandwidth is very important to have a continuous voice or video, but losing some packets could not be a big problem (AlSous & Marx Gómez, 2019).

Traditional networks have two main methods to guarantee the QoS:

– Integrated Services (IntServ):

  It was introduced in Braden et al. (1994) and use the Resource Reservation Protocol (RSVP) (Zhang et al., 1997) to guarantee the QoS per flow. In this method, each network flow is assigned determined resources in network elements using the RSVP protocol. The main challenges for this technique are the high overhead (computing) and the scalability.

– Differentiated Services (DiffServ):

  DiffServ came later and was proposed in Blake et al. (1998). Using the Differentiated Services Code Point (DSCP) in IP header (6 bits), it defines several classes (up to 64 classes). Network flows are aggregated and classified according to their DSCP. This helps in reducing the high overhead of IntServ, but causes a flexibility problem (fixed classes number) (Serban et al., 2002). In addition, each network flow cannot be guaranteed individually.

For a tuned network, there is also a need for traffic engineering to spread the network flows according to other requirements (e.g., load balancing). In order to support traffic engineering, traditional networks could use Multiprotocol Label Switching (MPLS) (Rosen et al., 2000). However, configuring and administrating a network (IntServ/DiffServ with MPLS) is hard and complicated. That is why, IntServ and DiffServ are not implemented to a large degree (Egilmez et al., 2013).

The flexibility and the programmability features of SDN are very important in offering guaranteed network services. Using SDN there are no limitations. According to the available resources (computing, networking, etc.), the appropriate QoS model with the required traffic engineering method could be applied. Moreover, a specific model could be designed and programmed for a specific network easily. The QoS could be guaranteed at any required level (e.g., flow, user, application, etc.). This flexibility gives the SDN a significant advantage over traditional networks (AlSous & Marx Gómez, 2019).

5 The Proposed Solution

According to the performed literature review, there is a lack of satisfactory backup solutions in cloud SDN, which take QoS criteria into consideration simultaneously. This research addresses this problem and introduces an SDN model for choosing an accepted routing path that satisfies the customer's QoS requirements.

The proposed solution takes three QoS criteria into consideration: delay, bandwidth, and packet loss ratio. Because it is targeting a backup service, the bandwidth and the delay are very important because backup services between data centers transfer huge amount of data. The packet loss ratio is very important as well, because transferring files cannot tolerate with loosing bits. The QoS criteria have impacts on each other and it is not enough to take only one of them into consideration (e.g., bandwidth). A selected path could have a high bandwidth and a low delay, which are very good QoS criteria. However, the packet loss ratio of this path is high. So, lost packets will be retransmitted after determining that they are missed. This degrades the whole backup operation.

Because in an SDN paradigm there is an ability to virtualize the network and divide it into several virtual networks (different resources), every network service could be assigned a separated virtual network (separated resources). The proposed solution introduces a method to take all QoS criteria into consideration simultaneously by choosing the right path. Selecting the right path/route in a virtual network is essential. The proposed solution is applied in an SDN network as a module could be added to the controller. It includes the following steps:

1. Establish the physical network.
2. Add the SDN controller and create the required virtual networks.
3. Assign each virtual network the needed resources.
4. One virtual network is used for backup service.
5. The added module (the proposed module) is used to check network paths and evaluate network links and devices.
6. Extract a relation between network paths and backup durations.
7. For future backup requests, the network paths are evaluated using the extracted relation and a suitable path could be chosen that satisfies the QoS requirements.

The full design of the proposed module was introduced in AlSous and Marx Gómez (2019).

5.1 Network Topologies

The used network topologies are similar to real ones (in cloud data centers) and they are "partially meshed." In order to have realistic results, two network topologies

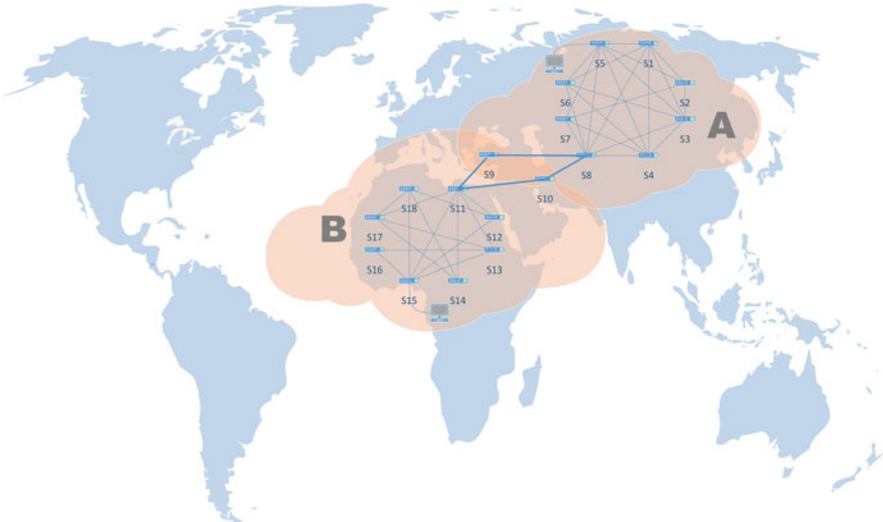


Fig. 4 Topology 1 (Modified after AlSous & Marx Gómez, 2019)

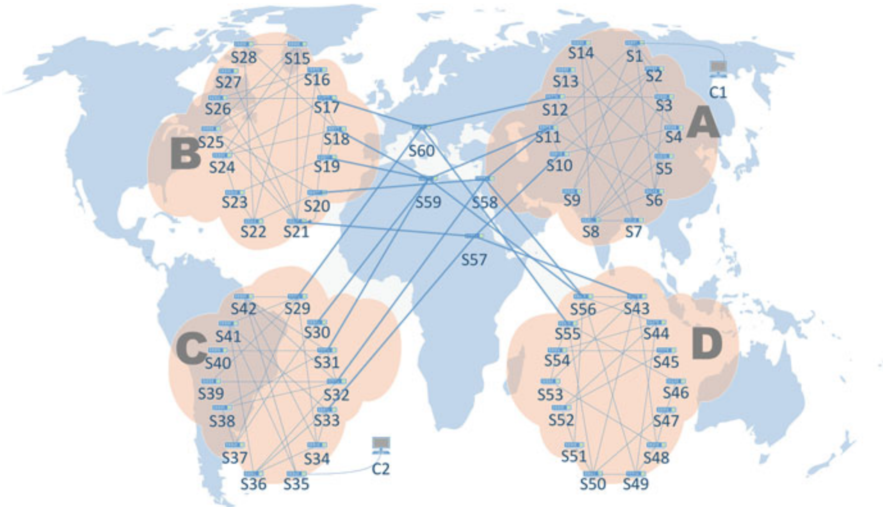


Fig. 5 Topology 2

were used in this research for testing and evaluation phases: The first network topology is small and contains 18 nodes (Fig. 4).

Figure 5 shows the second big network topology (60 nodes).

Both network topologies consist of several networks connected with each other using connections with a higher bandwidth.

5.2 Activity Diagram

In order to understand how the proposed model works, the following activity diagram (Fig. 6) helps in understanding the steps/activities of it:

The activity diagram shows in details that there are two parts of it:

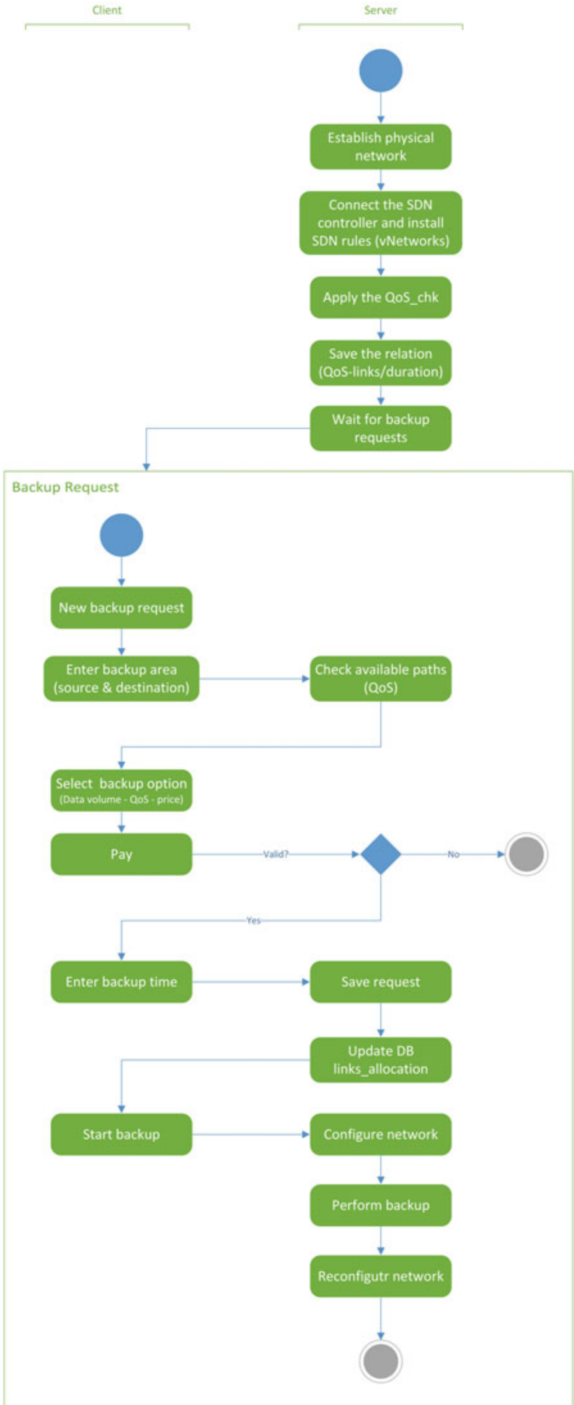
(a) The first part is applied only once, in the network establishment phase (including setting up the SDN network and extracting the relation between QoS/duration).

1. Establish physical network: Installing the network hardware.
2. Connect the SDN controller and install SDN rules: Add a controller to the network with the equivalent rules to network devices.
3. Apply the QoS_chk: Check the QoS criteria of network links.
4. Save the relation (QoS-links/duration): Extract and save the relation between QoS criteria and backup duration.
5. Wait for backup requests: The service is ready for receiving requests.

(b) The second part could be repeated, when there is an incoming backup request. It requests some details from the customer (source, destination, time, payment, etc. . . .). Moreover, at the end of this part, the backup request is performed as agreed (including the network reconfiguration process).

1. New backup request: A new request from a customer.
2. Enter backup area (source and destination): The customer enters the backup source and backup destination nodes.
3. Check available paths (QoS): The module checks all available paths between the source and the destination nodes (not longer than a specific value).
4. Select backup option (Data volume–QoS–price): The customer chooses the desired backup option.
5. Pay: Transfer the money to the provider.
6. Enter backup time: Determine the start_time of the backup.
7. Save request: The module saves the request.
8. Update DB links_allocation: Update the database that contains information about the allocation in each link.
9. Start Backup: A notification from the customer to start the backup.
10. Configure network: On time, insert equivalent rules in network devices to perform the backup.
11. Perform backup: Start transferring the data.
12. Reconfigure network: Remove the inserted rules.

Fig. 6 Activity Diagram



5.3 Sequence Diagram

The following sequence diagram (Fig. 7) shows in details how the user, the backup application, the backup module, the payment application, and the SDN network interact with each other.

The previous figure (Fig. 7) illustrates the detailed messages between different components of the system to handle a backup request from a customer.

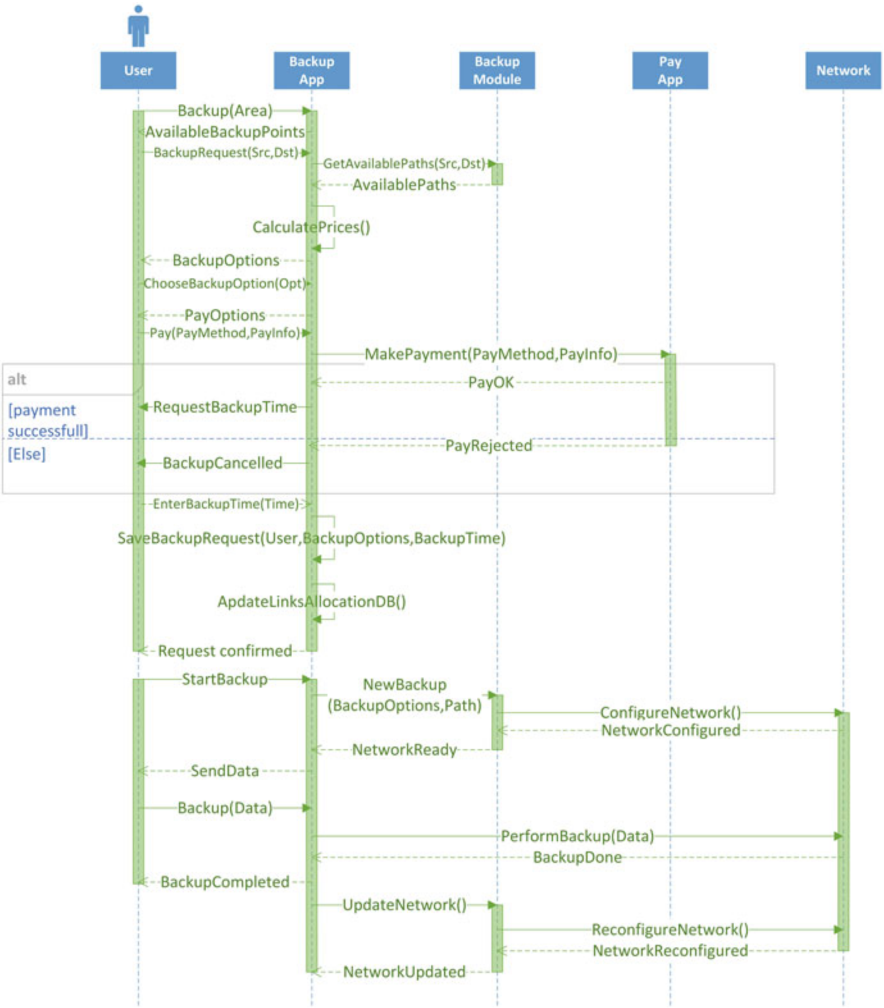


Fig. 7 Sequence Diagram

5.4 Evaluation Strategy

Many researches depend on using network simulators/emulators for development of an evaluation. Using real networks could be expensive. Moreover, in some cases it is not realistic to use real networks (e.g., cloud networks) for testing. On the other hand, network simulators/emulators could provide a very close environment to the real one. Many researchers used network simulators, e.g., (Salsano et al., 2014) and (Csoma et al., 2015).

There are several SDN simulators that could be used to develop and evaluate SDN research. After performing an extensive literature review, Mininet (Lantz et al., 2010) has been chosen to be the used emulator in this research for many reasons:

- Same hardware performance to the traditional networks (Bholebawa et al., 2016).
- Mininet introduces a similar network functionality (resources) to real environments (De Oliveira et al., 2014).
- It shows an accurate performance in the testing environment (Kaur et al., 2014).
- Any developed approach in Mininet is compatible with real SDN network environments and could be moved and applied there without any modifications (Lantz et al., 2010).

For all of that, this research used Mininet emulator for implementation and evaluation. Four dedicated servers in the professional labs of University of Oldenburg were used for that. Using the latest Linux Ubuntu, a redundant environment was established.

5.5 Evaluation Steps

1. Design 2 partially meshed cloud networks (small–big) for testing.
2. For each network size, generate a real dataset for the same source and destination by performing real backup operations (about 100,000 backup operations for three data files: small–medium–big).
3. For each dataset (there are six datasets), apply the AI techniques to 80% of it (training) and extract the relation between QoS and backup duration. After that, check the Root Mean Square Error (RMSE).
4. For each dataset test the extracted relation in step 3 on the remaining 20% and check the Root Mean Square Error (RMSE).
5. Generate new dataset between different source and destination and apply the previously extracted relation (step 3) to the new datasets to generalize the solution. At the end, check the Root Mean Square Error (RMSE).
6. Compare the used AI methods (steps 3-4-5) by checking the Root Mean Square Error (RMSE) to adopt one of them in future tests.

5.6 Used AI Techniques

According to the description of this research problem, there is a need to apply AI techniques to solve a linear regression problem. The approach should be able to predict the backup duration using the QoS parameters of this path. The following techniques were used to solve the problem (they have differences in the performance):

1. "Linear Regression—Linear"
2. "Linear Regression—Interactions Linear"
3. "Linear Regression—Robust Linear"
4. "Linear Regression—Stepwise Linear"
5. "Tree—Fine Tree"
6. "Tree—Medium Tree"
7. "Tree—Coarse Tree"
8. "SVM—Linear SVM"
9. "SVM—Quadratic SVM"
10. "SVM—Cubic SVM"
11. "SVM—Fine Gaussian SVM"
12. "SVM—Medium Gaussian SVM"
13. "SVM—Course Gaussian SVM"
14. "Ensemble—Boosted Trees"
15. "Ensemble—Bagged Trees"
16. "Gaussian Process Regression—Squared Exponential GPR"
17. "Gaussian Process Regression—Matern 5/2 GPR"
18. "Gaussian Process Regression—Exponential GPR"
19. "Gaussian Process Regression—Relational Quadratic GPR"
20. "Neural Networks".

For all of the mentioned AI techniques, a dataset of thousands of rows was used. The dataset includes the following data (each row represents a backup operation using a specific path):

Path's Bandwidth–Path's Delay–Path's Packet Loss Ratio–Backup Duration
The training parameters are the first three values (QoS parameters) and the backup duration is the target. At the end of the training phase, a relation between QoS parameters and backup duration is extracted. The relation could be used for evaluation. For any future backup operations, backup duration could be anticipated by using the QoS parameters of any path. For testing the mentioned AI techniques, Matlab 2019b was used.

6 Results

6.1 Datasets

Three datasets are used for testing:

1. Training dataset:
   It represents 80% of the backup dataset (fixed source and destination nodes: a to b) and it is used for training phase of the AI method.
2. Testing dataset:
   The remaining 20% of the first dataset (a to b). It is used only to test the extracted relation from the training dataset.
3. Different source and destination dataset:
   It is used to generalize the approach. That same extracted relation from step (1) is applied to this dataset between different source and destination nodes (c to d). This step is significant to be sure that the extracted relation works for any source and destination nodes.

6.2 Network Topologies

As mentioned before, two network topologies are used for testing:

1. Small network: 18 nodes (Fig. 3).
2. Big network: 60 nodes (Fig. 4).

6.3 Data File Sizes

Three data file sizes are used for testing the approach:

1. Small data file: 1 MB
2. Medium data file: 20 MB
3. Big data file: 100 MB

6.4 Evaluation Results

This section contains detailed information about the testing results. There are six tables to show the results for all combinations (network size–data file size). The evaluation parameter is the Root Mean Square Error (RMSE):

1. RMSE-Training:
   The resulted RMSE from applying the extracted relation from the training dataset (80%) on the training dataset (itself).
2. RMSE-Testing:
   The resulted RMSE from applying the extracted relation from the training dataset (80%) on the testing dataset (20%).
3. MSE-Diff source and destination:
   The resulted RMSE from applying the extracted relation from the training dataset on the different-source-destination dataset.
4. RMSE-Avg:
   The average of the previous three RMSE values.

In each table, the minimum RMSE-avg is showed in dark gray. However, the second minimum value is showed in hell gray color. According to the listed results, neural networks could lead to achieve the minimum RMSE-avg after tuning.

6.5 Small Network-Small Data (Table 1, Fig. 8)

Table 1 Results: Small Network-Small Data

AI Method	RMSE - Training	RMSE - Testing	RMSE - Diff source and destination	RMSE - Avg
Linear Regression Linear	2.8791	2.8097	2.6500	2.7796
Linear Regression Interactions Linear	2.8781	2.8076	2.6445	2.7767
Linear Regression Robust Linear	3.2052	3.1421	2.8991	3.0821
Linear Regression Stepwise Linear	2.8780	2.8085	2.6461	2.7775
Tree Fine Tree	3.3673	3.2322	3.1782	3.2592
Tree Medium Tree	3.1029	2.9984	2.9090	3.0034
Tree Coarse Tree	2.9641	2.8843	2.7780	2.8755
SVM Linear SVM	3.1556	3.0957	2.8811	3.0441
SVM Quadratic SVM	3.1525	3.0873	2.8892	3.0430
SVM Cubic SVM	3.1483	3.0803	2.8804	3.0363
SVM Fine Gaussian SVM	3.1430	3.0748	2.8982	3.0387
SVM Medium Gaussian SVM	3.1467	3.0903	2.8846	3.0405
SVM Course Gaussian SVM	3.1536	3.1002	2.8954	3.0497
Ensemble Boosted Trees	2.9033	2.8297	2.6833	2.8054
Ensemble Bagged Trees	2.9153	2.8314	2.7091	2.8186
Gaussian Process Regression Squared Exponential GPR	2.8777	2.8076	2.6437	2.7763
Gaussian Process Regression Matern 5/2 GPR	2.8778	2.8007	2.6430	2.7738
Gaussian Process Regression Exponential GPR	2.8823	2.8091	2.6546	2.7820
Gaussian Process Regression Relational Quadratic GPR	2.8777	2.8080	2.6447	2.7768
Neural Networks	2.7743	2.8133	2.6495	2.7457

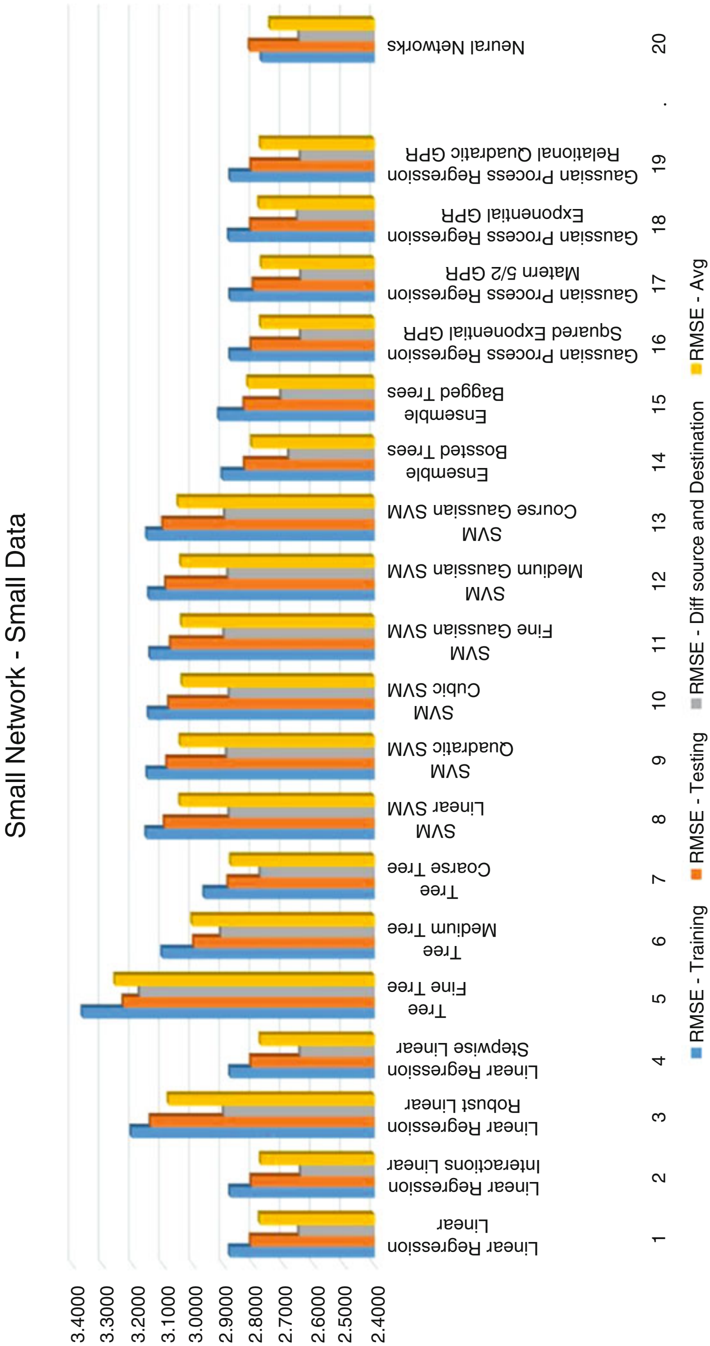


Fig. 8 Chart: Small Network-Small Data

6.6 Big Network-Small Data (Table 2, Fig. 9)

Table 2 Results: Big Network-Small Data

AI Method	RMSE - Training	RMSE - Testing	RMSE - Diff source and destination	RMSE - Avg
Linear Regression Linear	2.8141	2.8842	2.6771	2.7918
Linear Regression Interactions Linear	2.8136	2.8841	2.6756	2.7911
Linear Regression Robust Linear	3.1403	3.1961	2.9189	3.0851
Linear Regression Stepwise Linear	2.8141	2.8842	2.6771	2.7918
Tree Fine Tree	3.3013	3.3128	3.1929	3.2690
Tree Medium Tree	3.0437	3.0627	2.8185	2.9750
Tree Coarse Tree	2.8910	2.9497	2.7879	2.8762
SVM Linear SVM	3.0719	3.1302	2.9004	3.0342
SVM Quadratic SVM	3.0780	3.1478	2.9127	3.0462
SVM Cubic SVM	3.0774	3.1472	2.9119	3.0455
SVM Fine Gaussian SVM	3.0754	3.1197	2.9736	3.0562
SVM Medium Gaussian SVM	3.0696	3.1266	2.9078	3.0347
SVM Course Gaussian SVM	3.0782	3.1356	2.9075	3.0404
Ensemble Boosted Trees	2.8384	2.9018	2.7149	2.8184
Ensemble Bagged Trees	2.8585	2.9205	2.7753	2.8514
Gaussian Process Regression Squared Exponential GPR	2.8129	2.8832	2.6854	2.7938
Gaussian Process Regression Matern 5/2 GPR	2.8131	2.8825	2.6934	2.7963
Gaussian Process Regression Exponential GPR	2.8195	2.8852	2.6930	2.7992
Gaussian Process Regression Relational Quadratic GPR	2.8129	2.8830	2.6815	2.7925
Neural Networks	2.6748	2.8841	2.7060	2.7550

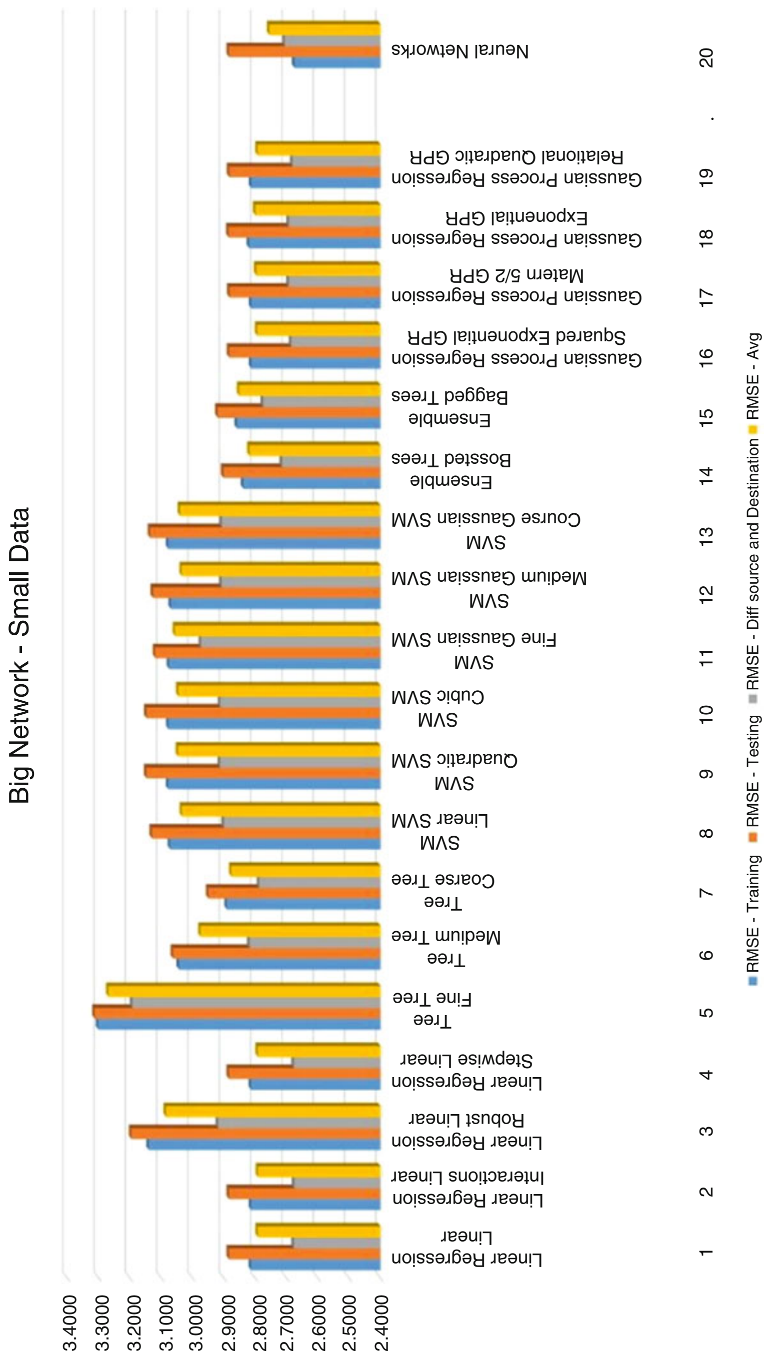


Fig. 9 Chart: Big Network-Small Data

6.7 Small Network-Medium Data (Table 3, Fig. 10)

Table 3 Results: Small Network-Medium Data

AI Method	RMSE - Training	RMSE - Testing	RMSE - Diff source and destination	RMSE - Avg
Linear Regression Linear	22.5840	22.4797	23.4082	22.8240
Linear Regression Interactions Linear	22.5880	22.4771	23.4389	22.8347
Linear Regression Robust Linear	22.6110	22.5203	23.5639	22.8984
Linear Regression Stepwise Linear	22.5860	22.4844	23.4170	22.8291
Tree Fine Tree	26.4740	26.2846	27.2149	26.6578
Tree Medium Tree	24.3540	24.1436	25.3030	24.6002
Tree Coarse Tree	23.2440	23.1268	24.1516	23.5075
SVM Linear SVM	22.6810	22.5823	23.6460	22.9698
SVM Quadratic SVM	22.6490	22.6122	23.7142	22.9918
SVM Cubic SVM	22.6720	22.6394	23.9190	23.0768
SVM Fine Gaussian SVM	23.5470	23.3106	25.6996	24.1857
SVM Medium Gaussian SVM	22.7820	22.7001	24.2154	23.2325
SVM Course Gaussian SVM	22.6680	22.6273	23.6635	22.9863
Ensemble Boosted Trees	22.9390	22.8155	23.2678	23.0074
Ensemble Bagged Trees	23.0220	22.8965	23.8890	23.2692
Gaussian Process Regression Squared Exponential GPR	22.5750	22.4935	23.3989	22.8225
Gaussian Process Regression Matern 5/2 GPR	22.5720	22.4890	23.4143	22.8251
Gaussian Process Regression Exponential GPR	22.6900	22.6309	23.5342	22.9517
Gaussian Process Regression Relational Quadratic GPR	22.5710	22.4866	23.4238	22.8271
Neural Networks	21.9629	22.5423	23.3847	22.6300

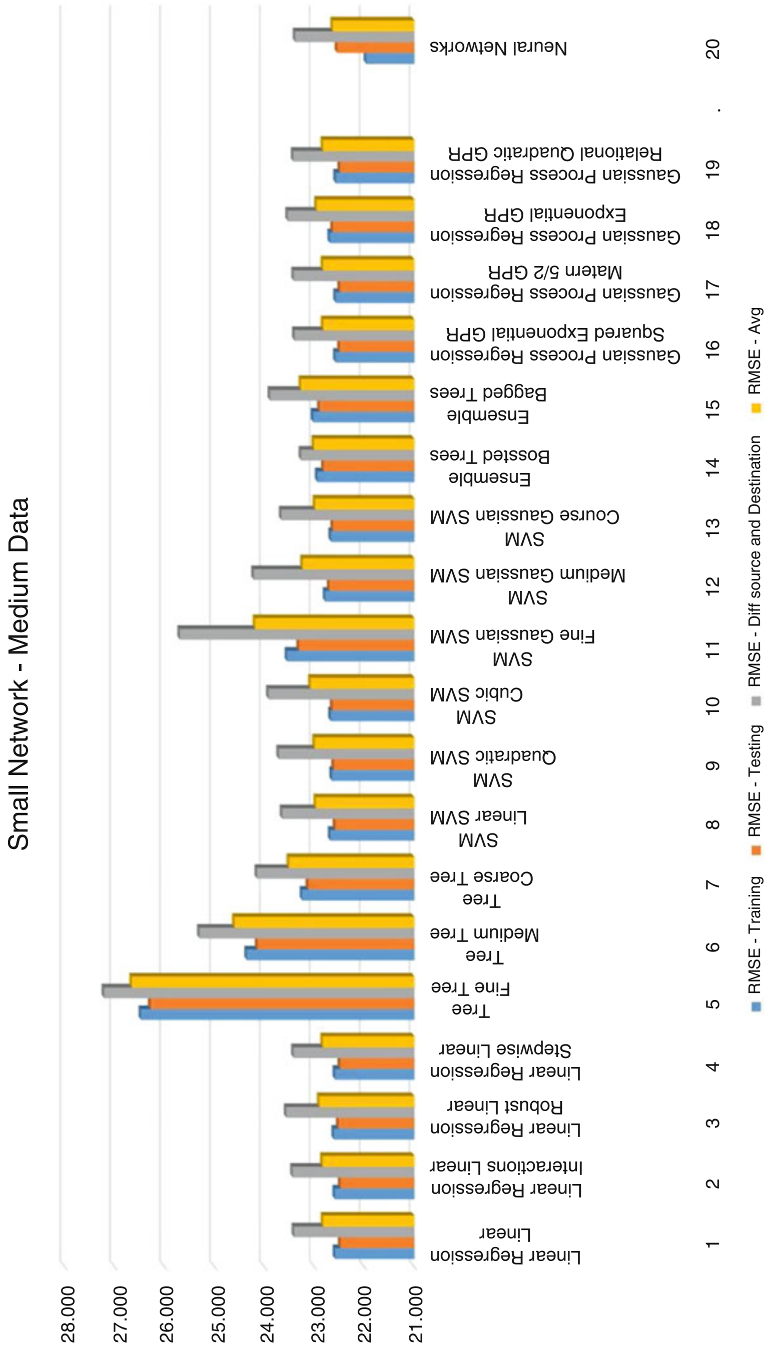


Fig. 10 Chart: Small Network-Medium Data

6.8 Big Network-Medium Data (Table 4, Fig. 11)

Table 4 Results: Big Network-Medium Data

AI Method	RMSE - Training	RMSE - Testing	RMSE - Diff source and destination	RMSE - Avg
Linear Regression Linear	22.9760	22.7538	22.4615	22.7304
Linear Regression Interactions Linear	22.9690	22.7495	22.5121	22.7435
Linear Regression Robust Linear	22.9890	22.7767	22.5231	22.7629
Linear Regression Stepwise Linear	22.9730	22.7493	22.4991	22.7405
Tree Fine Tree	26.8810	26.6509	25.6404	26.3908
Tree Medium Tree	24.8740	24.3331	24.2995	24.5022
Tree Coarse Tree	23.6300	23.3907	23.3235	23.4481
SVM Linear SVM	23.0220	22.8040	22.5772	22.8011
SVM Quadratic SVM	22.9900	22.7456	22.6958	22.8105
SVM Cubic SVM	22.9980	22.7459	22.5535	22.7658
SVM Fine Gaussian SVM	23.7930	23.5690	26.8151	24.7257
SVM Medium Gaussian SVM	23.0910	22.8335	22.8220	22.9155
SVM Course Gaussian SVM	22.9910	22.7478	22.6495	22.7961
Ensemble Boosted Trees	23.3330	23.0281	22.7399	23.0337
Ensemble Bagged Trees	23.3660	23.0153	22.9300	23.1038
Gaussian Process Regression Squared Exponential GPR	22.9340	22.6897	22.4941	22.7059
Gaussian Process Regression Matern 5/2 GPR	22.9340	22.6996	22.4560	22.6965
Gaussian Process Regression Exponential GPR	23.0400	22.7524	22.5758	22.7894
Gaussian Process Regression Relational Quadratic GPR	22.9350	22.6852	22.4859	22.7020
Neural Networks	22.2415	22.7153	22.4304	22.4624

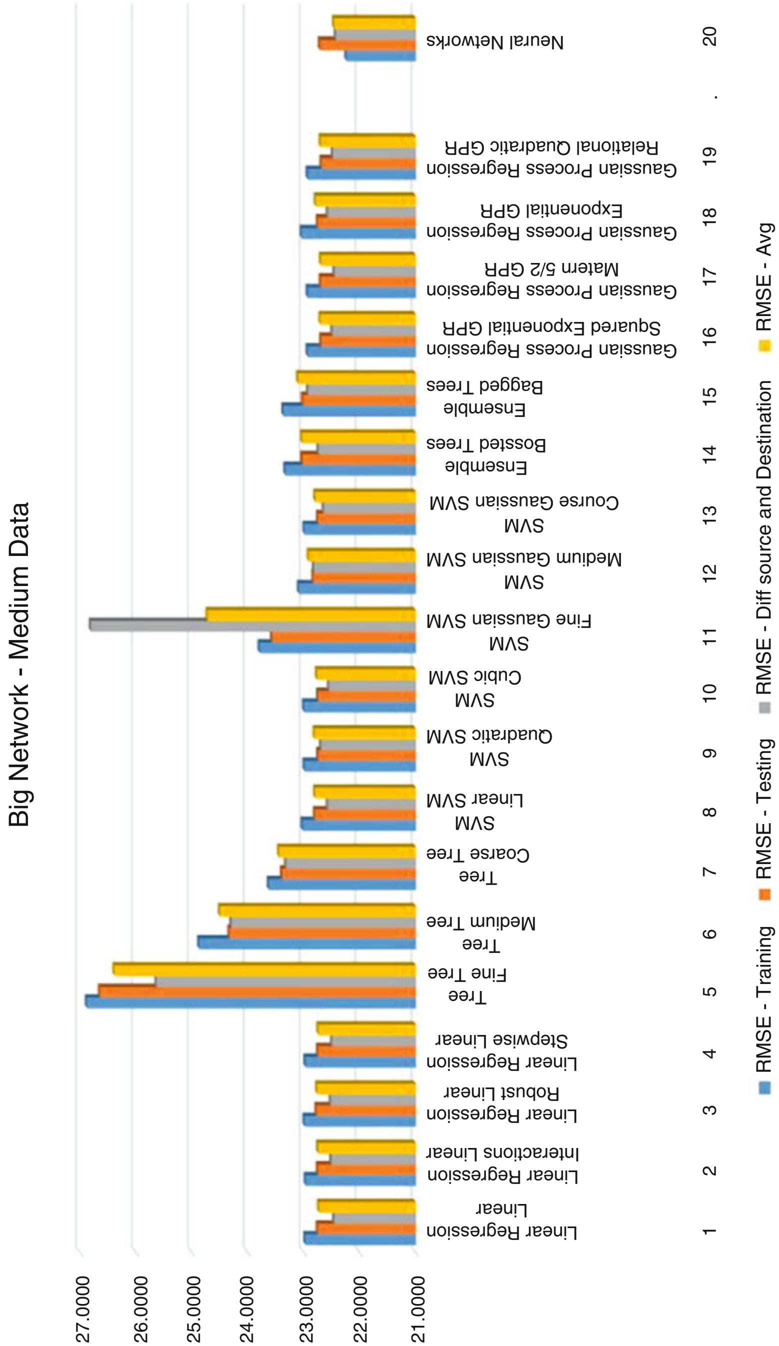


Fig. 11 Chart: Big Network-Medium Data

6.9 Small Network-Big Data (Table 5, Fig. 12)

Table 5 Results: Small Network-Big Data

AI Method	RMSE - Training	RMSE - Testing	RMSE - Diff source and destination	RMSE - Avg
Linear Regression Linear	41.8050	42.1014	45.5411	43.1492
Linear Regression Interactions Linear	41.6220	41.8495	44.8609	42.7775
Linear Regression Robust Linear	41.8420	42.2906	45.7418	43.2915
Linear Regression Stepwise Linear	41.6150	41.8557	44.8686	42.7798
Tree Fine Tree	47.8690	47.3285	52.9584	49.3853
Tree Medium Tree	44.2960	44.3042	48.2612	45.6205
Tree Coarse Tree	42.6340	42.7145	46.4516	43.9334
SVM Linear SVM	41.8430	42.3840	45.7923	43.3398
SVM Quadratic SVM	41.4380	41.5621	44.8069	42.6023
SVM Cubic SVM	41.4470	41.5568	44.7420	42.5819
SVM Fine Gaussian SVM	43.0860	42.9233	57.9788	47.9960
SVM Medium Gaussian SVM	41.5700	41.6204	45.1448	42.7784
SVM Course Gaussian SVM	41.4960	41.6450	44.9038	42.6816
Ensemble Boosted Trees	46.0760	43.7304	48.3027	46.0364
Ensemble Bagged Trees	43.1040	42.7238	46.2327	44.0202
Gaussian Process Regression Squared Exponential GPR	41.4060	41.5050	44.6703	42.5271
Gaussian Process Regression Matern 5/2 GPR	41.3970	41.4839	44.6552	42.5120
Gaussian Process Regression Exponential GPR	41.7610	41.9562	44.7915	42.8362
Gaussian Process Regression Relational Quadratic GPR	41.4040	41.5076	44.6695	42.5270
Neural Networks	40.6727	41.4826	44.7841	42.3131

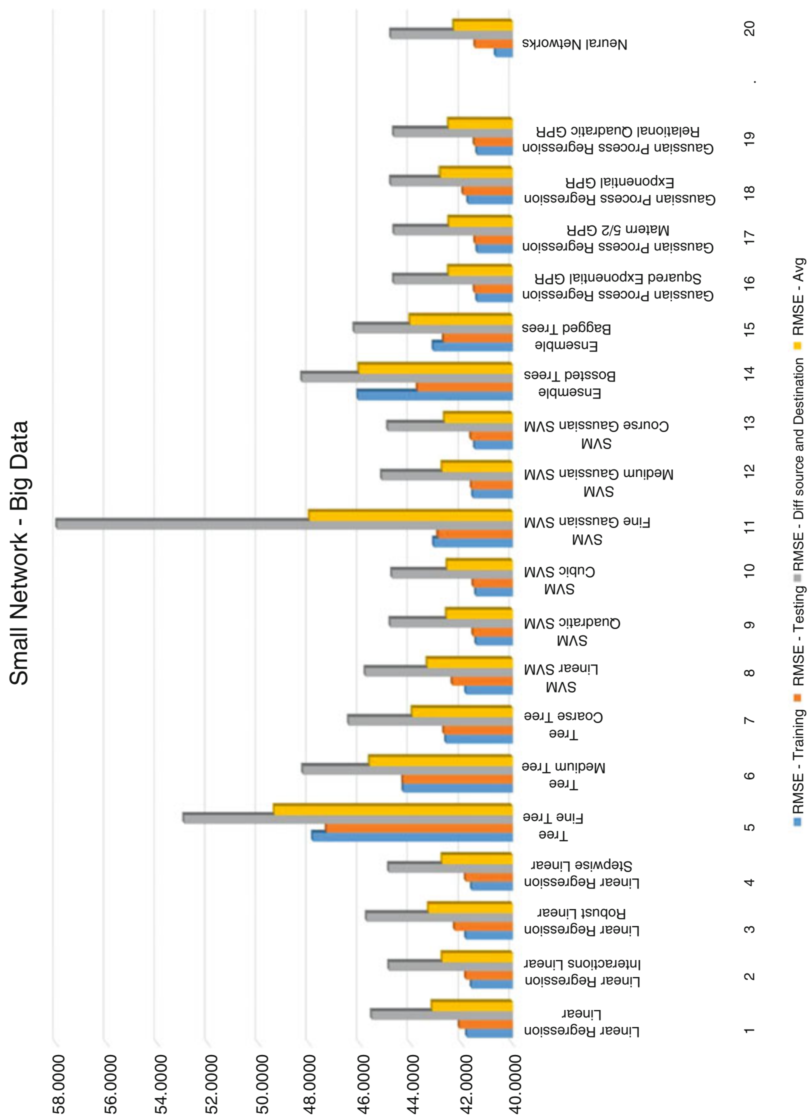


Fig. 12 Chart: Small Network-Big Data

6.10 Big Network-Big Data (Table 6, Fig. 13)

As the previous figures and tables show, neural networks could be a very good AI technique for this research's problem.

Table 6 Results: Big Network-Big Data

AI Method	RMSE - Training	RMSE - Testing	RMSE - Diff source and destination	RMSE - Avg
Linear Regression Linear	42.8090	41.9997	44.8020	43.2036
Linear Regression Interactions Linear	42.7180	41.8303	43.8355	42.7946
Linear Regression Robust Linear	42.8310	42.0408	44.9601	43.2773
Linear Regression Stepwise Linear	42.7270	41.8303	43.8355	42.7976
Tree Fine Tree	49.3660	48.9556	50.4519	49.5912
Tree Medium Tree	45.4490	44.3362	47.5091	45.7648
Tree Coarse Tree	43.6480	42.5271	46.8758	44.3503
SVM Linear SVM	42.8150	42.0793	44.9215	43.2719
SVM Quadratic SVM	42.1140	41.1469	43.2559	42.1723
SVM Cubic SVM	42.0910	41.0467	43.4829	42.2069
SVM Fine Gaussian SVM	46.2710	45.5015	78.1769	56.6498
SVM Medium Gaussian SVM	42.3390	41.4826	47.1952	43.6723
SVM Course Gaussian SVM	42.1410	41.1643	44.3449	42.5501
Ensemble Boosted Trees	46.9120	46.4243	49.2289	47.5217
Ensemble Bagged Trees	43.4020	42.5696	45.6464	43.8727
Gaussian Process Regression Squared Exponential GPR	42.0460	41.0353	43.2576	42.1130
Gaussian Process Regression Matern 5/2 GPR	42.0370	40.9918	43.3500	42.1263
Gaussian Process Regression Exponential GPR	42.4670	41.2438	43.7511	42.4873
Gaussian Process Regression Relational Quadratic GPR	42.0440	41.0060	43.2888	42.1129
Neural Networks	40.6268	41.2181	43.5303	41.7917

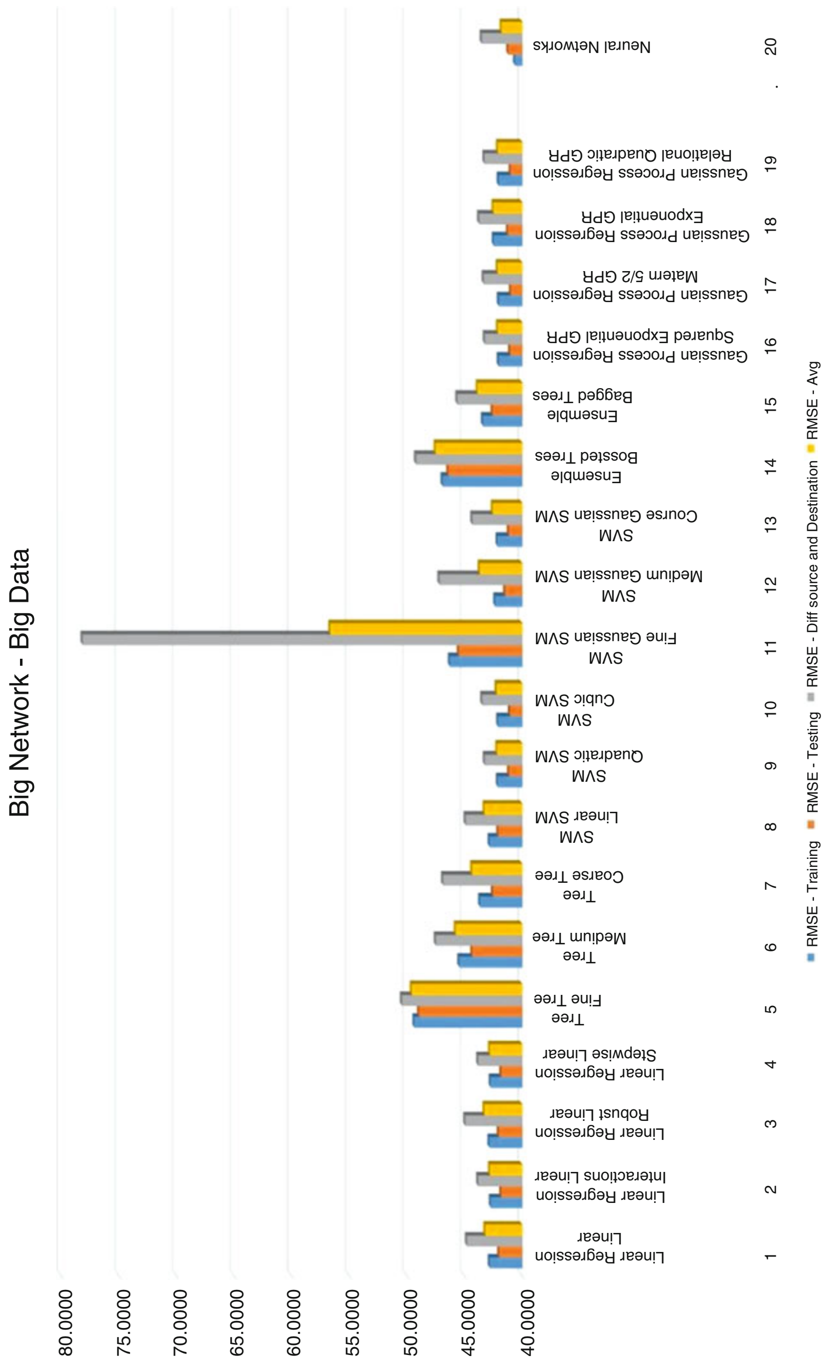


Fig. 13 Chart: Big Network-Big Data

Table 7 The Evaluation Matrix

	Small files	Medium files	Large files
Small network	12.66%	11.33%	5%
Big network	6.78%	6.79%	5.25%

6.11 The Evaluation Matrix

There are six cases that were tested and according to them, the following evaluation matrix could be filled (Table 7):

The filled values in the evaluation matrix represent the values of the related RMSE. For small and medium data files, the performance is not good in small networks. However, this performance is enhanced remarkably in the big network. For large data files, the performance is very good and almost the same for small and big networks. The packet loss ratio has a significant impact on the results. It is a random value for each link and when the files are small, and according to the randomness, the results RMSE could be very big (and sometimes very small). On the other hand, bigger files take longer time to be transferred and this way, the applied packet loss ratio is closer to the given value (e.g., 1%). Using a link for a long time (same file) causes a more stable performance regarding the packet loss ratio.

7 Summary

Backup services are significant cloud services to save data from being lost. However, these service still need improvements regarding network Quality of Service criteria. Software Defined Networking is a new networking paradigm which depends on the concept of separating data and control planes. This makes the network management operation more flexible. In addition, it utilizes the network resources at a higher level (resource sharing). Moreover, using SDN gives the application plane more permissions to control the network according to the applications' requirement. The proposed approach in this research targets the problem of offering a cloud backup service that guarantees the QoS for customers using SDN. The model was implemented and tested. The evaluation results showed a very good performance regarding the response time and the error ratio. The research could be enhanced in the future by adding many new features (e.g., apply energy-saving algorithm—add the hardware type to the extracted relation, etc.).

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Part V
Resilience Through Culture

Social Network Platforms and the Oshiwambo Practice of Eengano

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1 Introduction

"Eengano" is a competitive, oral game traditionally practiced by all the Owambo tribes, the dominant ethnic group in Namibia. In this game, groups of people, usually belonging to the same family, playfully engage in posing and answering riddle-like questions. Like intergenerational instruction in other African oral traditions (Finnegan, 2012), in former years Owambo communities participated in Eengano regularly, to convey cultural knowledge, beliefs, and values, as well as the nuances of language. However, changes in lifestyle, rural-to-urban migration, education away from home, and exposure to technology have eroded the frequency and practice, and younger generations are increasingly unfamiliar with Eengano. This not only threatens to preserve the knowledge of Eengano and the literary expressions contained in them, but also contributes to intergenerational cultural gaps and language loss. Preservation of Eengano contributes to resilient and sustainable communities, by promoting the indigenous or traditional knowledge, or the understanding of ideas, concepts, and practices of their ancestors (Rival, 2009). Indigenous knowledge disappears if a younger generation has not learned it before the older generation dies (Adom, Chukwuere, Addo, & Thulla, 2020).

In this chapter, we present the first insights into using social media and social network technologies to play Eengano digitally. We explored how people appropriate digital social networks to play Eengano, to understand ways that these platforms can promote both intergenerational social connections and knowledge

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transfer, and mutual learning and empowerment, and contribute to an archive of riddles for future generations.

We summarize the context of our research and describe how Eengano was trialed on the three most used social network platforms in Namibia. We then present some of our findings and gathered insights about interactions, and discuss the suitability of using these platforms for playing Eengano.

2 Eengano and the Owambo People of Namibia

The Owambo people constitute approximately 50% of Namibia's 2.6 million population and about 2% of Angola's population. Although there is no consensus on their exact origin, it is generally believed that they descend from people who had migrated to present-day northern Namibia from the upper regions of the Zambezi, now in Zambia, between the 15th and 17th centuries, nearly 200 years before the German colonization of Namibia (Grotpeter, 2012; Tonchi, Lindeke, & Grotpeter, 2012). Some researchers, however, trace their origin to East African countries such as Kenya and Uganda, but others believe that they may have originated in West African countries such as Nigeria or Senegal. Both East and West African cultures have active Eengano traditions (Kyoore, 2010; Finnegan, 2012), and hence, this practice can be considered indigenous to this group of people although they may not have been indigenous to the area in which they currently live.

Before Namibia's annexation by the British after World War I, Owambo tribes lived in northern Namibia without disturbance, tending goats and cattle and cultivating the staple food mahangu and other vegetables for survival. Their interactions with Europeans were mostly limited to generally amicable relationships with Finnish Christian missionary stations. However, after annexation in the early nineteenth century, and later the South African administration, Namibia was divided into homelands, and the area inhabited by the Owambo people was renamed Owamboland. The Owambo people resisted this invasion but were crushed by British and Portuguese militaries (Stokes, 2009), and as the twentieth century proceeded, they were isolated from the south, (which makes up two-thirds of the country), and then segregated by Apartheid rule. It was only 30 years ago after Namibia defeated the imposed regime and gained independence from South Africa, that the Owambo people regained their freedom.

2.1 Insights of Eengano

Although many cultural practices in Namibia have drastically changed or vanished as a result of colonialism and Christianity, Eengano is one of the many rich traditions that withstood the test of time and survived these forces. Shapi, Ashekele, and Cheikhyoussef (2012) reported that different Namibian communities devised ways to enable them to express and preserve some of their traditional knowledge and practices (Shapi et al., 2012). All Owambo dialects in Namibia, including AaNdonga, Ovakwanyama, Aakwambi, Aangandjera, Aambalantu, Ovaunda, Aakolonkadhi, and Aakwaluudhi, maintained their Eengano tradition during the colonial era. The practice formerly served to educate the young ones entertainingly, and was reserved for leisure-time sessions in the evenings. Members of a household gathered around the fire lit in the central courtyard (also known as "*Olupale*") of their homestead, for a session locally known as "*Oxungi.*" The Head of the House or other elders in the house would initiate the riddling session with the phrase "*Taambiimo,*" which literary translates to "Let me give you one from the many," to indicate the beginning of the Eengano session. Other participants in the session would then answer by saying "*Eta,*" which literary translates to "Bring it on," to indicate their readiness to participate in such a session. The original proposer of "*Taambiimo"* would then pose a riddle, a brief saying with an obscure or ambiguous meaning (Ikeji, 2007), and wait for the others to attempt to answer the riddle. Participants were given as many chances as they need to attempt the answer. This practice continued until the Riddler informs the participants that they have given the correct meaning, or the participants relinquish their right to continue by saying "*Nda lelwa,*" which literary translates to "I have given up trying." The Riddler could then give hints or the actual answer to the riddle. The one who had the correct answer, whether the Riddler or one of the participants, would at this point switch roles and become the Riddler. This riddling order is important as it directed the order of play.

Significant rural-to-urban migration has meant Owambo people increasingly work in urban centers such as Windhoek, Namibia's capital, some 600kms from their rural origins; although they typically maintain strong links with their family homes in villages. Nonetheless, migration and increasing access to televisions, computer games, and cellphones for entertainment in village homes, means Oxungi gatherings at Olupale to occur less regularly, and younger people have fewer opportunities to learn Eengano. Further, contemporary Namibian school education does not prioritize traditional Oshiwambo education, especially the use of riddles. Lilemba (2009) describes that only 51.1% of 45 Namibian teachers interviewed said that they used riddles during teaching activities with children aged 6–15 years; and, indeed, some teachers refuted the idea that riddles can cultivate knowledge. Potentially, this might reflect that younger generations of teachers, who were schooled far from their rural homes, did not experience the value of riddles and proverbs to learning (Lilemba, 2009). This has implications on sustaining Eengano, further contributing to the erosion of indigenous knowledge.

2.2 Eengano Practice in Other Countries

Studies in other African language groups suggest that riddling is important to foster participation in their societies (Blacking, 2007; Eastman, 1984) as well as to educate and engage young people in a competitive game (Blacking, 2007). Engaging in riddles also assists in developing thinking skills, understanding language, and acquiring social values (Awedoba, 2000; Justin, 2013). Besides, oral traditions can foster "narrative resilience" which enables individuals and communities to "articulate and assert their identity, affirm core values and attitudes needed to face challenges, and generate creative solutions to new predicaments" (Kirmayer, Dandeneau, Marshall, Phillips, & Williamson, 2011). To our knowledge, there is no written literature about Eengano in northern Namibia and, we propose, there is a need to devise mechanisms to deliberately encourage riddling practices and realize their many benefits in Namibia.

3 Social Media as a Cultural Archive in Namibia

Increasingly, indigenous groups around the world leverage social media to address issues of their physical displacement, in mutual support of their cultural identity, and to revitalize their languages (e.g. Bidwell & Hardy, 2009; Leong, Lawrence, & Wadley, 2019; Randoll, 2015). In Namibia, while Oxungi gatherings, in which intergenerational teaching through Eengano and other practices used to occur, are decreasing, people maintain communications with their families and peers using WhatsApp Groups. There are also numerous different Facebook groups which support sharing traditional cultural knowledge beyond family groups (Shihomeka & Amadhila, 2020), for instance, a Facebook group "Riddles, Maths and Politics inside Namibia – Tushungileni," created in 2014, has more than 147 followers although participation has been limited. It is the way people interact with each other via social media that is the "cultural archive," as defined by James (1999), for it is their interactions that store, express, and reproduce their indigenous knowledge. Communication mediated by social media, of course, differs from face-to-face communicating around a fire in many ways but all interactions embed histories of interactions that came before. They embed multiple references to ancestral meanings that people apply in new contexts. Indigenous knowledge is not, after all, some static, unchanging set; rather, it is embodied in acts.

Many authors (e.g. Thorpe, 2009) argue that technology can provide opportunities for real-life learning that would otherwise occur in physical environments. The integration of social media into the lives of younger people, who spend significant time interacting with them on their mobile phones (Peters, Winschiers-Theophilus, & Mennecke, 2015), suggests that they might offer a platform for interacting with elders around their cultural knowledge. Unlike some platforms, the interpersonal connectivity that social networks offer can potentially support interactions according to the logic, protocols, and conversational rules of traditional play. Several online platforms have been developed globally specifically for playing riddles, but do not include the rules that would happen in a face-to-face play. For instance, GoodRiddlesNow.com is a large database of logic puzzles that allows participants to play riddles, save their current status, and retrieve it later and skip riddles and/or view answers they cannot solve. However, in contrast, the Eengano tradition involves turn-taking patterns between people and solving the current riddle before proceeding to the next.

4 Translating Eengano into Online Play

While social media offers significant potential to slow the loss of cultural knowledge, affordances of the medium inherently interact with the transfer of information and the representational form. Translating information from spoken to written forms can, for instance, loose knowledge that is embedded in the intangible aspects, such as the way something is said and to whom it is said (Finnegan, 2012). Yet a range of media are now used in social networking including text, audio notes, photos, video, and location pins, and they can support different interactional styles. Each social networking platform has different features that could support the playing of riddles better than the others. For instance, older generations of knowledgeable Oshiwambo speaking people tend to have the least access to smartphones and the internet required for social media. This could partly be attributed to their places of residence and inability to pay for data, and least conversant with technology and interactive play. Further, most interactions between people using social media are dominated by written text, partly due to the high cost of data to use video and voice. The textual form, while valuable in interactions, can limit the richness of oral communication (Finnegan, 2012), which may be part of the captivation of Eengano. When people engage in Eengano in Oxungi gatherings at the Olupale, the engagement does not only involve the use of their voices but the entire body, as in other African oral forms (Finnegan, 2012), to richly express, for instance, emotions.

Our study considers the role of the medium in the game. Our primary aim was not to obtain a comprehensive dictionary of riddles, but rather to explore ways to revive the fading practice of playing riddles. According to Tyson (2015), the three most commonly used social networking sites in Namibia are Facebook, WhatsApp, and Instagram. Thus, we sought to explore which of these might be most suited to digital Eengano, motivate a desire to play Eengano, and provide a platform to accumulate riddles for an archive.

5 Methodology

A total of 26 Oshiwambo speaking people participated in our trials of Eengano on WhatsApp, Facebook, and Instagram between June and September 2017. This included 11 men, aged between 19 and 35 years, and 15 women, aged between 20 and 45 years. We first outline the basic play and how this was customized for the different platforms, and then we summarize the way we gathered data.

5.1 Play and Verification for the Different Platforms

We sought to simulate, as much as possible, participation and group dynamics in a real Oxungi, which is typically limited to one household of fewer than 15 people. Thus, we recruited three participants, designated as the "Heads" of the households who then invited other participants. One was Head is male and two are female, and all are acquainted with the first author, who is doing this research as part of his MSc studies. The only criteria used to select the group Heads was that they should be well versed in Eengano, and they should have basic familiarity with, and access to, the three social network platforms used in the trial. As such, no comprehensive sampling criteria were necessary to identify the Heads of the households. The Heads acted as the administrators on each respective social network platform and had the responsibility of adding other members to their households. We asked each Head to invite between three and ten people to their "*Olupale,*" by distributing a letter that explained the purpose of our study. Each Head had the freedom to choose who they wanted as part of the household. We offered no compensation and participation was completely voluntary. As further explained in our results, approximately 12% of the people they recruited were family relations. No additional information on the expectations of the play or interactions was given to them, as it also contributed to the findings of the study. Once Heads had identified and recruited the participants, we taught them, telephonically, to add members to their respective social media groups. The process to create a group and add members differed for the different platforms. The first author also ensured that the participant's questions and/or concerns regarding the research or their participation were handled at all times.

Each of the three households was expected to play their riddles on each of the three different applications. We began the trials using WhatsApp, followed by Facebook, and lastly Instagram. Households had a month to play on each platform, and all groups practiced on the same platform (e.g., WhatsApp) before moving on to the next. We requested that the actual riddles be posed in Oshiwambo, but otherwise, participants were free to communicate in any language and to use whichever features they deemed appropriate for Eengano. We also did not restrict them in terms of allowable platform features they could use during the play, o use of preferred language when asking questions or providing clarification.

Just like the playing of Eengano in a physical setting, we asked Heads to commence the Eengano session by posing the first riddle on the social network platform. All the members in the Olupale network could see the riddle, and any member who could post an answer to the riddle was allowed to do so. The first member to give the correct answer could then pose the next riddle. Points were awarded to the Olupale members for posing the "accepted or verified" riddles as well as for the first correct answers to create a competitive dialog. The questions and answers were verified by the group Head before moving on to the next riddle. We did not impose any restrictions on timing, the order, or urgency of expected responses to the riddles, as we sought to explore whether participants would assume norms that apply in physical settings, such as night-time riddling, to the social media setting.

5.2 Data Gathering and Analysis

The first and second authors are Oshiwambo speaking and were added as members of the households for observation purposes. They observed how participants used each of the three platforms (numbered Olupale 1, Olupale 2, and Olupale 3 in this chapter) to play Eengano, and recorded notes during the play of Eengano. At the end of each trial (i.e., after a month of play on each platform), the riddles and answers posed on each household were downloaded off the platforms in different formats (e.g., text messages, voice notes, video notes, etc.) for analysis. We sought to find out if the participants were able to successfully play the game on each of the platforms used and to determine if they were adhering to the rules of the game using this new mode of play.

After all trials were concluded, we undertook a preliminary analysis of how many Eenganos were posted, the affordances of the platform for play, and how the participants overcame any limitations to enable successful play. This analysis guided semi-structured individual interviews with all participants. We conducted and recorded telephonic interviews to gain insight into the features of each platform that most suited playing and sharing Eengano and participant's perceptions of digital Eengano. We then transcribed the interviews and our observational notes of the participation in Eengano and interactions during the trial. We removed redundancies, repetitions, and irrelevant information and then coded the transcripts and records to generate categories and insights that emerged from the data (Mayring, 2000), avoiding the use of preconceived categories (Kondracki, Wellman, & Amundson, 2002). Firstly, we coded the keywords to determine the order of the play (taambimo, eta) then we categorized features from each platform in terms of emoji, voice notes, video conferencing. We downloaded and manually counted the conversations from the platforms to determine which platform was used most. Finally, we abstracted the main findings to develop a taxonomy that interprets the playing of Eengano in a virtual environment.

6 Findings

Out of 26 participants, 19 indicated that they were already acquainted with Eengano and the other 7 had an idea about the practice and knew just a few riddles. Two of the Heads speak Oshindonga and one Oshikwambi and since they often chose family members for their "*Olupale,*" other participants were typically from the same tribe. However, we observed that the Eengano posted in the different groups that participated in this research mainly used the Ndonga dialect (Oshindonga). There are riddles in all the different tribes of the Owambo tribes, however only Oshindonga and Oshikwanyama languages that are taught in Namibian schools and Oshikwambi do not yet have an orthography. Thus all other Oshiwambo tribes, other than Oshikwanyama speakers, would use Oshindonga to write in Oshiwambo.

Participants did not always stick to the rules when playing the game. For example, it is normally the Head of the Household that starts a riddling session by posing the phrase "*Taambimo.*" In one group, however, the Head delegated this role to a participant and only posted the riddle after the selected participant did not respond to this request. We also noted the delay introduced in responding to riddles on a platform that affords asynchronous communication. In a real (Oxungi) setting, the riddler would not wait for long for participants in the Olupale to respond. However, riddlers using social media sometimes waited for days before anyone responded to their riddle. In some cases, riddlers gave the solution to the riddle, without any participant indicating "*Ndalelwa*" to signal they had given up trying. Further participants did not strictly enforce the order of play, and posed new riddles, while there were active riddles awaiting answers.

The number of riddles posted differed greatly per group and platform. Olupale 1 posted the highest number of riddles using the WhatsApp platform, with a total of 34 verified riddles, although it had 134 unique discussion points on this platform. Olupale 2 and Olupale 3 had 23 and 15 verified riddles, respectively. We observed that very little or no play took place on the Instagram platform for all three groups. This was due to several reasons. Firstly, users, especially the Heads of the House, may not have been comfortable with Instagram. Secondly, the order of platforms meant that by the time we trialed the game with Instagram, the initial excitement in playing had dwindled and participants had posed all their known riddles and did not have any new riddles to contribute (Table 1).

The use of language may have also hindered participation. During the interview sessions, some participants revealed that they found language to be a challenge. We also observed, for example, on several occasions participants indicated their willingness to pose a riddle by saying "Taambamo," which is singular rather than plural, and there were many spelling and grammar mistakes and incoherent sentences that used a mixture of Oshiwambo and English.

Eengano sessions in olupale are typically reserved for nighttime when people gather together. In our trials, however, participants posed their riddles any time of the day, and their responses were not always synchronous as is expected in olupale. The correctness of the solution to the riddle was always verified by the riddler or the Head of the household with assistance from a nominated verifier before the next

Table 1 Number of verified Eengano that were successfully riddled in this trial

Olupale	WhatsApp	Facebook Messenger	Instagram
1	34	14	2
2	23	2	0
3	15	4	0

riddle could be posed. We observed, however, that in an online play, a participant could post a riddle and divert the attention of other participants to this new riddle without having solved the previous riddle.

The different oral and visual cues that people use to make the play fun and enjoyable in a face-to-face session are not easily transferrable to the digital environment. Yet, participants found varied ways to enhance their communication. Using WhatsApp, for example, participants used mostly texts, including emojis, which they combined with voice notes. For Facebook Messenger, they also used emoji, voice notes, video calls, and texts. Participation in Instagram was very low, and in the instances where they participated, it was limited to text.

7 Discussion

As mentioned, traditionally, in the face-to-face setup, the order in which the play flows is important and denoted by the keywords "*taambimo,*" "*eta,"* and "*nda lelwa*" in that order. Participants did not always follow this order. They could pose a riddle without preparing other members with the keyword "*taambimo*"; any member can arbitrarily (attempt to) answer; and, if participants did not always indicate that they did not know the answer or have given up trying. This disrupted the order of the riddling process.

Traditionally people are collocated when they played Eengano and exchange riddles and answers synchronously. All three social networks, however, afford spatially distributed people to participate in a single session of Olupale in simulating the playing of Eengano but also provided affordances that are not typically acceptable in face-to-face sessions. The asynchronicity of social media changes the dynamics of the game, sometimes enabling riddles to carry over or span more than one active riddle. Further, not all participants caught up with posts when they were absent from active sessions, and thus sometimes participants who had been inactive in previous sessions posted a riddle that had already been posed. Some inactive participants would suddenly post a new riddle, without accounting for an unsolved riddle that other participants were still seeking the meaning.

Participants demonstrated great excitement to get involved in the trial when we introduced the game on WhatsApp but their enthusiasm and participation significantly declined a month later when we introduced Facebook. Both our observations and interviews suggested that they no longer felt eager to participate. Heads had to constantly remind participants to remain active and play did not occur as naturally as before. All participants were active on the WhatsApp platform. This could, however, be because participants had more riddles to pose initially. By the time we introduced Instagram, there was almost no participation. This order effect makes it difficult to evaluate which platform is most suited. However, participants' perceptions of the platforms might have also affected their participation. For instance, one participant expressed concerns regarding the visibility of his posts to the public on Facebook and felt that WhatsApp is more reliable and secure.

8 Conclusion

Reviving the practice of playing traditional riddles has the potential to contribute to the preservation of indigenous knowledge, which is essential not only for recreational and educational purposes but could also contribute to the resilience of communities. While it is not easy to maintain the interest of young people in an age-old traditional game, such as Eengano, this research has demonstrated that modern ICTs can potentially be harnessed to entice diverse groups of people to participate in this tradition. It is thus imperative to identify platforms that can make riddling as interactive and interesting as possible, if it is to be successfully re-introduced to Namibian youth, who are used to modern-day riddles, mostly in English.

Our trials suggest that social media networks provide unique affordances such as permanency and accessibility of content that extend traditional oral practices. Each of the social networking platforms trialed has affordances that could support playing of Eengano. In our trials, WhatsApp was the most used platform for online riddling followed by Facebook, and Instagram was hardly used. However, we could not conclude with certainty that users preferred WhatsApp over the other two platforms, as other factors could have affected our findings. At the same time, the asynchrony afforded by all three social media platforms disrupted the order of play and permitted users to participate in the play regardless of the time of day or to start a new discussion irrespective of the riddle trail. This sharply contrasts with face-to-face riddling, which requires participants' full attention, and does not provide opportunities to be engaged in any other activity at the same time. We also found a contrast in the timing limitations, where Eenganos are only played in the evening (usually after supper) in face-to-face sessions, but continuous, unlimited play was observed in online sessions. Successful simulation of online riddles requires synchronous active participation, but this is difficult to coordinate in the trialed platforms. Asynchrony inherent in the trialed social media platforms also meant that participants could not keep up with riddles posted while they were engaged in other activities.

Exploring the appropriation of technologies, such as social media, in traditional practices offers important insights for considering how to include Oshiwambo symbols and identities in technology design activities more generally. As discussed elsewhere, relationships between language and technology production can exclude some Oshiwambo people, such as rural dwellers, which inhibits fully involving social, intellectual, and emotional capitals in innovation (Aludhilu & Bidwell, 2018). Thus, our explorations suggest that the use of social media in the rich game of Eengano cannot only preserve indigenous knowledge within Oshiwambo social groups, but also contributes this indigenous knowledge to Namibian innovation, which eventually, can also contribute to a more resilient society in general.

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An Investigation of E-Government Web Accessibility for Visually Impaired Persons in Namibia

Teopolina Uutsi and Tulimevava K. Mufeti

1 Introduction

Governments all over the world are striving to provide their citizens and businesses with value-added electronic services (Alshehri & Drew, 2010; Mtebe & Kondoro, 2017; Torres, Pina, & Acerete, 2006). Electronic government (also known as e-government) is believed to have the potential to significantly improve government-to-citizen interaction, by providing equal access to government services for all its citizens (Fang, 2002). Although many governments in Africa have also introduced various e-government initiatives for their citizens, most have not been successful in developing accessible websites (Mtebe & Kondoro, 2017; Nakatumba-Nabende, Kanagwa, Kivunike, & Tuape, 2019; Verkijika & De Wet, 2017). In the Namibian context, we are not aware of any research attempts to determine the accessibility of e-government for persons living with disabilities. This research study, therefore, aims to investigate e-government use by and accessibility for visually disabled/impaired people in Namibia. The study contributes to a larger body of work investigating e-government accessibility for persons living with disabilities in developing countries, with a focus on Africa.

The benefits of e-government are well documented in the literature. According to Twizeyimana and Andersson (2019), e-government promotes improvements in public services, administrative efficiency, open government capabilities, ethical behavior & professionalism, social value & wellbeing, and trust & confidence in the government. Davids, Kabanda, and Agangiba (2017) further reported the benefit to government of reduced operational costs. Strategic use of e-government is also believed to lead to greater accountability, responsiveness, and transparency on the

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part of governments, while enabling citizens' participation in decision making (Ahn & Bretschneider, 2011). Other reported benefits include reduced corruption, greater transparency, increased convenience (Torres et al., 2006), direct citizen participation (Ahn & Bretschneider, 2011), and expanded the ability to reach larger numbers of citizens for improved service delivery (Alshehri & Drew, 2010). ICT helps make the interaction between government and citizens fast and efficient (Torres et al., 2006). When accepted and correctly utilized, it also raises the level of citizen satisfaction.

Most governments today have a national e-governance agenda and implemented e-government portals to heighten the visibility of public services. In Namibia, for example, the government launched an e-Government Strategic Action Plan for the Public Service of Namibia for 2014–2018. The plan aimed to provide a roadmap for developing a "one-stop-shop" for online government services for the benefit of all Namibian citizens (Office of the Prime Minister, 2014). In most countries, however, there are only limited studies looking at accessibility, usability, and the adoption and utilization of those portals (Verkijika & De Wet, 2017). This is despite the fact that the literature reports usability and web access issues to be a major deterrent to e-government use (Craven & Nietzio, 2007; Verkijika & De Wet, 2018), and a major contributor to users' perceptions of government websites. The literature on the accessibility of e-government websites is therefore scant. In order for e-government to have an impact on sustainable development, the United Nations (UN) recommends that governments should ensure that no one is left behind in the implementation of their national e-governance agenda (United Nations, 2018).

People Living with Disabilities (PWD), particularly the visually impaired/disabled, are often inadvertently excluded from e-government initiatives and may have difficulties/limitations with accessing e-government facilities. Although not intentional, the social exclusion of citizens from e-government consequently discriminates against PWD, which ultimately also infringes on their constitutional rights in the Namibian context. It is a pity that in most cases, it is the threat of legal penalties for infringement, rather than a genuine desire for inclusivity and expected benefits, that prompt improved web accessibility (Yates, 2005). To ensure the inclusive Society for All envisaged in Namibia's National Disability Council Act of 2004,[1] and that no one is left behind (United Nations, 2018), it is important to ensure web accessibility for all in e-government services.

Users who are visually impaired require different forms of assistive technologies such as narrators, speech synthesizers, and/or magnifiers to access web applications, and consequently, e-government applications (Davids et al., 2017). However, compatible applications are required to enable assistive technologies to be used. Several web accessibility guidelines created by international standards groups such as the World Wide Web Consortium (W3C) are available to guide web developers and ensure that their applications are compatible. In most cases, however, web developers do not design their applications with PWD in mind. In other cases, lack of advocacy and awareness of PWD concerns has hindered inclusion in developing

[1] https://www.lac.org.na/laws/2004/3360.pdf

countries (Davids et al., 2017). The literature, therefore, emphasizes the need to raise awareness at all levels of society.

People living with disabilities must be included and served by e-government platforms in the same way as everyone else in Namibia. To the best of our knowledge, only one study web accessibility of a single ministerial website has been done in Namibia (Fröhlich & Peters, 2017). That study focused on general web accessibility rather than on the needs of PWD. This chapter, therefore, highlights accessibility and usability issues for PWD within the e-government sector in Namibia. It first reviews the literature on previous studies of web accessibility and describes how they were conducted. It then presents the methodology of a study conducted to determine the accessibility of government websites in Namibia, followed by the findings, which indicate that Namibian websites do not conform to W3C accessibility guidelines. The chapter highlights accessibility concerns that need to be addressed to ensure that the visually impaired/disabled population in Namibia is included and can benefit from the electronic services of e-government.

2 Literature Review

2.1 Definitions

Visual impairment and visual disability are used in this study to refer to users who have a decreased/partial ability or complete inability to see or read text displayed on a technological device or screen. These users would typically require additional assistive technologies such as screen reading software, screen magnification, alternative mouse and keyboard devices, alternative pointing devices, refreshable braille displays, and voice input to enable access (Davids et al., 2017). While accessibility generally covers a wide range and combinations of disability, our focus in the present study is solely on the needs of people with visual impairment or disabilities.

Web accessibility is described as the "inclusive practice of ensuring there are no barriers that prevent interaction with, or access to, websites on the World Wide Web by people with physical disabilities".[2] Although web accessibility is usually considered in tandem with web usability, and existing research suggests a correlation between the two practices (Verkijika & De Wet, 2018), our interest in this study relates only to accessibility.

E-government is defined here simply as the use of ICT to provide government services. Torres et al. (2006) argue that e-government is not necessarily the same as e-governance, and the two terms ought not to be confused. They argued that both the public (government) and private sectors have governance components that could be enhanced through the utilization of ICT, and this is what e-governance refers to. E-government, on the other hand, also incorporates governance processes and

[2] https://en.wikipedia.org/wiki/Web_accessibility

concepts but is only undertaken by the public sector (government). This distinction is important in our context, and the definition we have adopted of e-government in this paper is the use of ICTs to enable the delivery of public services to all citizens.

In this study, our focus is thus on understanding the accessibility challenges that users with visual impairment/disability face when accessing e-government services in Namibia.

2.2 Studies on Web Accessibility

Over the past few years, several studies assessing the accessibility of government or ministerial websites have been reported in the literature (Davids et al., 2017; Fröhlich & Peters, 2017; Mtebe & Kondoro, 2017; Nakatumba-Nabende et al., 2019). Although undertaken in different countries and by various researchers, most studies concluded that the sites evaluated do not conform to accessibility standards (Verkijika & De Wet, 2018). The evaluation usually on the basis of conformance with the Web Content Accessibility Guidelines (WCAG). However, data collection uses different methodologies and takes into account different aspects of accessibility including sociological (Fröhlich & Peters, 2017), legal, ethical (Kamoun & Almourad, 2013), technical, and cultural issues, and in some cases this leads to inconsistent results (Kamoun & Almourad, 2013).

Davids et al. (2017) conducted a systematic literature review aimed at determining the accessibility of e-government websites on the African continent. Using Google Scholar and nine (9) reputable journals on information technology and disability, they identified seven (7) articles that were relevant to their study. They noted that the use of automated tools and the lack of involvement of PWDs meant that the studies were mainly quantitative. They recommended that more qualitative studies with the involvement of PWDs, and interpretive studies aimed at understanding the correlation between technological, social, and political factors, be carried out to identify barriers and provide a more holistic view of accessibility.

Mtebe and Kondoro (2017) assessed the conformance of Tanzanian government websites with WCAG and US Federal usability guidelines. Sampling 18 ministerial and 4 departmental websites, they used the automated website testing tool, SortSite, to scan a maximum of 100 pages per website and determine the accessibility priority levels of each website. They found that 82% of the sampled sites had accessibility issues. The most commonly found issues included: the unexpected opening of new browsing windows, links with no equivalent text contents, and color contrasts between text and background colors. Their conclusion emphasizes the importance of ensuring that the government's policies and regulations on accessibility and usability meet its obligations to its citizens.

Kamoun and Almourad (2013) conducted a study to assess and rank e-government websites in Dubai. Their main aim was not only to assess accessibility but also to use the accessibility proxy score and determine its correlation with website ranking. Using a free automated assessment testing tool, WaaT, they evaluated 21 governmental websites for accessibility and compared each website's accessibility to its overall ranking. In contrast to earlier claims, their findings indicated a weak positive correlation between website quality and accessibility. They, therefore, recommended that quality rankings must take accessibility issues into consideration since e-government's main role is to ensure universal accessibility for all citizens, which cannot be achieved without accessibility for PWD.

Venter and Lotriet (2005) examined the web accessibility of South African websites for visually impaired/disabled users and found that web content developers were not using accessibility guidelines and many of them were not even aware of the existence of such guidelines.

2.3 The Web Content Accessibility Guidelines

Several factors are used to determine the accessibility of websites. Yates (2005), for example, argues that web designers should consider users who: cannot read or comprehend text on a site, have a slow connection, use smaller devices with smaller displays, cannot comprehend the language on the site, and those with old browsers. The Web Content Accessibility Guidelines (WAGC) provide internationally recognized and adopted guidance. Their purpose is to provide recommendations for web designers to help them ensure their web content is accessible or capable of being represented in formats that are accessible to people with different sensory, physical, and cognitive abilities. The WCAG are based on the following four principles[3]:

- Perceivable: the ability of a person with a disability to identify the contents of the web site through a screen reader, screen magnifier, or other assistive technology.
- Operable: the ability of a person with a disability to navigate user interface components, for example, keyboard shortcuts for someone unable to use a mouse.
- Understandable: people with different cognitive abilities must be able to operate the user interface and understand information on the web site.
- Robust: the technology must be compatible with assistive technology and should be able to accommodate future upgrades of assistive technology.

Each of the principles has associated guidelines. The guidelines for each principle are summarized in the following Table 1:

In addition to the WCAG, the World Wide Web Consortium (W3C) also has a Web Accessibility Initiative (WAI), through which they have developed the Accessible Rich Internet Applications (ARIA) Suite. The WAI-ARIA addresses accessibility challenges presented by advanced web applications such as those with dynamic content or advanced user interface controls. W3C defines three levels of

[3] https://www.w3.org/TR/2008/REC-WCAG20-20081211/#guidelines

Table 1 Web Content Accessibility Principles and Guidelines

Principle	Guidelines
Perceivable	• Provide text alternatives for any non-text content • Provide alternatives for multimedia • Adaptable—Allow for content to be presented in different ways without losing information or structure. • Distinguishable: Enable users to see and hear content
Operable	• Keyboard accessible: Make all functionality available from a keyboard. • Enough time: Give users enough time to read and use content. • Seizures: Do not design content in a way that is known to cause seizures. • Navigable: Provide ways to help users navigate and find content and determine where it is.
Understandable	• Make text readable and understandable. • Make web pages appear and operate in predictable ways. • Help users avoid and correct mistakes.
Robust	• Maximize compatibility with current and future user tools.

web accessibility standards: A, AA, and AAA

- Level A—the most basic web accessibility features. Most websites conforming to these guidelines are accessible but not convenient for PWD.
- Level AA—deals with the biggest, most common barriers for disabled users. It is the preferable level as it balances ease of use and coding.
- Level AAA—the highest (and most sophisticated) level of web accessibility.

Conformance with Level A of web accessibility indicates that the web page has the bare minimum features to benefit all users but does not meet the required accessibility standards. In addition to the minimum (basic) features, the AA also defines specific criteria for ensuring that interactive elements such as form inputs can be accessed via the keyboard. Furthermore, web designers need to ensure that their code is designed to enable assistive technologies. These technologies should be able to determine the order and flow of web pages by differentiating between content elements, actionable items, and media.

2.4 Web Accessibility Testing Methods

Studies cited in the literature used different tools and measures for determining the accessibility of government websites. Most studies cited in this chapter focus on the ability of add-on technologies to enable access to the web for people with visual impairments, for example, through the use of assistive technologies. Other studies, however, were based on theoretical frameworks such as the Technology Acceptance Model (Djamasbi et al., 2006) and Rawls Moral Theory (Kamoun & Almourad, 2013). This section briefly explains some of the common approaches in web accessibility evaluation.

The Technology Acceptance Model (TAM) is widely used in literature as a theoretical framework for determining the perceived usefulness and perceived ease of use of information technology. Djamasbi et al. (2006), however, argued that on its own, TAM does not cater to disabled technology users and investigated how it could be improved to cater for the needs of visually impaired users. Their study redesigned a careers website to make it more accessible and recruited eight visually impaired users to determine its usability before and after the redesign. In addition to perceived usefulness and perceived ease of use, they suggested a modified model for TAM, where information accessibility is also a determinant of adoption, especially for users with visual disability. Their later study on the acceptance/rejection of audio and music websites by visually impaired users also confirmed that adoption and usage of websites largely correlates with the reliability and accessibility of information on the site (Loiacono, Djamasbi, & Kiryazov, 2013). Web developers should, therefore, strive to improve the accessibility of websites, to cater to the increasing number of individuals with vision impairments resulting from extended life expectancy.

An approach to evaluation that is widely reported in the literature is the use of automated testing tools. Many automated testing tools are available; some are free, and others are available on a commercial basis. W3C keeps a list of available tools (World Wide Web Consortium, 2020), which include AChecker, Wave, Sort Site, and Total Validator. However, the W3C warns that although automatic tools are helpful in identifying potential accessibility issues, they can sometimes produce false and misleading results. This was the observation of a number of researchers, who also argued that automated tools are unable to detect all accessibility problems (Mankoff & Tran, 2005; Vigo, Brown, & Conway, 2013). In addition, automated tools generate lengthy reports, may require special expertise that is not readily available amongst web developers (Vigo et al., 2013).

Another type of evaluation strongly in evidence in the literature is user testing. Voykinska, Azenkot, Wu, and Leshed (2016) argue that it is important to involve actual users in accessibility studies. Their study involved more than 60 people with visual disability/impairment and identified several challenges that visually impaired and blind users face in accessing social networking sites. Their findings indicated that visually challenged users had issues with “pervasive visual elements, complicated page structure, and infinitely scrolling feeds that are incompatible with screen readers.” Sierra and Togores (2012) also argue that web accessibility can only be determined if evaluation is focused on user experience. They further contend that designing an application for sighted people and later adding additional features to enhance accessibility for low vision or blind people is not sufficient, suggesting that specific applications targeted at visually impaired users are more appropriate if the best user experience is to be achieved. While effective, however, involving actual users in the evaluation can be costly and does not guarantee that the results will be similar for all disabled users.

Reliance on a single method of evaluation is criticized in the literature (Vigo et al., 2013). Using a combination of automated, manual, and user experience techniques, Hassanzadeh and Navidi (2010) recruited three groups of users, each composed of five people, to evaluate 21 government websites in the Republic of Iran. Their results show that websites given the highest accessibility rankings by automatic testing tools were ranked lowest in manual and user experience evaluations. They conclude that the adoption of a single evaluation method does not "guarantee authentic" results, and recommend that it would be more effective to use a combination of all three methods.

In another study, Craven and Nietzio (2007) use a task-based approach involving 20 participants to simulate and test searching and browsing experience remotely using an online testing and evaluation form. Their participants are drawn from the following user groups: blind, visually/hearing/physically impaired, dyslexic, and a control group with no disability. Their user-testing tool is designed on the premise that automated tools do not capture all accessibility features and barriers on a web page. Their findings suggest that the task-based accessibility approach provides more comparable results than random exploration. Hence, they recommend that the task-based approach be combined with automated testing and the results aggregated to improve accuracy.

As shown in this section, there is no consensus on which method of testing produces the best results. It is clear, however, that the approach should include a variety of methods, preferably with the participation of potential website users. The use of multiple testing methods could be costly, however, and may only be appropriate when testing a single website. Since this chapter evaluates more than one e-government website, the automated testing tools approach was the preferred option, despite the shortcomings noted. Automated testing tools were also more appropriate, as it is not realistic to involve real users in a setting where multiple websites will be evaluated.

3 Research Methodology

This main objective of this study is to determine the accessibility level of e-government websites in Namibia. All official ministerial websites found on the government portal (http://www.gov.na/web) were considered in this study. The portal has links to 19 ministerial websites (listed in Table 2), which were all analyzed and investigated from the following viewpoints: validity of the HTML and Cascading Style Sheet (CSS) code, overall web accessibility measurement score, color contrasts, and the use of Accessible Rich Internet Applications (ARIA). To determine the validity of HTML and CSS, two automatic evaluation tools, provided free of charge through the W3C Markup Validation Service, were used. The tool enables validation of the syntax of web documents, by either pasting the code directly onto their web page, or by providing a URL for the page to be tested. In addition, two automated testing tools were also used to determine the overall web accessibility measure, color contrasts, and the use of ARIA: Chrome Lighthouse and the WAVE Chrome extension.

Table 2 List of ministerial websites evaluated

Description	URL
Ministry of Justice	http://www.moj.gov.na/
Ministry of Agriculture, Water and Land Reform	http://www.mawf.gov.na/
Ministry of Defense and Veteran Affairs	http://www.mod.gov.na/
Ministry of Education, Arts and Culture	http://www.moe.gov.na/
Ministry of Environment, Forestry and Tourism	http://www.met.gov.na/
Ministry of Finance	http://mof.gov.na/
Ministry of Fisheries and Marine Resources	http://www.mfmr.gov.na/
Ministry of Health and Social Services	http://www.mhss.gov.na/
Ministry of Home Affairs, Immigration, Safety and Security	http://www.mha.gov.na/
Ministry of Higher Education, Training and Innovation	http://www.mheti.gov.na/
Ministry of Industrialization and Trade	http://www.mti.gov.na/
Ministry of International Relations and Cooperation	http://www.mirco.gov.na/
Ministry of Information Communication Technology	http://www.mict.gov.na/
Ministry of Labor	https://mol.gov.na/
Ministry of Mines and Energy	http://www.mme.gov.na/
Ministry of Public Enterprises	https://mpe.gov.na/
Ministry of Sport, Youth and National Service	http://www.msyns.gov.na/
Ministry of Urban and Rural Development	http://www.murd.gov.na/
Ministry of Works and Transport	http://www.mwt.gov.na/

Although Firefox is reported as the primary browser for those requiring the use of screen readers,[4] the Google Chrome web browser was used in this study, because it is the most popular browser in Namibia, being installed on 69% of workstations in June 2020.[5] The Lighthouse Chrome extension is also already included within Chrome, and the WAVE extension can easily be added as an extension. In addition, Chrome also has the ChromeVox Classic Extension that reads out website contents to visually impaired users. Together, these tools were combined to determine if the web content met the Web Content Accessibility Guidelines standards.

Using web analysis and testing tools, we visited the homepage of each of the identified e-government websites. The home page URL entered/evaluated using the web evaluation tools, and the results of each evaluation were grouped and analyzed. The web evaluation across all pages was conducted in the same day, to avoid skewed comparisons due to changed contents over time (Luján-Mora, Navarrete, & Peñafiel, 2014). Two websites, those of the Ministry of Higher Education, Training & Innovation and the Ministry of Gender Equality & Children Welfare, were not accessible on the date of the evaluation. As a result, their evaluation results are not included in this paper.

[4] https://webaim.org/projects/screenreadersurvey7/

[5] https://gs.statcounter.com/browser-market-share/all/namibia

4 Research Findings

4.1 Purpose of Government Websites

The websites evaluated were designed to enable local, regional, and national governments to disseminate information and enable citizens to access e-services. The prominent features of the homepages were: (1) to provide a high-level description of ministerial activities; (2) to provide contact details and portfolios for office holders; (3) to describe the roles and responsibilities of the ministries; (4) to post vacancy details and public relations work; (5) to provide downloadable forms for services offered by the ministry; and (6) to list application requirements for public services.

4.2 HTML Version Used Most in Namibian e-Government Websites

The extent of website accessibility is largely measured by the use of state-of-the-art technologies. The version of Hypertext Markup Language (HTML) being used in the websites' source code has been widely described in the literature.

Figure 1 shows that 89% of the websites whose source code was examined used HTML5, with the remaining 11% making use of the XHTML version.

4.3 Validity of HTML and CSS Code

To determine the validity of the HTML and CSS code used to create e-government portals, the homepage address of each portal was pasted into the W3C HTML Validator and the W3C CSS validator. The second and third column of Table 3

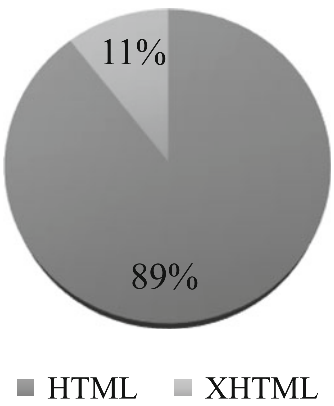

Fig. 1 HTML version used in e-government websites

Table 3 Automated tools evaluation results

Website	W3C HTML validator		W3C CSS validator		LightHouse		WAVE			
	Errors	Warnings	Errors	Warnings	ARIA	Accessibility	Errors	Warnings	ARIA	Contrast
Ministry of Agriculture, Water and Land Reform	45	31	33	1500	3	83	10	15	77	26
Ministry of Defense and Veteran Affairs	34	28	17	1527	34	79	11	8	239	62
Ministry of Education, Arts and Culture	94	97	7	13	7	43	4	57	0	58
Ministry of Environment, Forestry and Tourism	10	14	4	719	21	76	10	56	158	77
Ministry of Finance	–	–	84	974	4	78	3	73	86	42
Ministry of Fisheries and Marine Resources	34	36	25	1451	18	80	9	2	179	33
Ministry of Health and Social Services	36	27	32	1625	22	78	32	21	145	33
Ministry of Home Affairs, Immigration, Safety and Security	70	42	22	1449	24	85	13	21	123	39
Ministry of Industrialization and Trade	77	14	4	28	7	71	5	20	0	0
Ministry of Information Communication Technology	35	36	17	1453	19	80	9	10	125	65
Ministry of International Relations and Cooperation	64	27	30	1553	18	75	23	42	91	13
Ministry of Labor	–	–	106	963	20	82	3	5	64	46
Ministry of Land Reform	39	23	35	1523	22	88	3	20	77	9
Ministry of Works and Transport	61	33	35	1440	17	80	15	6	129	35
Ministry of Urban and Rural Development	40	32	21	1444	20	81	13	9	99	72
Ministry of Sport, Youth and National Service	79	33	66	1543	18	82	5	48	171	32

shows the number of HTML and CSS errors and warnings that were detected by the HTML and CSS validators.

It is interesting to note, however, that the number of errors detected by the W3C HTML Validator and the W3C CSS Validator does not correspond to the Light weight accessibility value shown in column 3 of Table 3. In addition, it can also be observed that the higher number of errors and warnings from the W3C validators did not necessarily translate to a higher number of errors detected by the WAVE tool. Apart from the website of the Ministry of Health and Social Services, the issues resulting from the HTML and CSS code as evaluated by the WAVE tool were generally below 25, which is relatively good compared with the W3C validators. This inconsistency in the results from automated tools is not unique to this research (Hassanzadeh & Navidi, 2010), and necessitated the use of an actual screen reader to supplement the results.

4.4 Alternative Text for Non-text Elements

The alt attribute is used to provide an alternate text description for an image in cases where users are not able to view the image, or the browser is unable to display it. The inability to view/display an image could be due to a number of causes. Firstly, the Internet connection of the user could be slow, disabling download of images. The second reason might be an error in the source attribute, where a referenced image might have been deleted or is no longer available. For visually impaired users, however, it is more common for the image display to have been disabled because the page visitor is making use of a screen reader. The alt attribute is thus important for visually impaired users. As shown in Fig. 2, however, only 16 percent of the government websites investigated in this research had non-text elements with equivalent, alternative, and meaningful text for images displayed on their homepages.

Figure 2 also shows that 84% of government websites do not meet the requirement to add an alternative text to the non-text elements on their websites. Upon further inspection, we found that the government websites developed with XHTML were especially lacking in this regard, and had no alternative text elements at all, while the websites developed with HTML5 appeared to rely more on captioning of non-text elements, instead of including the alternative text in the code. While this is useful, it is not recommended for web accessibility because where a user is relying on a screen reader, vital information will be lost in translation. In addition,

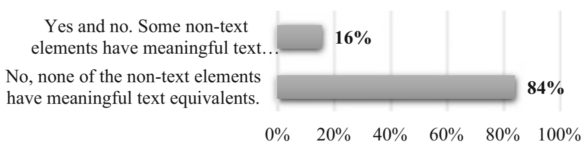

Fig. 2 Alternative text for non-text elements

the alternative text should be displayed when the mouse is hovered over non-text elements. Websites that rely on captioning for non-text elements are not considered accessible for people living with visual impairments/disabilities, and it is therefore highly recommended that Namibian e-government websites make explicit use of the alt attribute.

4.5 WAI-ARIA

ARIA results from Lighthouse and WAVE automated tools were inconsistent. To measure how ARIA is employed in Namibian government websites, therefore, a screen reader narrating the roles and properties of the websites was used. The results are shown in Fig. 3.

All government websites inspected were found to have "Roles to describe the type of widget presented, such as "menu," "tree item," "slider," and "progress meter." This implies that users relying on a screen reader are included in the narrative of the website.

In addition, more than a third (70%) of all government websites were found to have roles to describe the structure of the web page, such as headings, regions, and tables (grids). The screen reader reads each header out as the user progresses through the content, notifying the user of a heading, a paragraph, etc. This is an important role as it helps the user to navigate the website.

Sixty-eight (68) percent of all e-government websites were found to have properties to describe the state widgets were in, such as "checked" for a checkbox, or "has pop-up" for a menu. This is particularly important where users with visual impairments/disabilities have to fill in a form or a survey.

Visually impaired users who rely on assistive technology such as screen readers might prefer to use keyboard navigation instead of a mouse because of the built-in instinctive navigation offered by keyboards. The difference between the keyboard and the mouse is that when users navigate using a keyboard, access to links on the screen is sequential, and users have to tab through all the links one by one before reaching a link of interest. ARIA then provides easy keyboard navigation for web

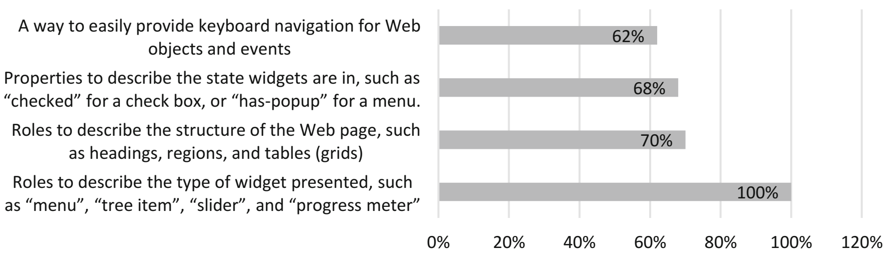

Fig. 3 ARIA roles/guidelines

objects and events and 62 percent of the e-government websites were found to have such functionality.

All these roles, states, and properties interact with ARIA to provide assistive technology for describing elements and behaviors with simple HTML when they do not exist natively, for example, tabs, drop-downs, live regions, tooltips, modal windows, etc. ARIA also defines how an interface component must interact with the keyboard to standardize the user experience with keyboard navigation. The slight disadvantage of these techniques is that they are not yet supported by every browser and even when the newest version of a browser supports it, older versions will not be updated to support it, and some people will continue to use these older browsers (WebAIM, 2017).

4.6 Links and Use of Color in Websites

All websites observed and investigated on the Namibian e-government portal scored 100% in the link visual accessibility test. This means that all the links on the websites were graded as easy to spot, without the need to rely exclusively on color on the web page. Screen readers could always tell the user when they encountered a link. In addition, no text was overlaid on background images on any of the websites tested. This is satisfactory because it makes text decipherable even for a person with low vision.

Table 4 shows the results of the accessibility contrast test carried out on the websites sampled.

Only 26 percent of the websites tested passed the color accessibility contrast test. The rest of the websites (74 percent) did not meet the WCAG's recommended minimum requirements for adequate contrast between the color of the text and the color of the background. Of the 74 websites that did not pass the color accessibility test, five were recommended to increase the contrast of the web page by at least 40 percent, four were recommended to increase the contrast of the web page by at least 30 percent, and the rest were recommended to increase contrast by more than 80 percent. These figures illustrate how far most Namibian e-government websites are from the WCAG's recommended minimum requirements for contrast accessibility.

Table 4 Background color vs text contrast test

	Percentage of websites tested
Yes	26
No	74
Total	100

4.7 Ability to Disable Cascading Style Sheets

Disabling style sheets on a website can get rid of unnecessary decoration and color, thus making it more appropriate for people with visual impairments/disabilities. Since HTML is what creates a website at their most basic level, it makes sense to disable CSS in order to test web accessibility and see that a site structure is built up logically.

In our research, we found that 84 percent of government websites were viewable without style sheets or with style sheets turned off, or in cases where the stylesheets were not supported by the web browser. The remaining 16 percent were not viewable without style sheets. Of these 16 percent, the fonts were found to be too big and the headings, lists, and headers had no mark-up that enabled them to be recognized as such. In terms of web accessibility for visually impaired/disabled viewers this is a good representation because if the style/colors become too much of a viewing burden, they can simply disable the CSS and still make full use of the website.

Figure 4 shows a contrast demonstration for one website, the first with stylesheets fully enabled and working and the other with all stylesheets disabled and still legible.

4.8 Accessible Portable Document Format

While testing the accessibility of PDF files on the e-government websites, we found that only 19 percent of the websites had pdf files that were created in a way that was

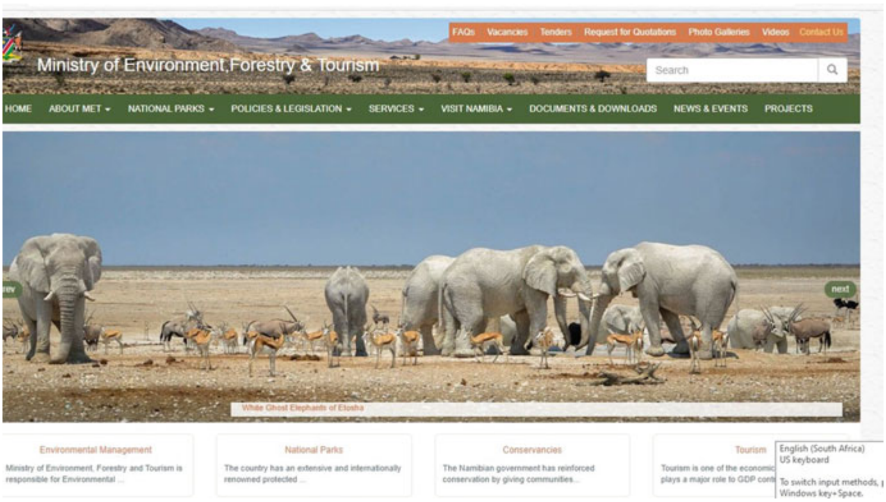

Fig. 4 Screenshot (http://www.met.gov.na/, 2019) with CSS enabled view

likely to maximize their usability for people with visual impairments/disabilities. While most pages included links to .pdf files, the files were created either by "printing to .pdf" or by scanning something into .pdf without running it through an optical character recognition (OCR) process. As a result, most of the PDF documents on e-government websites could not be read by screen readers. Our evaluation thus revealed that 81 percent of the homepages contained links to inaccessible PDF files.

4.9 Interactive Forms

Forms are commonly used to provide user interaction on e-government websites and applications. They are mainly used as a data collection instrument that is filled in by a user and submitted through the same website for various reasons including login, job applications, providing feedback, registering, commenting, and purchasing. Interactive forms can pose problems for or hinder web accessibility if not designed properly, especially for people using screen readers if the programmer does not make certain that users can access all the information, they need to fill out the form. (Zulfiqar et al., 2020).

Of all the websites tested, it was found that 68% did not have accessible forms embedded in their webpages, and 32% had forms only for customer feedback and that did not meet the web accessibility guidelines minimum requirements: see the discussion below.

5 Conclusion and Recommendations

This research aimed to evaluate the accessibility of e-government services for PWD in Namibia. It was based on the premise that poorly designed e-government portals and websites hinder people with disabilities from participating in e-government. Furthermore, inaccessible websites not only present a barrier to participation, but they could also be perceived as discrimination against PWD, as well as an infringement of constitutional rights.

Most e-government websites visited were designed mainly to communicate information and to update the public on the essential services and operations of the Namibian government. The Namibian government has made some progress with the implementation of e-government, and with web accessibility. Close to 90% of all e-government portals evaluated were built in HTML5. Despite this, however, 84% of Namibian e-government websites were found not to comply with the web accessibility guidelines in relation to the addition of alternative texts to non-text objects to make them accessible to people with disabilities, particularly the visually impaired community. This meant that only 16% of the websites sampled passed the test with regard to alternative text. We also found that downloadable PDFs on the websites could not be accessed with a screen reader. This is an area of concern, because it implies that important documents on e-government websites are inaccessible. However, we did find that most homepages adhered to WAI-ARIA guidelines for describing the structure of the web pages and for HTML semantics.

Overall, the results from automated tools and the use of a screen reader were inconsistent. Results from different automated tools varied and were also very different from those obtained by using a screen reader. The findings of this research are thus consistent with those reported in the literature, which suggest that automated tools may be subjective, and advise against reliance on automated tools alone. Using a screen reader results were much more consistent, proving a better tool for evaluating accessibility than automated testing tools. Unlike other studies that confirmed that web accessibility in Southern Africa is poor, the results of this study are inconclusive due to the differences observed from automated evaluation tools compared with the use of screen readers. The present study, therefore, recommends that further work be undertaken to determine the usability of e-government websites, as current studies based only on one category of evaluation tools were varied. In the meantime, the government needs to provide specific guidelines for web developers to enable them to address accessibility challenges for the visually impaired. Inclusive access for all will contribute to the development of a more sustainable and resilient society.

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