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THE FOURTH INDUSTRIAL REVOLUTION: DEVELOPING INNOVATION CAPABILITIES THROUGH SMART TECHNOLOGY ADOPTION

by

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Abstract

The Fourth Industrial Revolution (4IR) is quickly changing the world we work in, affecting not only what we do, but how we do it. One of several resulting problems is that actors across academia, business and government often struggle to leverage the technologies brought on by this paradigm, negatively affecting their ability to innovate and strategize. One way to address this is to ensure effective adoption of smart technologies pertaining to the 4IR, as technology remains a critical pillar in the innovation landscape. This is not to say that information systems research on technology adoption is poor, quite the opposite, as this is one of the most mature branches in the field. Despite this, the pervasive nature of this paradigm has triggered arguments as to what is the most viable model or framework to leverage resulting smart technologies. Furthermore, the existing literature has not produced as much on developing regions when compared to its western orientated counterparts.

The aim of this thesis is to address this gap by furthering the current understanding of the 4IR paradigm and smart technology adoption to develop innovation capabilities within various contexts, specifically within the developing region of South Africa. This study provides its findings through five sequential parts in article format. The parts encompass a usage case of technology adoption in the region (Part 1), insights into supportive mechanisms to do so (Part 2), a tangible artefact to support technology adoption by leaders (Part 3) and global trends on technology adoption models within the 4IR (Part 4). From these investigations, the primary contribution is formulated, the conceptual Smart Technology Adoption Model (STAM) that is grounded on global trends pertaining to 4IR technology adoption (Part 5). However, as noted, there is a need for further investigations within developing regions. Consequently, the model was empirically tested to ensure its validity within a South African context. A key finding is that the tested STAM model aligns strongly to the original TAM model in terms of simplicity and subsequent ease of understanding, with contextual additions including smart technology aspects, perceived risk, technological capabilities and relative advantage being identified as fundamental in smart technology uptake in the region.

The thesis is based on action research to provide several considerations and practical insights towards the enablement of innovation, by adopting smart technologies across sectors to create new forms of value. Each investigation addresses a different aspect of the research questions posed while maintaining coherent contributions within the thesis. The reason to leverage this knowledge is to strengthen innovation capabilities of individuals and organisations alike through technological advancements, such as those brought on by the 4IR. This in turn, can support decisions by leadership who can now better understand the possibilities and relate it to return on investment, protecting financial performance and drive needed economic development. Moreover, the findings presented offers a starting point to leveraging symbiotic collaboration points of individuals in varying contexts through technology adoption, albeit in academic or business environments, to rapidly advance innovation capabilities to navigate this paradigm towards a future ready workforce.

Keywords: Digital capabilities, Developing economy, Digital transformation, Fourth industrial revolution, Future of Work; Information and Communication Technology, Industry 4.0, Information systems, Innovation

Table of abbreviations

3D: Three Dimensional

4IR: Fourth Industrial Revolution

AI: Artificial Intelligence

AM: Additive Manufacturing

ANT: Actor Network Theory

AR: Augmented Reality

BI: Behavioural Intention

DIH: Digital Innovation Hub

DOI: Diffusion of Innovation

DSC: Digital Scholarship Centre

I4.0: Industry 4.0

ICT: Information and Communications Technology

ICT4D: Information and Communications Technology for Development

IoT: Internet of Things

IS: Information Systems

PEoU: Perceived Ease of Use

PU: Perceived Usefulness

R&D: Research and Development

SA: South Africa

STAM: Smart Technology Acceptance Model

TAM: Technology Acceptance Model

TBP: Theory of Planned Behaviour

TC: Technological Capabilities

TRA: Theory of Reasoned Action

UTAUT: Unified Theory of Acceptance and Use of Technology

VR: Virtual Reality

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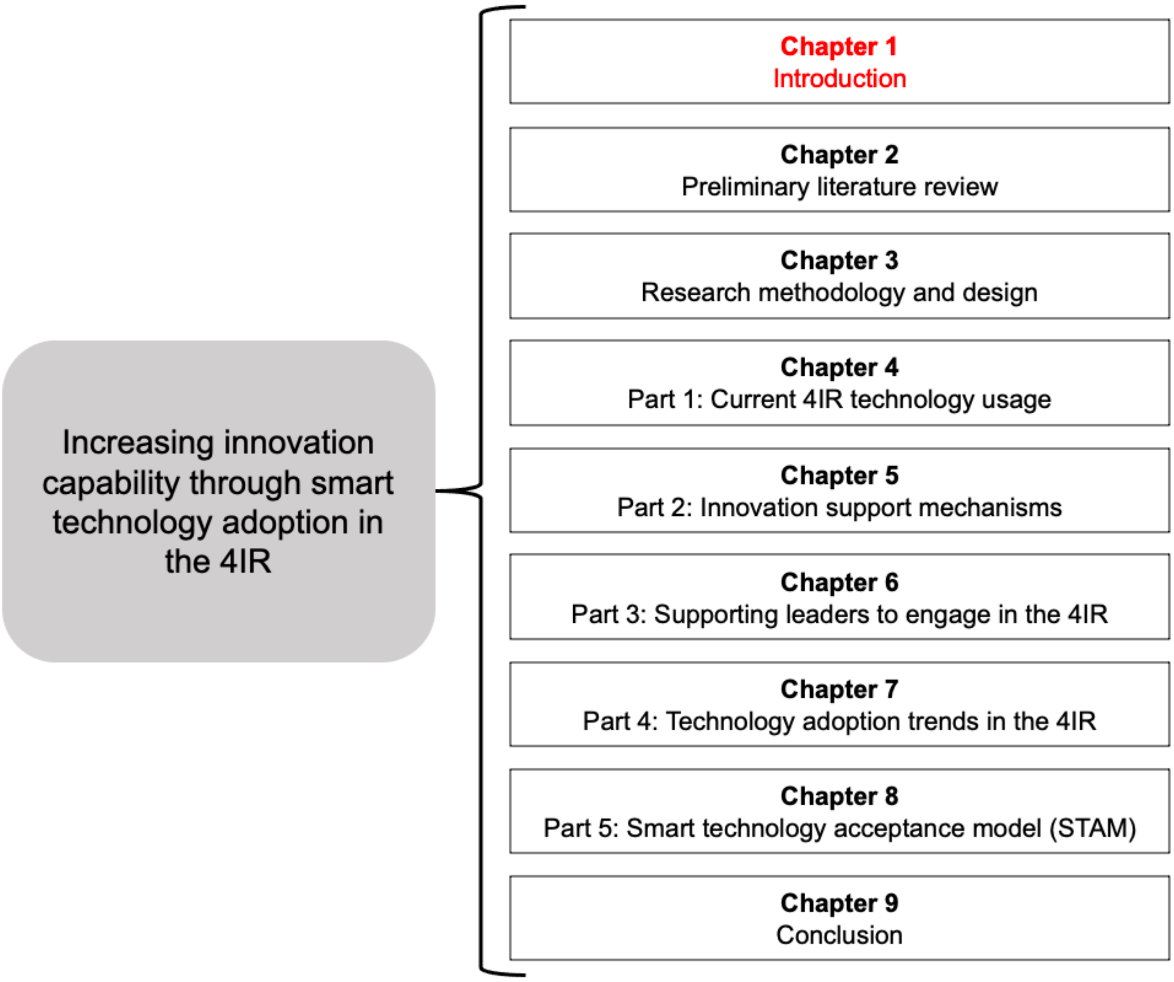
1 INTRODUCTION

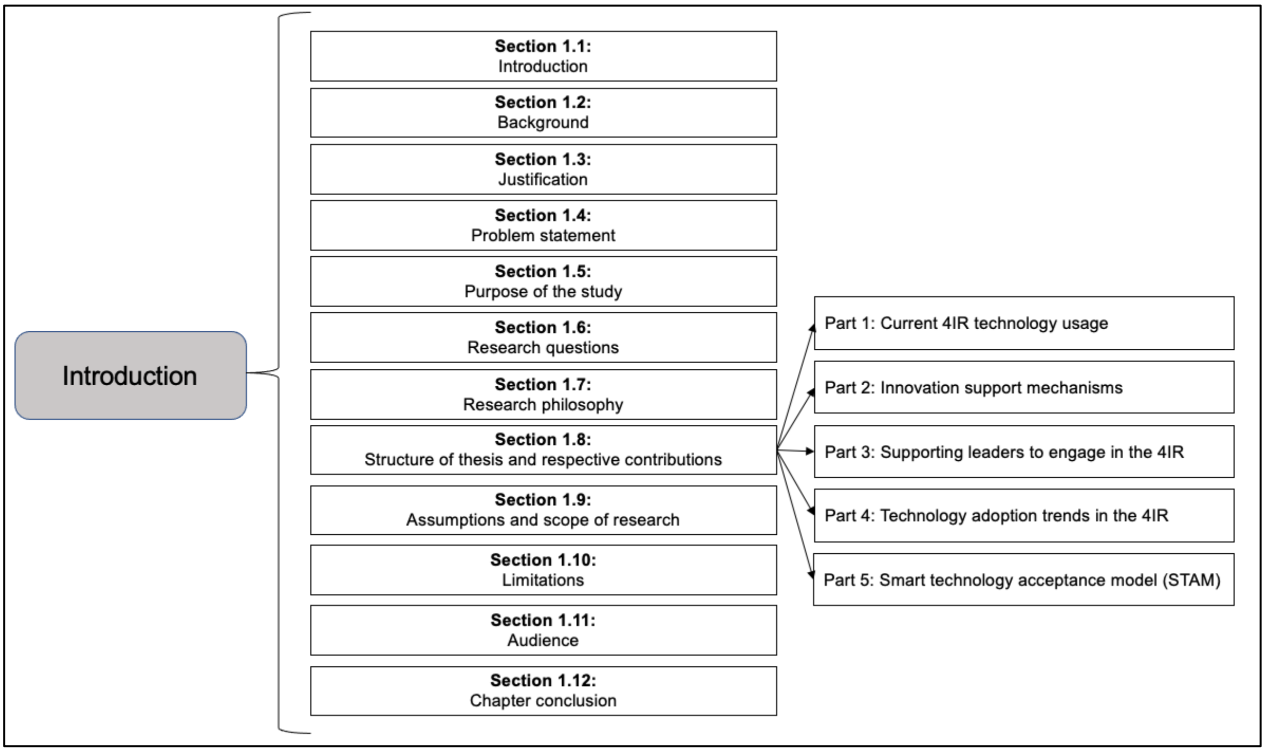


1.1 INTRODUCTION

In the last decade, there has been a substantive body of published research on the Fourth Industrial Revolution (4IR), also referred to as Industry 4.0 (I4.0). One key aspect within this has been the role technologies (often referred to as smart, novel or emerging) and systems have in driving innovation, where developing regions such as South Africa (SA) are focusing efforts to ensure effective engagement in this paradigm. The researcher notes that the concepts of innovation, Information Systems (IS) and technology adoption are by no means new. However, in the advent 4IR, there are new considerations leading to the formulation of this thesis.

In this introductory chapter, the reader is presented with a structured approach to how the thesis contributes to existing literature, noting the insights needed and how they are achieved. Accordingly, the researcher first introduces key concepts to guide the reader through critical background information on the 4IR. Based on this, the justification for the thesis is presented followed by the problem statement. The purpose of the study and resulting research questions are then addressed. The philosophical underpinnings and structure are then reviewed. The structure is non-conventional, as five sequential parts are formulated through journal article format to address the research questions. Notwithstanding, there are several assumptions and limitations of this thesis that are noted, with a certain audience focus. Chapter conclusions are then presented. Argument drawings, which are visual outlines are provided throughout the study to guide the reader on the complex 4IR discourse and the researcher's proposed solution to the research questions. Figure 1-1 provides a visual outline of this chapter.

Figure 1-1: Visual outline for chapter 1



1.2 BACKGROUND: RAPID CHANGES ATTRIBUTABLE TO THE 4IR

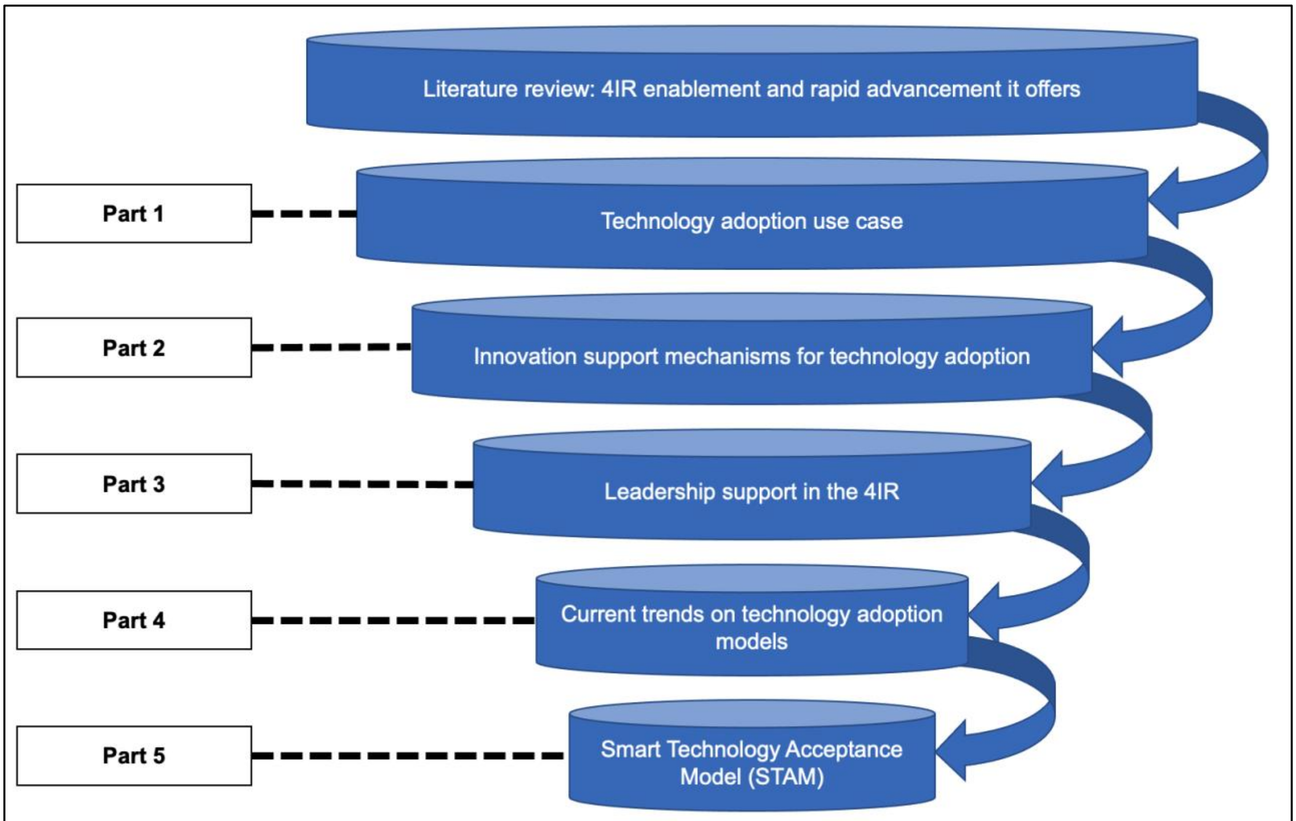
It has been argued that the 4IR paradigm has impacted various facets of human existence (Park, 2017; Schwab, 2017), from devices people interact with, to the way goods and services are consumed. As a result, there has been rapid increases in global competitiveness and technological advances across various sectors (Makridakis, 2017). This is not to say that existing Information Communication and Technology (ICT) and IS are not vital, rather that this is being expanded upon (Berman, 2012). Consequently, IS and associated ICT continue to be vital to enhance decision making capabilities and activities such as innovation on various levels in varying contexts (Botha, 2017). However, in the context of 4IR, which is vastly multi-faceted, more robust IS that can organise ICT components and new smart technologies of the 4IR is required (Issa *et al*., 2018).

It is worthwhile to note for the reader, that according to Chen and Chen (2019), I4.0 relates more to the process, technology and management aspects of supply chains, where systems intertwine to enhance manufacturing and automation. The 4IR however, considers the larger perspective of technological and human integration. As a result, these terms are used interchangeably, as I4.0 can be seen as a component of the 4IR, where technologies and systems interact to enhance the production and creation of new forms of value (Schwab, 2017; Sutherland, 2020). Notwithstanding, the technologies pertaining to this paradigm continue to rapidly change. Consequently, so too are job roles and future work tasks. A factor within this is the very IS which supports the integration and adoption of technologies (Schwarzmüller *et al*., 2018). An argument noted by Ayentimi and Burgess (2019), Lee *et al*. (2018) and Xu *et al*. (2018) is that the 4IR has a vast range of opportunities, both tangible and intangible which could be gained such as economic growth or job creation. As a result of these potential benefits, the researcher noted a need to investigate the possibilities that can be leveraged within this paradigm, but also assess existing models and frameworks to help leaders navigate the rapidly changing environment they operate in.

This is not to say that IS research that focuses on technology adoption is poor, quite the opposite, as this is one of the most mature branches in the field. However, the pervasive nature of the paradigm and its impacts has raised gaps in research. In regions such as SA, there has been an interest on smart technologies potential to support innovation. One way to do so is through technology adoption. It can therefore be argued that stakeholders including business organisations, academia as well as government could benefit from the analysis of the 4IR, and the associated IS theories being used to leverage the smart technologies it encompasses (Oztemel and Gursev, 2018).

This is where the thesis places itself, as it aims to further the current understanding of the 4IR paradigm, with critical contributions on how they have been adopted to enhance business and everyday life (Part 1), especially where they have expanded interconnection and upgraded computerized abilities, alongside robust IS (Botha, 2017; Schwab, 2017; Ward, 2016). Included in this sense are the innovation mechanisms that can be integrated into larger ecosystems to support innovation and engage in the 4IR (Part 2). Stemming from this, the thesis considers how to support leaders to engage in this paradigm's technologies (Part 3). What was found is that technology adoption remains critical in providing needed skills for an ever-changing future of work. However, Part 1, Part 2 and Part 3 were all based on existing technology adoption models which were deemed relevant to each context. Nonetheless, global trends in research on which model is best suited or most used was unclear. Subsequently, a critical review of existing literature pertaining to the technology adoption models used, and constructs needed for organisations to innovate was conducted (Part 4) to support sustainable uptake and pivot needed actions and associated strategies in this paradigm. Finally, to facilitate adoption of smart technologies to develop innovation capabilities, a baseline tool from a global perspective was constructed. The resulting model was referred to as the Smart Technology Acceptance Model (STAM). Furthermore, to make it relevant for a developing region, it was then empirically tested in the region of SA for needed insights (Part 5). An overview of the five parts is shown in Figure 1-2.

Figure 1-2: Visual funnelling towards main research contribution over five parts



1.3 JUSTIFICATION FOR RESEARCH TOPIC

Ellis and Levy, (2008) notes that *why* research is being conducted is of vital importance as it needs to impact future research areas and not focus on the authors own personal gain. For this thesis, previous literature highlighted that stakeholders' need to be able to leverage innovation by effectively using 4IR technologies to remain relevant and ensure sustainability in a rapidly changing market (Ivančić *et al.*, 2019). When making decisions and attempting to formulate a Return on Investment (ROI) from technology, a rational and steadfast stance needs to be taken by leadership (Xu *et al.*, 2017). This is to protect the financial performance and sustainability of an organisation. One way to achieve this is the strengthening of innovation through technological capabilities (Castelo-Branco *et al.*, 2019). This could allow for more engagement with customers, closer ties within business ecosystems, smarter supply chains and more opportunities for the future of work (Luthra *et al.*, 2020; Wilkesmann and Wilkesmann, 2018). Current trends in research also notes a movement to leverage the 4IR, with a focus on skills by persons who innovate, entrepreneurs. In this sense both Small to Medium (SMEs) and multinational businesses are looking to or are already engaging with these technologies.

The basis of this is to support talent in organisations, academic graduates or entrepreneurs by ensuring a sufficient level of skills (Kaivo-Oja *et al.*, 2017). Lack of innovation is said to be negatively impacted by ineffective adoption of 4IR technologies in a developing world such as SA. This could be attributable to various factors, including perceptions and lack of applicable frameworks or models on how to effectively adopt and leverage technologies of the 4IR toward innovation (Ghouri and Mani, 2019; Lasi *et al.*, 2014). This thesis aims to address this by conducting research in the context of a developing world such as SA, where challenges, possibilites and a tangible tool is provided to engage in the 4IR across industries (Castelo-Branco *et al.*, 2019). The investigation is based on previous literature and established methods to ensure non-replication of work and provide new and needed insights.

1.4 PROBLEM STATEMENT

In the face of uncertainties brought on by the rapid changes of 4IR, actors such as business leaders, academic institutions and government are rightly concerned about how to continually innovate for a sustainable future (Dengler and Matthes, 2018; Wilkesmann and Wilkesmann, 2018). Various studies have already been conducted on innovation policies to address this (Dahlander and Gann, 2010; Geels, 2004; Landström *et al.*, 2015; Malerba, 2002; West *et al.*, 2014; Youtie and Shapira, 2008). However, this has occurred in more developed or western orientated systems. As a result, gaps remain regarding the effective adoption of 4IR technologies which have the potential to advance innovation in various sectors.

This is of particular interest when the context of the technologies development and knowledge required to achieve the application potential is considered. This thesis recognises that there are various phases in implementing or using technologies, as well as the level of readiness to leverage these (Bendul and Blunck, 2019; Yeow *et al.*, 2018). Nonetheless, a research problem that arises is **“actors often fail to innovate in the Fourth Industrial Revolution (4IR) due to a lack of smart technology understanding”** (Ellis and Levy, 2008; Kaivo-Oja *et al.*, 2017; van Laar *et al.*, 2017, 2019).

1.5 PURPOSE OF THE STUDY

In 2019, the South African government released a white paper (Department of Science and Technology South Africa, 2019) that encompassed a collection of development initiatives for the 4IR, part of which are assigned to larger ecosystems and universities in the region. This places further pressure on academia to provide skilled graduates who are ready for an ever-changing future of work. Media in the region has echoed this with a need to address job shortages through skills development (Kruger and Steyn, 2021, 2022a). Important to note from the onset, is that the concept of skills needed, business development and innovation are not new challenges in SA. This is a mature discourse where several actions are being generated. However, this is a complex debate due to the impacts of ever-changing technologies and lack of technical infrastructure. Moreover, previous efforts lack insights into tangible functions and current levels to guide individuals who fulfil organisational requirements and business development for job creation (Botha, 2019; Sutherland, 2020).

This is where the thesis joins the debate, as it provides examples of technology adoption (Part 1), insights into supportive mechanisms to do so (Part 2), a tangible artefact to support technology adoption (Part 3) and global trends for further understanding (Part 4) within the 4IR. From these investigations, a conceptual model (Part 5), STAM, based on global trends in technology adoption, was constructed. By using this model, leaders can begin to better understand the status of smart technology adoption in the 4IR and use it to channel resources and support business development areas. Moreover, in Part 5, the STAM model is empirically tested in SA to generate insights for developing regions. The potential for this is to help with updating strategies that can address the changes in the future of work and business models, primarily because of the advanced change empowered by innovations of the 4IR in such regions (Frank *et al.*, 2019).

This argument can also be deemed relevant as academics are tasked in two spheres in the 4IR. Firstly, deliver graduates who are suitably skilled and upskill the existing workforce for a future of work. Secondly, drive needed knowledge creation through research and facilitate innovation. Based on this, seven consecutive research study papers are presented through five sequential parts. All of which are guided by research questions that all pertain to the support and engagement in the 4IR by stakeholders, at the basis of which is innovation capability development.

1.6 RESEARCH QUESTIONS

The primary research question for this study relates to supporting the engagement in the 4IR paradigm towards innovation development, particularly the role of smart technologies. The primary research question is: **"How can we support 4IR technology adoption to enhance innovation capabilities?"**

This research question was approached through five sequential parts. Each part investigates a different section to answer the primary research question. The research questions that are addressed in each part are as follows:

- **Part 1**: Have there been successful adoption cases that demonstrate innovative outcomes using 4IR technologies?
- **Part 2:** What innovation mechanisms can support the uptake of smart technologies in developing regions such as South Africa?
- **Part 3:** How can we support leaders through technology adoption in a developing region such as South Africa?
- **Part 4:** What are current trends in technology adoption model uptake in the 4IR paradigm?
- **Part 5:** Addresses the primary research question "How can we support 4IR technology adoption to enhance innovation capabilities?" by providing a tool that uses individual level constructs, the Smart Technology Acceptance Model (STAM).

1.7 RESEARCH PHILOSOPHY

Prior to reviewing the philosophy adopted for this thesis, three comments are made to help readers follow the main arguments with more ease and prevent arguments getting seconded by other standpoints. (1) Firstly, the researcher has a keen interest in the influence of innovation ecosystems, to support not only graduates but also existing persons in the workplace who require life-long learning to remain relevant. The effect of these mechanisms has received attention in terms of their configuration and functional deliverables. What was found lacking is assessing the tangible outputs they create, the skills they support and alignment across the global market to achieve positive outcomes in this regard. Finally, the effects they have in terms of facilitating conditions and introducing relative advantage was deemed important. Although graduate employability and development is beyond the scope of this thesis, it could be a key formulation for future research. This seemed especially pertinent with an ever-changing future of work. (2) In aligning and introducing skills to participants, populations of literate users was considered. In the investigations, despite a large focus to leverage the 4IR and established mechanisms and white papers, basic digital literacy remains a prevalent barrier. This is not to mention infrastructure issues in the region. As such, on the commencement of this study, the research focused on attaining value and developing innovation despite the apparent disadvantages of the region. At a centre point in this regard are academic institutions and the role they have in achieving this. (3) The researcher is aware that there are several difficulties in measuring technology readiness, but also tracking new forms of value produced under the 4IR paradigm. Moreover, certain researchers have argued that there is a lack of rigor, especially in case study and qualitative research. The researcher in this sense deployed different methods to capture the observations and ensure its validity whilst addressing the research questions.

In this regard, this thesis took on a *pragmatic philosophy, or pragmatism*. The reason for this is that it allows the articulation of the researchers' beliefs about the reality of this study, which aligns to the comments made. In this regard each articles contribution and investigation were applied based on application, to formulate a needed answer to the problem at hand. The theoretical framework belief system focuses on practical and applied research and allows for the integration of different perspectives to help interpret data (Peffers *et al.*, 2018). With this ability, the focus is on addressing the research questions to each respective part.

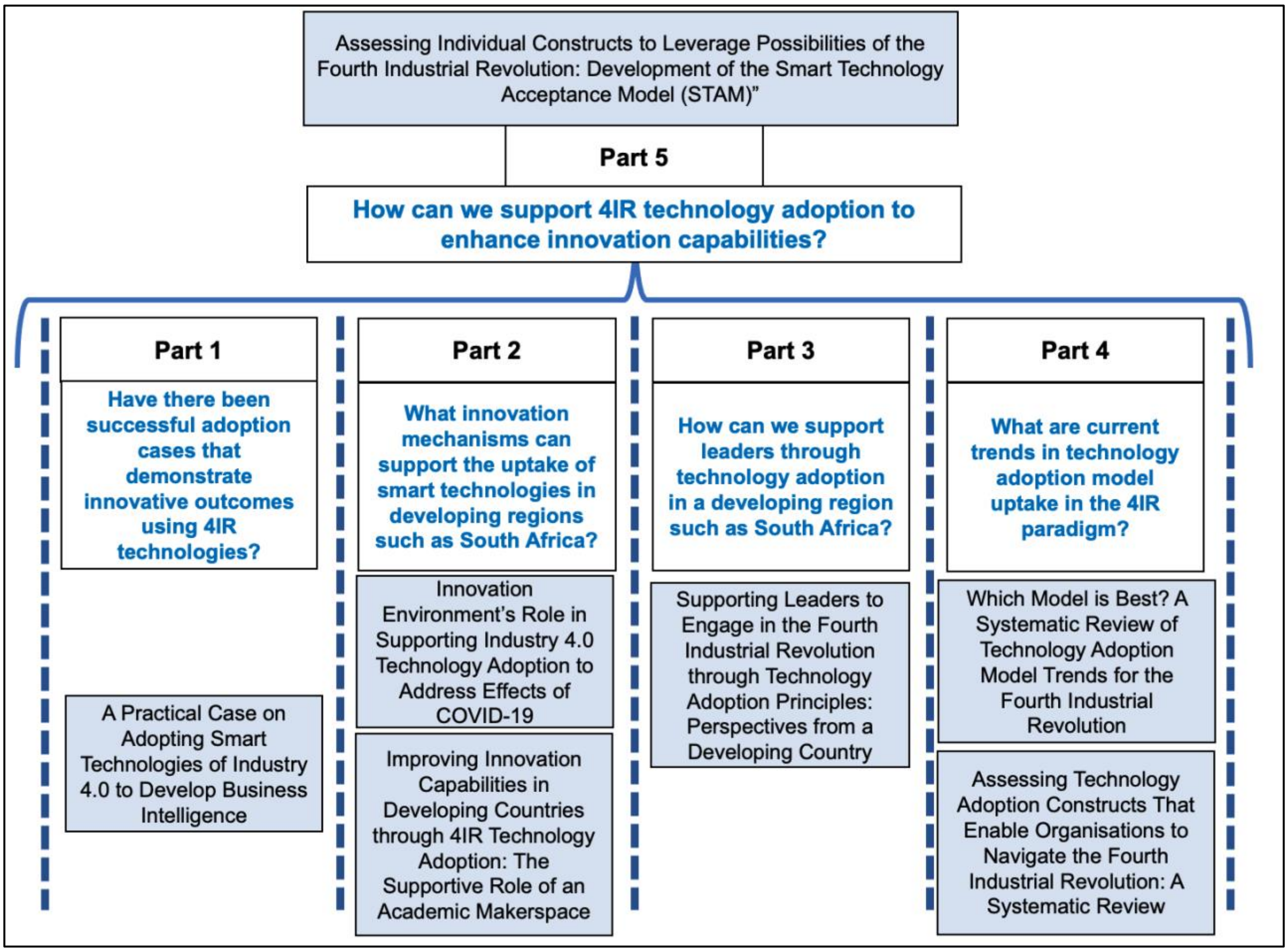
As a result, the research focuses on the questions, and not on the restrictive nature of other paradigms (Biesta, 2010; Saunders *et al.*, 2009). Tashakkori *et al*. (1998) notes that a *"study what interests you and is of value to you, study in the different ways in which you deem appropriate and use the results in ways that can bring about positive consequences within your value system"*. Consequently, the data collection techniques used in each respective study was not restricted to one constrained viewpoint, especially since the data on the phenomenon of using 4IR technologies can originate from multiple sources.

1.8 STRUCTURE OF THESIS AND RESPECTIVE CONTRIBUTIONS

The thesis was designed based on established research guidelines per Ellis and Levy (2008), Gill and Johnson (2010), Rashid *et al*. (2019) and Wagner *et al*. (2012). The resulting chapters developed includes the introduction, literature review, methodology and research design. This is then followed by five result parts presented in article format, ending with the conclusion, references and appendices. The reader may note, that for ease, each articles associated references, keywords, abbreviations, figures, tables and appendices were presented in their respective part and in a format required by the respective journal. However, the tables, figures and references were not linked within the thesis so as to provide an easy to navigate document. Notwithstanding, the thesis offers a multi-method approach in the results section, where the preliminary literature review was used to formulate the research questions. This is because of the purpose of the study, which is to produce a model that can support smart technology adoption that can guide various actors to leverage technologies of the 4IR. By following a multi-method approach that bases itself on a logical flow, the thesis provides rigor and reliability. As such, the phases that follow form part of the research design. Each article is enriched by providing introductory notes, which proposes the research question being addressed.

Importantly, to ensure alignment to a central concept, each part of this thesis is integrated and aligned to each respective research question. The combination of which provides needed insights that culminate in addressing the primary research question. The reader will note that the literature review used to develop these parts is presented in Chapter 2. Within this chapter, a brief review of current models was also provided for needed context. The research methodology and design are presented in Chapter 3. The subsequent chapters address each part in turn towards the final contribution. For the readers ease, the purpose of each part as well as its contribution is provided from the onset in this chapter. The theme overview of each is reviewed in Figure 1-3.

Figure 1-3: Central theme to develop innovation using smart technologies



1.8.1 Part 1: Current 4IR technology adoption

The first part of the study is structured as an investigation of current usages of 4IR technology adoption. In this instance a practical case to enhance business intelligence by entrepreneurs. This was performed in SA to further inform current 4IR technology usage in the region and add needed insights. This section answer's Part 1 of the research question "*Have there been successful adoption cases that demonstrate innovative outcomes using 4IR technologies?".*

The first article entitled "*A Practical Case on Adopting Smart Technologies of Industry 4.0 to Develop Business Intelligence*" notes that existing literature on technology adoption theories to enhance innovation have been well established. Despite this, gaps remain regarding practical cases on how such technologies have been adopted, particularly in non-western contexts to support decisions. This study considers a case of smart technology implementation by entrepreneurs in collaboration with an academic makerspace in a developing region. The purpose is to provide insights for industry practitioners, business leaders and entrepreneurs in developing regions to create new forms of value through business intelligence by effectively adopting I4.0 technologies. The **contribution** is that the study supports the importance of entrepreneurs to innovate, but also provides a practical example on how to develop solutions through a conceptual model. At the basis of which is technology adoption principles. Theoretically, it adds to literature for individual adoption levels of smart technology in a developing region context to develop business intelligence to create value.

The findings from Part 1 are used as foundational insights to Part 2 of the researchers' arguments, where the collaborative efforts with a support mechanism facilitated this uptake.

1.8.2 Part 2: Innovation support mechanisms to engage in the 4IR

By using findings from Part 1, Part 2 of the study answers the second research question "*What innovation mechanisms can support the uptake of smart technologies in developing regions such as South Africa?"*. This question is deemed pertinent, as it investigates tangible functions that have been integrated into academic institutions that form part of a larger innovation ecosystem. Findings of which noted that there are abundant global initiatives, where these offer a premise for actual graduate and employee successes. To do so, two case studies stemming from an academic makerspace are used and presented in the article.

The second article of the thesis that adds to Part 2 is titled "*Innovation Environment's Role in Supporting Industry 4.0 Technology Adoption to Address Effects of COVID-19*". This article noted that health systems were severely strained at the start of the COVID-19 pandemic, where the demand for Personal Protection Equipment (PPE) could not be met. The challenge faced by many countries was how to innovate quickly to create PPE and other needed solutions. The subsequent research gap identified was a lack of practical insights on how to support such novel technology adoption, particularly those that stem from Industry I4.0 within a developing world context. Even in the instance of a pandemic. To address this previous literature on I4.0 technology, the role of innovation environments and theoretical principles of technology adoption was reviewed. A practical case from an academic makerspace based in a South African university was then assessed. The **contribution** is that the results show innovation environments offer an agile platform to leverage innovation by streamlining certain critical success factors of I4.0 technology adoption, which is presented in a model. This article was accepted by *The International Journal of Innovation and Technology Management* in 2022 (Kruger and Steyn, 2022b).

The third article of the thesis that adds to Part 2 titled "*Improving Innovation Capabilities in Developing Countries through 4IR Technology Adoption: The Supportive Role of an Academic Makerspace*" aims to provide practical insights through a conceptual framework on the supportive role of an innovation mechanism to enhance 4IR technology adoption of its users. The **contribution** is that the supportive mechanism assessed conducts activities that supports 4IR technology adoption for innovation capability development of its users within a larger academic ecosystem. Certain activities also align with developed regions initiatives. The results imply that innovation mechanisms such as an academic makerspace could act as a strategic tool in developing regions universities to stimulate innovation to leverage opportunities of the 4IR.

The findings from these articles helps bind the arguments to technology adoption, particularly as facilitating conditions created by these mechanisms can support smart technology adoption. Investigating the functions demonstrated the supportive and positive uptake of technologies towards new forms of value creation. However, individual skills developed by such environments to enhance innovation capabilities within this paradigm required further investigation leading to Part 3.

1.8.3 Part 3: Supporting leaders to engage in the 4IR

The third part provides what the researcher believes contextually relevant, as it focuses on supporting leaders to engage in the 4IR paradigm through smart technology adoption. This stemmed from Part 2 that notes how supporting innovation is occurring, with future research noting changes in the future of work and needed skills. Part 1 and Part 2 provided information on the technologies usage and ways to support their uptake. Part 3 focuses on an artefact to support uptake of these smart technologies, addressing the research question "*How can we support leaders through technology adoption in a developing region such as South Africa?"*

The fourth article is the only article for Part 3, entitled *"Supporting Leaders to Engage in the Fourth Industrial Revolution through Technology Adoption Principles: Perspectives from a Developing Country".* The study notes that SA face's several prominent challenges. One of them is the ability to leverage technological advancements such as those brought on by the 4IR. The aim of this study is to explore ways to support leaders to engage in the 4IR paradigm based on technology adoption principles, as few studies have considered value creation at an individual user level. To achieve this, existing literature on the 4IR and technology adoption theory constructs are assessed. Using action research principles an artefact could be developed based on findings of 35 industry leaders enrolled in a master's level IS program which focuses on strategizing and making technology relevant for business success was used. The **contribution** is the artefact developed to improve leaders' perceptions and support their engagement in the 4IR paradigm. From a developing country perspective, this research presents practical implications to developing leaders due to their potential to leverage 4IR technologies to positively impact Sustainable Development Goals such as fair work and economic development (SDG 8).

Part 1, Part 2 and Part 3 utilised technology adoption as a core construct in assessing effectiveness. In this sense, a question raised was current trends in this regard, as well as the associated constructs that can be used by organisations to leverage the 4IR. As a result, the researcher noted a gap in the research, not debating the maturity of models and technology adoption, rather the current trends in the 4IR paradigms usage. This gap led to Part 4.

1.8.4 Part 4: Technology adoption trends in the 4IR

Part 4 provides the reader with a comprehensive systematic literature review of current technology adoption model trends pertaining to the 4IR paradigm. This stems from a research gap identified when conducting research in Part 1, Part 2 and Part 3, which is an unclear view of the most suitable model, or models being applied in this paradigm. Two articles were formulated in in this regard, the first noting which model is best. The second focused more on organisations, as the business aspect of technology in the 4IR can be considered important. The research question "*What are current trends in technology adoption model uptake in the 4IR paradigm*?" is comprehensively addressed. As with the other parts, both are in article format and have been submitted for publication.

The fifth article to address Part 4 specifically considered the actual models used in 4IR literature entitled "*Which Model is Best? A Systematic Review of Technology Adoption Model Trends for the Fourth Industrial Revolution*". The purpose of this study is to determine which technology adoption model, or models, are primarily used when assessing smart technologies in the 4IR construct. It is not to investigate the rigour of existing models or their theoretical underpinnings, as this has been proven. This study **contributes** theoretically by providing a baseline to develop a generalisable 4IR model grounded on existing acceptance trends identified. Practically, the insights demonstrate the current trends for strategists and policymakers to understand technology adoption within the 4IR to direct efforts that support innovation development, an increasingly crucial factor for survival in the digital age.

Future research noted a need to investigate additional constructs that were impactful whilst considering the level of research they were applied to. As a result, the sixth article investigated the organisational level; entitled "*Assessing Technology Adoption Constructs That Enable Organisations to Navigate the Fourth Industrial Revolution: A Systematic Review*". This is because a comprehensive assessment on which model and its associated constructs is unclear, especially one that can guide organisations to leverage the technologies of this paradigm. This study aims to address this by identifying which models and their associated constructs positively influence the implementation of smart technologies stemming from the 4IR at an organisational level. The **contribution** is prominent contextual areas of interest with 480 constructs identified. However, only influential constructs were reviewed in detail and weighted, which is presented through a conceptual model.

Based on these trends and usages, a tool that considered a global perspective for individual innovation through technology adoption was required. Moreover, the tool needed to have contextual relevance for SA that is making specific efforts to support innovation in the 4IR as noted earlier.

1.8.5 Part 5: Smart Technology Acceptance Model (STAM)

This is the final part of the thesis results, Part 5, that looks to address the final research question "*How can we support 4IR technology adoption to enhance innovation capabilities*?"

by noting "*the most effectual individual technology adoption model constructs for smart technology acceptance of the 4IR*".

The seventh article entitled "*Assessing Individual Constructs to Leverage Possibilities of the Fourth Industrial Revolution: Development of the Smart Technology Acceptance Model (STAM)",* provides a conceptual model for individuals that was developed based on a systematic literature review. This is because, as noted in Part 4, individuals are the innovators, students, graduates, leaders and entrepreneurs. The **contribution** is a conceptual model referred to as the Smart Technology Adoption Model (STAM) with core constructs weighted that is applicable from a global perspective. To add insights into the understudied regions such as SA, the model is also empirically assessed in the region using structural equation modelling. The resulting outcomes identified influential constructs that can be used as an effective and easy to understand tool to integrate technologies across actors, supporting their uptake towards innovation capability development.

1.8.6 Overview of structure

Using a structured approach based on existing literature, the reader is guided on how the thesis addresses the research questions, providing unpublished insights into trends in the 4IR, but also a functional tool for a developing region such as SA.

First and foremost is the introduction, Chapter 1, which provides a snapshot of the research, its purpose, the contributions, and a guide to navigate the thesis.

Previous literature, Chapter 2, is presented next, as it provides established information on the 4IR, its technologies, impacts and technology adoption models to navigate the paradigm.

Chapter 3 reviews the research methodology and design on how each parts contribution was achieved.

Chapter 4 to 8 reviews each part in detail, with the contributions provided in article format. In each chapter, the associated research question and introductory notes are provided for ease of reference for the reader. The aim of the approach is to align with the pragmatic philosophy, as the focus is to answer research questions effectively.

Chapter 9 encompasses the conclusion chapter. This is important as an overview of each article's contribution is briefly reviewed, and guidance is provided to the reader on how they coherently lead on one another to address the primary research question. For the readers purposes, the overall structure throughout the chapters to achieve this is shown in Figure 1-4. Table 1-1 notes the articles within the thesis and its status.

Figure 1-4: Visual overview of the thesis structure

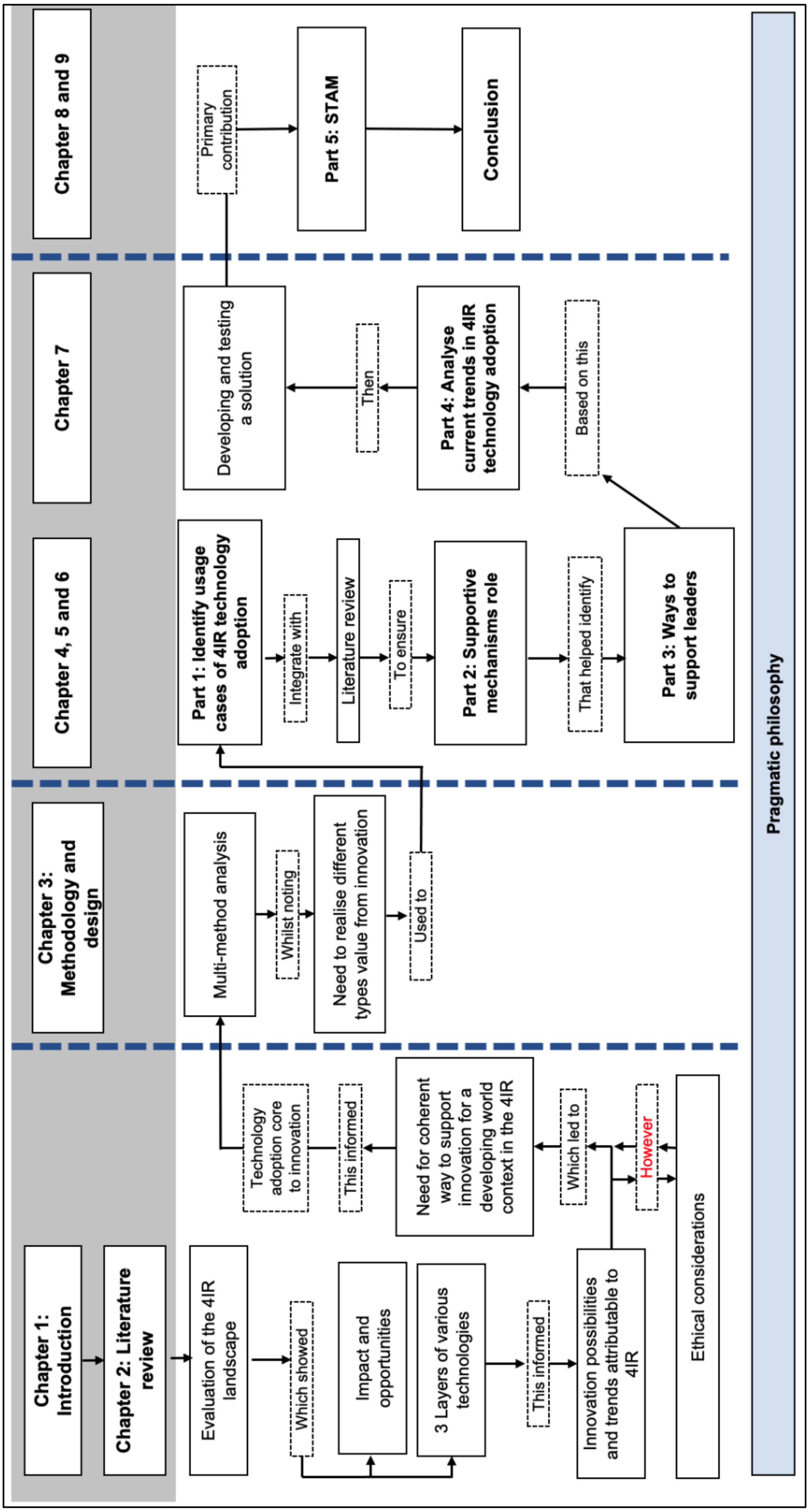


Table 1.1: Overview of article submissions and status

Article number	Part of thesis	Article Title	Journal submitted to	Status
1	1	A Practical Case on Adopting Smart Technologies of Industry 4.0 to Develop Business Intelligence	Communications in Computer and Information Science (CCIS) proceedings	Accepted
2	2	Innovation Environment's Role in Supporting Industry 4.0 Technology Adoption to Address Effects of COVID-19	International Journal of Innovation and Technology Management	Accepted
3	2	Improving Innovation Capabilities in Developing Countries through 4IR Technology Adoption: The Supportive Role of an Academic Makerspace	Research Policy	Awaiting feedback
4	3	Supporting Leaders to Engage in the Fourth Industrial Revolution through Technology Adoption Principles: Perspectives from a Developing Country	Information Systems Frontiers	Awaiting feedback
5	4	Which Model is Best? A Systematic Review of Technology Adoption Model Trends for the Fourth Industrial Revolution	Technology in Society	Not accepted, editorial office recommended transfer to Technological Forecasting & Social Change
6	4	Assessing Technology Adoption Constructs That Enable Organisations to Navigate the Fourth Industrial Revolution: A Systematic Review	Telematics and Informatics Reports	Journal noted they do not have reviewers to process article, awaiting transfer
7	5	Assessing Individual Constructs to Leverage Possibilities of the Fourth Industrial Revolution: Development of the Smart Technology Acceptance Model (STAM)	Telematics and Informatics	Awaiting feedback

1.9 ASSUMPTIONS AND SCOPE OF RESEARCH

This research evaluates technologies of the 4IR. However, it is accepted that the technologies themselves continue to develop and evolve. Consequently, the primary technologies for this thesis include Additive Manufacturing (AM), AI, the Internet of Things (IoT), Cyber-Physical Systems (CPS), Cybersecurity, Big Data, Blockchain and Cloud Infrastructure. The research considers the human aspects of this technology's adoption and the impacts experienced (Xu *et al.*, 2018). The considerations specifically focus on the developing world context although global considerations from literature is acknowledged.

For this thesis, it is also assumed that 4IR technologies have multiple considerations, and these are lacking in the context of the developing world. Furthermore, the research assumes that these technologies are integrating into multiple aspects of human life and business. It is assumed that there are certain skills required to effectively develop and deploy such technologies. Finally, it is assumed that the usage of such technology must have certain considerations to protect the users and those who it affects (van Laar *et al.*, 2017).

1.10 LIMITATIONS

As with other studies, there are several limitations. The limitations of this study are that it does not attempt to predict the future, instead it aims to provide insights to aid actors to develop innovation capabilities. Not all technologies and their extensive impacts on society and perceptions on the adoption of technologies can be investigated. Furthermore, only published literature is used in most instances, causing a slight delay in current technologies presented. The South African context is extensive and could not be completely assessed. Consequently, the resulting STAM model needs to be furthered tested for contextual richness. Finally, the reader will note that each articles limitations is addressed in detail in each.

1.11 AUDIENCE

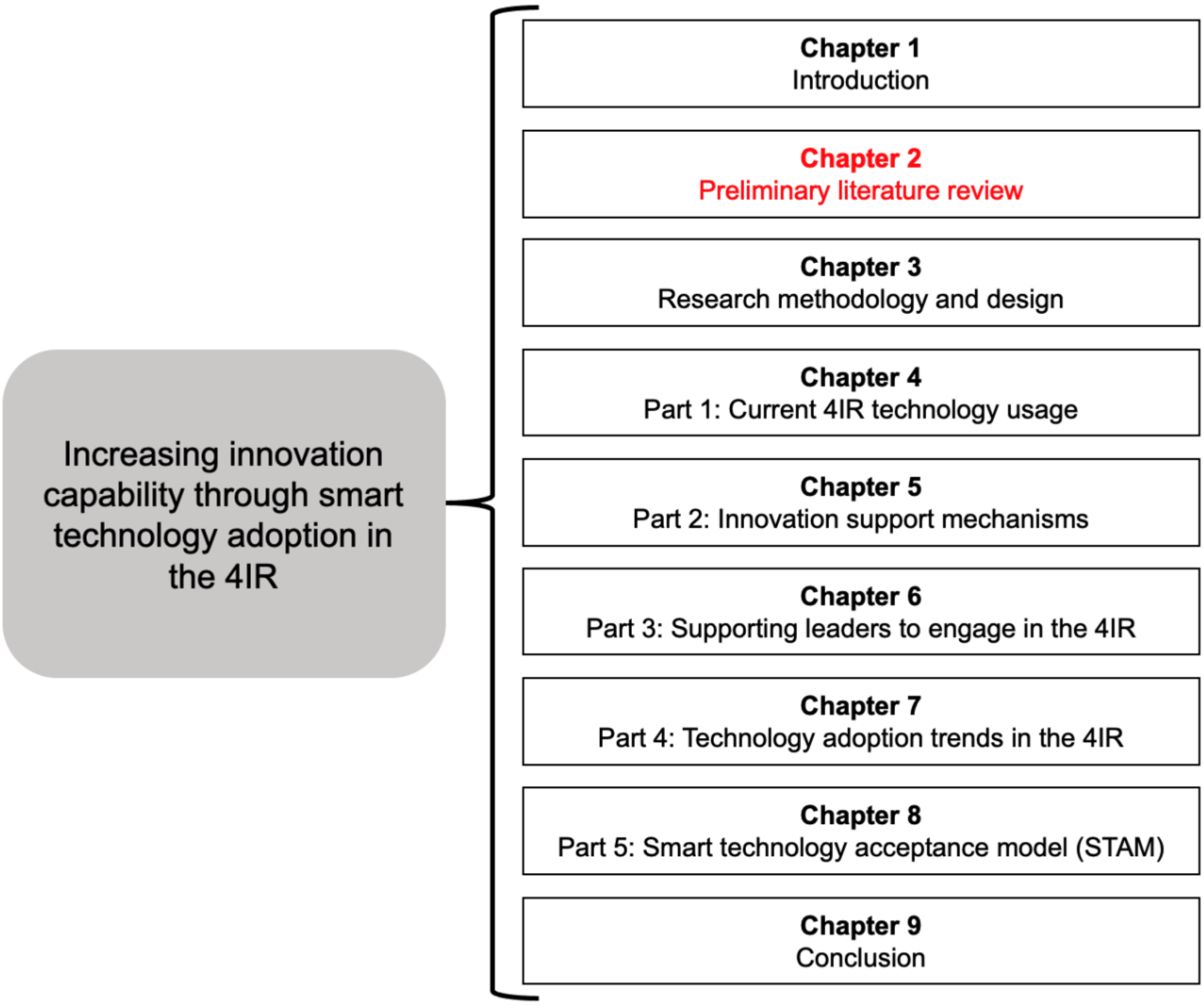
Taking the above insights into consideration, it demonstrates that there is still a need for further research to help actors through technology adoption and innovation (Schwarzmüller *et al.*, 2018). By evaluating the current trends and building a model that can aid in addressing ever-changing environments, actors can take advantage of 4IR technologies. As such, business leaders who need to prepare for an ever-changing future would be the audience of this research. Also, interested actors such as government and academia would also be potential audience members, as it will aid to identify, and address needed skills attributable to 4IR for the future of work and an inclusive Society 5.0. Finally, entrepreneurs who can use these technologies to innovate and develop needed businesses towards job creation.

1.12 CHAPTER CONCLUSION

This chapter introduces the reader to a structured approach to how this thesis contributes to literature, with a particular focus on the 4IR. A background was provided to the reader followed by the problem statement that was identified. The purpose of the study and resulting research questions were then addressed. The philosophical underpinnings and structure were then reviewed. The non-conventional structure was presented noting the five parts and contribution in each. When conducting the research there are certain assumptions, limitations and scope that must be considered, which were also reviewed. Finally, the intended audience was introduced.

In the next chapter, Chapter 2, the researcher presents an overview of existing literature that was used as the baseline to formulate the research questions of the thesis. After this, the research methodology is presented in Chapter 3. Using this, the reader should better understand the results section of how the research was approached. The five parts that encompass the results of investigations are then presented in turn, with conclusions, references and appendices provided.

2 PRELIMINARY LITERATURE REVIEW



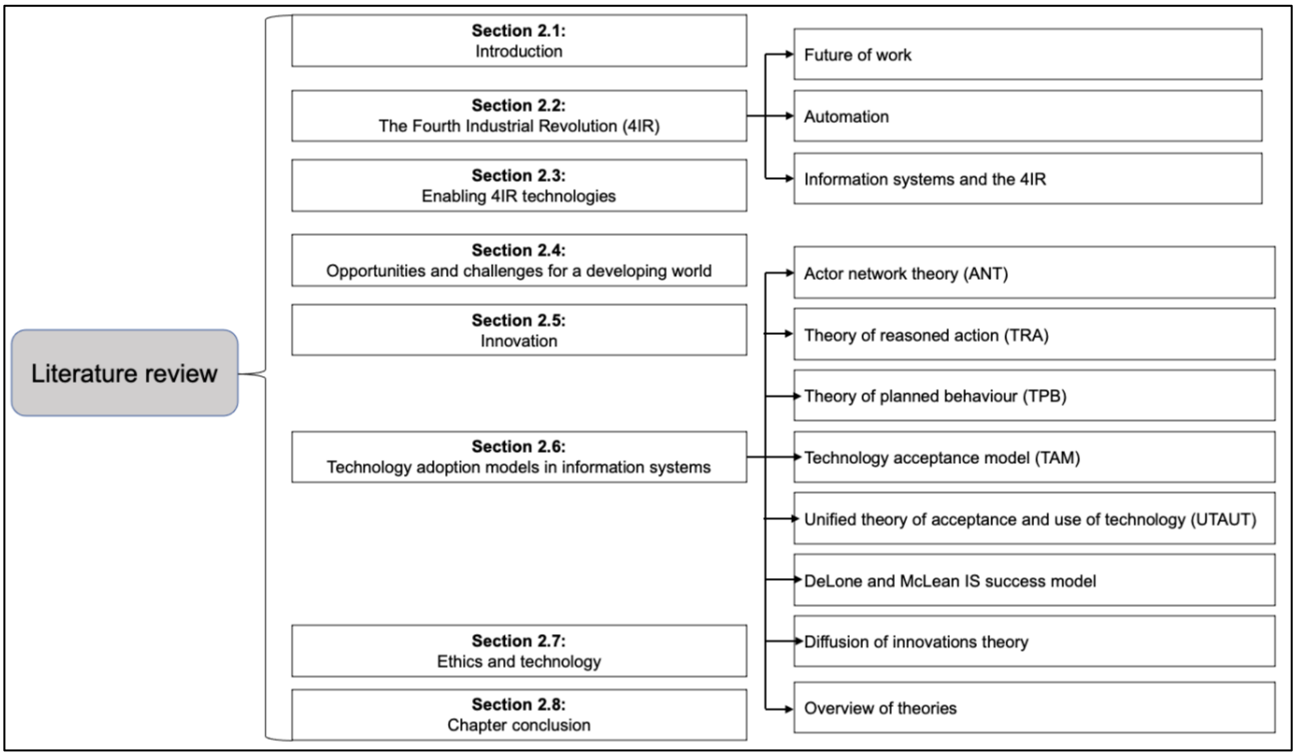
2.1 INTRODUCTION

Existing literature remains pivotal in formulating ideas and aids various stakeholders in their understanding of assorted concepts. Furthermore, a review of literature not only ensures non-replication of work but can add contextual insights or raise considerations for what knowledge is required. Within the 4IR, which can be argued to be a relatively new concept, several areas of research have already been conducted to encapsulate what it means, and how it is affecting society. However, what has also been noted in the research are gaps where further knowledge is required.

This chapter summarises existing literature that informed the thesis as well as the theory that grounded the initial research. The literature begins with what the 4IR is, its impacts on the future of work and automation. IS research and the 4IR is then addressed, with the several enabling technologies that can be considered as 'smart' being briefly reviewed. The opportunities and challenges are then reviewed, particularly for a developing country followed by what innovation is and support mechanisms that can enable it. At the core to this is the technology adoption theories used to date, which are also reviewed to provide the reader a knowledge base regarding technology adoption. Finally ethical considerations are presented with the chapter conclusion.

The literature review provides the baseline for critical analysis of current trends and possibilities attributable to the 4IR. There are six sections presented, each building a view of the existing literature. This is presented in Figure 2-1, which specifies each section.

Figure 2-1: Overview of chapter 2



2.2 THE FOURTH INDUSTRIAL REVOLUTION

The 4IR is a rapidly encroaching paradigm, where technologies integrate across the digital, physical and biological spheres at a rapid pace (Schwab, 2017). Research shows the explanation behind this publicity is the enablement and headway it offers business on a worldwide scale. This can include new service offerings or insights into activities not before conceivable (Castelo-Branco *et al.*, 2019). However, despite these opportunities, research argues that in reality, it remains difficult for businesses and other actors to realise potential applications (Botha, 2019). This is especially true for developing countries, where research looks to Information and Communication Technologies for Development (ICT4D) in an attempt to bridge the gap (Bai, 2018).

The rapid evolution of technologies suggests that massive changes in facets of human life will continue to be experienced (Rajan and Saffiotti, 2017). This includes the future of work (Halal *et al.*, 2016). Part of this evolution is the digital transformation and associated technologies which impacts existing ICT and IS. However, these systems do not operate in isolation as they rely on physical devices to provide needed data. These changes have in certain ways forced stakeholders to not only develop, but effectively utilise evolving technologies. Previous literature (Erol *et al*., 2016; Ganzarain *et al*., 2016; Park, 2017) states the major technologies in this regard includes but is not limited to AI, Big Data, Blockchain, Cloud Computing, Robotics, IoT and AM, also referred to as 3D printing technologies. Despite these technologies having different stages of maturity or adoption, the level of connectivity and integration between them has seen various impacts across industries. From an overall increase in productivity to the ability to develop new products, the 4IR has been attributed as the catalyst for the development of autonomous, sensor-based self-regulating systems (Bendul and Blunck, 2019; Rajan and Saffiotti, 2017a). This catalyst is said to be changing the way we live (Schwab, 2017; Xu, David, *et al*., 2018). From a developing country perspective, such as SA, embracing the 4IR creates an abundant need to drive skills development to rekindle economic growth and create high-quality jobs (Ayentimi and Burgess, 2019). However, this paradigm shift brings the risk of actual job losses. With an economy of over 29 percent in unemployment in 2019, a clear strategy to effectively navigate these technologies is needed to create a future of work readiness and effective technology adoption (Kaivo-Oja *et al.*, 2017; Magwentshu *et al.*, 2019).

As a result of smart technologies being continuously developed, alongside industrial grade connectivity, the very nature of business has, and continues to change (Luz Martín-Peña *et al.*, 2018). One key aspect of this is to enhance performance in the Decision Support Systems (DSS). This makes use of key metrics for decisions as well as areas for automation. A system that has stemmed from this and deliver direct interaction between computerised databases and analytics software is a DSS (Liao *et al.*, 2015). This system is greatly supported by a Customer Relationship Management (CRM). A CRM system is part of the DSS which governs the customers interaction with the organisation. This system describes customer relationships in sufficient detail so that decision makers and operational staff can access information directly and enhance their capability to address customer needs though customised product offerings, reminders and linkages to similar products (Zikmund *et al.*, 2010). When it comes to operational and internal efficiency, Enterprise Resource Planning (ERP) is used. However, these systems need to align with the business strategy. Despite systems capability and effective alignment, they need to be implemented and used by people. People tend to assume that they are ready to use these systems, or utilise them affectively, however in an operational and strategic sense, this is far from the truth (Schmitz *et al.*, 2017).

What has added to the complexity and pressure of business models, their systems and their people; is the rate of change and impact of technologies, especially thanks to the innovation opportunities raised by of the 4IR (Ganzarain *et al.*, 2016). Business models themselves are closely related to value creation. However, with the 4IR, older models have needed to be re-invented to address dynamics that impact their operations, strategy and IS to remain competitive (Bounfour, 2016). One such example is digital innovation brought on by AI. This alongside automation has the potential to increase the efficiency, productivity and profitability of an organisation (Ganzarain *et al.*, 2016). As more individual tasks, especially repetitive and mundane become automatable, the very nature of work also changes. As such we see that *"organisations need to strengthen their innovation, digital, and technology capabilities in order to capitalise on new opportunities, and they need the skills to support that investment."* (PWC, 2018) As is with innovation, especially digital innovation, leaders need to make decisions, but are now able to do so with more insights attributable to business intelligence and data analysis using Big Data (Schwarzmüller *et al.*, 2018). The term digital system refers to the combined efforts of digital innovation to bring actions and practices that change or complement existing paradigms towards value creation (Hinings *et al.*, 2018). With this we see that more individual tasks become automatable, causing jobs to be redefined and revalued. Capitalising on prospects stemming from digital transformation and innovation is as much about talent as technology. People, not systems, drive innovation and realise its full commercial potential. This does require certain skills (Sousa and Rocha, 2019). However, advanced technology brings anxiety for employees with the disruption it brings with it (Leitão *et al.*, 2017). Consequently, concerns about skills requirements have never been higher to ensure optimal system performance. A major variable within the digital innovation landscape is the people aspect, as they are the innovators, not the machines. This does however require critical skills to not only take advantage of technologies but also reduce workforce disparity (Sousa and Rocha, 2019).

2.2.1 Future of work

With the 4IR, it is difficult to offer insights to a future that does not yet exist. What is clear is that AI already has the capacity to automate and take over certain functions, impacting existing jobs (Grace *et al.*, 2018; Halal *et al.*, 2016). However, for this to be done well, AI requires reliable inputs, primarily data, before it can function effectively. This means it is dependent on other technologies to collect and collate needed data. One way to do so is through physical devices which can connect and provide data in real-time. Many of these devices form part of IoT (Lu, 2017). Based on this, AI has a level of dependency on data and the technologies which gather it. The development of dependant technologies alongside open-source platforms have driven systems which are now able to incorporate aspects of AI. This includes machine learning (ML). ML is the ability of a computer algorithm to advance automatically through experiences. As these systems advance, new approaches rooted in research have allowed for ML to make data more efficient and relevant (Oussous *et al.*, 2018). With Big Data, ML has been expanded to process languages and images which computers were not able to understand before (Kitchin, 2014). With this efficiency and new data areas, AI can more accurately and automatically, through computations, mine and detect patterns to build predictive models (Qin *et al.*, 2016). The technicalities behind this are extensive, especially when trying to develop an effective IS that can use such technology and create value (Rehman *et al.*, 2019). This value can include automation for increase efficiencies, to knowledge management for effective decisions. However, there are other areas of practice that are enabled by AI such as robotics. This is because AI can make decisions and action certain responses in physical form. One such example is service robots (Kaivo-Oja *et al.*, 2017). With a capacity to manifest in physical form, further automation of the production of goods and services becomes possible (van Laar *et al.*, 2017); with a large potential to positively impact the global economy (Magwentshu et al., 2019; Park, 2017).

With the level of potential functionality, the human paradigms importance becomes apparent, as automation and its usages affect the future of work and how we as people engage with technology (Jakesch *et al.*, 2019; Kaivo-Oja *et al.*, 2017). As a result, debates arise regarding the level and depth this technology will have on the global labour market. The depth is said to be extensive, with an expected 70 percent of Asia and North America expecting AI to replace highly skilled jobs due to cost efficiencies (Quacquarelli, 2019). This is not limited to one industry, as several others are also being impacted. An example of this is China, who is looking to automate a possible 51 percent of its labour force across various industries (Quacquarelli, 2019). With some jobs already being replaced such as cashiers, the human labour market is likely to change drastically, especially in agriculture, forestry and fishing. This could impact up to 50 percent of current jobs as a direct result of automation (Manyika *et al.*, 2017). This extends to what skills development is required for highly skilled jobs. This is unclear, especially since AI has the increasing potential to perform more complex roles in fields of law, architecture and medicine. In Africa, this is also true, and academic institutions are tasked with preparing the future workforce (Magwentshu *et al.*, 2019; Quacquarelli, 2019).

In terms of skills, employers worldwide consider analytical, quantitative skills and technical skills as abilities that AI will be able to be outperform when compared to humans by the year 2030 (Kitchin, 2014; Park, 2017b). To address this, it is argued that if humans can learn how it works, it can be used to make them more efficient at their job (Quacquarelli, 2019). Despite this, many today are working more than before, although with less physical effort than in jobs of the past. Although AI contributes to 4IR, the automation of work through AI agents might take over some of the mundane tasks, Thus, providing more time for leisure activities (Torresen, 2018).

2.2.2 Automation

Research shows that the 4IR calls for a shift to rethink organisational leadership, management and governance (Hasselbalch, 2019). Based on this, society is said to require leaders who are not only technology experts, but also possess a good understanding of what enabling technologies can do for their organisations (Lee *et al.*, 2017). With these changing variables, business organisations, academic institutions and government need to review possibilities to drive internal efficiencies and overall effectiveness for the general good. This then has led to studies which demonstrate various systems that enable people to address the impact of technologies, and perhaps leverage innovation opportunities raised by of 4IR (Ganzarain *et al.*, 2016). However, with 4IR, there is a need to address various dynamics that impact strategy, IS and physical activities that create value (Bounfour, 2016). One such example is digital innovation brought on by AI. This alongside automation has the potential to increase the efficiency, productivity and profitability of an organisation (Echeverría and Tabarés, 2017). However, this raises the issue of trust regarding job security (Ganzarain *et al.*, 2016). As more individual tasks become automated, the very nature of work is argued to be changing (van Laar *et al.*, 2017; Schwarzmüller *et al.*, 2018).

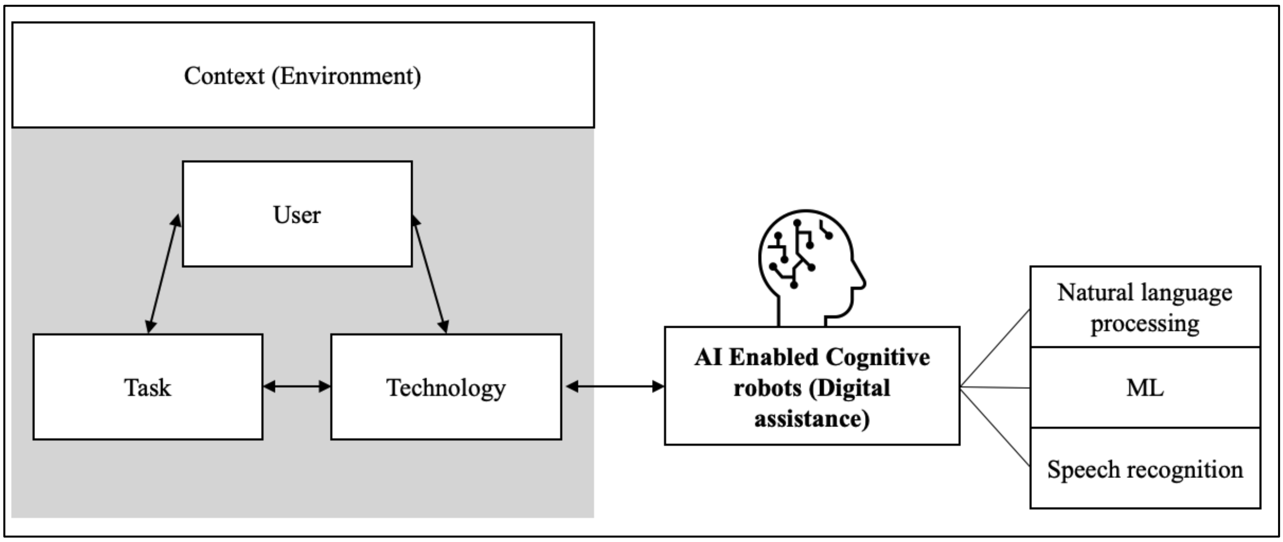
2.2.3 Information systems and 4IR

To effectively realise digital activities within the 4IR, a robust IS which can collect and integrate new technologies to the benefit of the organisation is said to be a fundamental requirement (Alp and Cevikan, 2017; Chen *et al.*, 2012). This is because an IS facilitates coordinated activities across an organisation in real-time using various technologies (Issa *et al.*, 2018). In so doing, IS have been shown to enhance decision making across organisational hierarchies to address changes quickly (Bendul and Blunck, 2019). Notwithstanding, IS as a science considers a diverse set of factors, especially when looking at the effective adoption of emerging technologies of the 4IR (Nikou, 2019). Walsham (2012) enforces this shift as "*The IS field should embrace the old and the new in terms of both technologies and settings*". With regards to the 4IR then, IS research plays a pivotal role (Erol *et al.*, 2016; Ganzarain *et al.*, 2016; Park, 2017a) as it can guide users in effective technology adoption towards improving their innovative capabilities in this changing setting (Rogers, 2003). This is especially true as it does not consider technological artefacts existing in a vacuum (Peng and Guo, 2019). Instead, it considers various paradigms and principles towards effective human design and technology usage (Maedche *et al.*, 2019). In this instance, their ability to adopt 4IR technology to innovate (Botha, 2019).

This can be argued as important, as the 4IR technologies are increasing the ability of systems to become self-aware (Echeverría and Tabarés, 2017) and automate functions within a supply chain (Sutherland, 2020). Research shows that jobs are made up of numerous work activities with varying automation possibilities, however, the work activities that can be automated immediately are usually those tasks that depend on pre-specified and routine activities including data collection and processing (Morgan, 2019). As a result, 5 percent of all occupations could be fully automated according to a report by McKinsey

Global Institute (2017). This is expanded, where nearly 60 percent of all occupations have at least 30 percent of tasks which could be automated by the current technology on hand. This was derived from evaluations of 2000 work activities across 800 occupations (Manyika *et al.*, 2017). As such, we are seeing that automation has caused job displacements. However, this is being extended, especially where automation can result in the reallocation of cognitive tasks and activities traditionally performed by humans (Autor, 2015). AI based research shows that technological capabilities on platforms has vast potential for automation of such cognitive tasks (Echeverría and Tabarés, 2017). For example, AI systems can handle customer complaints, automate budgets and expenditure and optimise warehouse logistics. These are enabled through deep ML and neural networks, creating a promising avenue of research within IS (Maedche *et al.*, 2019). The process of IS and context-based interactions enabled through AI is demonstrated in Figure 2-2.

Figure 2-2: Information systems and context-based interactions using AI



Source: Adapted from (Echeverría and Tabarés, 2017; Maedche *et al.*, 2019).

IS as a science, which considers various interrelated facets, can be argued as a core pillar to guide academia such as universities and colleges to effectively integrate technology and enhance innovation capabilities to address the imminent impact on the future of work arising from this paradigm shift (Frey and Osborne, 2013). One key area of research is ICT4D, as it encompasses the analysis on understanding the conditions of social distortions and why they occur in the developing context. More importantly, it notes what can be done differently to contribute to the notion of a better world (Sahay, 2016). ICT4D notes that some reasons for failure to address gaps and develop a better world is a lack of ICT infrastructure as well as a lack of skills (Chipidza and Leidner, 2019).

2.3 ENABLING TECHNOLOGIES OF THE 4IR LANDSCAPE

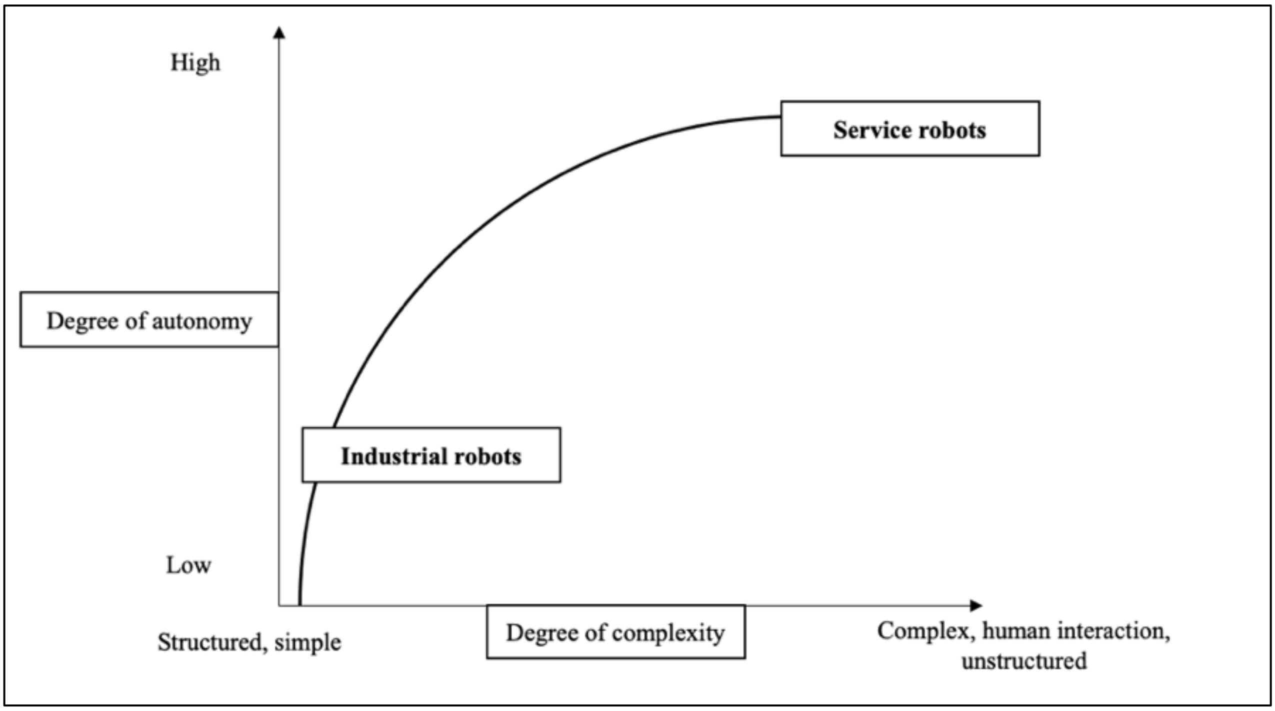
The expanse of technology which drives interconnection and computerised abilities like never before is contended to have been brought about by the 4IR (Bagheri *et al.*, 2015).

This shift is said to encompass a plethora of enabling technological capabilities impacting several domains (Frank *et al.*, 2019). As a result, actors such as business, academia and government are believed to be moving quickly to leverage this movement (Carayannis *et al.*, 2006). In an attempt to formalise the novel technologies currently in place, and to address those being developed, the 4IR is divided into three primary layers (Longo *et al.*, 2017). The physical, connectivity and digital layers. Despite having only three layers, this paradigm shift is complicated due to combination and interconnection possibilities between the technologies which offer coordination between organisations on a worldwide scale (Carolis *et al.*, 2017). This can include new service offerings or insights into activities, not before conceivable (Castelo-Branco *et al.*, 2019).

The first layer is the *physical layer*. This layer consists of technologies that have hardware to detect changes in an object or physical environment to capture data (Oztemel and Gursev, 2018). This pertains primarily to the concept of IoT. The IoT is an innovative paradigm that facilitates enhanced communication between people and smart objects (Sethi and Sarangi, 2017). This is done through inter-connected capabilities of such devices. IoT hardware includes sensors which are able to detect physical changes in temperature, light, pressure, sound or motion (Bauer *et al.*, 2015). These devices are able to conceptualise or gather data from the physical world which can be used for the detection of logical relationships of one object to another in terms of their location or activity (Leitão *et al.*, 2016). A vital aspect of IoT is the associated technology's ability to not only gather this data, but also be interconnected to be able to relay information to a system (Lee *et al.*, 2017). Mobile devices are considered IoT, where mobile applications enable further capabilities of such devices through ubiquitous computing capability. These then also further machine-user interactions to deliver new experiences which can share data (Guo *et al.*, 2017). Research notes that the IoT forms a strong relationship with I4.0, which is the optimisation of manufacturing using emerging technologies of the 4IR, in that they are used to optimise the supply chain, including aspects of manufacturing, logistics and customised production (Lasi *et al.*, 2014). 4IR then is changing industrial ecosystems to highly complex systems, and is now further enabled with IoT, most notably the creation of strong networks (Xu *et al.*, 2018) to provide better efficiency, quality and productivity across several industries (Kaivo-Oja *et al.*, 2017). As a result of this, the sheer volume of interconnected IoT devices is immense. According to Fortune Business Insights (2021), over 1463 billion devices are estimated for 2027, with an estimated 250 billion devices in circulation at the end of 2019. This resulted in an estimated end user spending of around 248 billion United States dollars for 2019. IoT then demonstrates a real business opportunity, and estimates suggest that IoT could grow into a market worth $7.1 trillion by 2020 (IDC 2014).

What is important to note from the physical layer, is there are technologies which can act as feedback mechanisms. This means they can manifest digital aspects or systems into the physical world to carry out tasks (Holler *et al.*, 2014). For this reason, we have seen a surge in robotics development performing various functions (Kaivo-Oja *et al.*, 2017). The first was industrial robots which primarily automate structured and simple tasks. These are usually prioritised in terms of task with automatic execution through explicit programming (Wasén, 2015). However, with AI and IoT providing multi-sensory information and automatic path planning, there has been progress towards service robots. These look to be autonomous agents, which considers comprehensive environmental factors and communicates with it, increasing the possibility to understand and emulate human actions (Rajan and Saffiotti, 2017b). As a result, robots are becoming ubiquitous with exceptional capabilities to mimic human abilities (Kaivo-Oja *et al.*, 2017). Figure 2-3 demonstrates the phase and progression from industrial robots to more complex and autonomous robots, powered by digital systems and innovation.

Figure 2-3: Robotics transitions towards complex interactions



Source: Adapted from (Kaivo-Oja *et al.*, 2017; Rajan and Saffiotti, 2017; Wasén, 2015).

The second layer is the *connectivity layer*. This is where the connection of smart devices stemming from IoT is enabled. To achieve this, various technical communication models and technological principles including 3G, 4G, 5G, Bluetooth, IP networks, WiFi, Radio-frequency Identification (RFID) or Near Frequency Controller (NFC) are being used (Kunst *et al.*, 2019). These are being further enhanced by developers to increase the ability of IoT, or smart devices within the physical layer (Lasi *et al.*, 2014). This layer uses vital aspects of IS principles, as it acts as the platform to enhance and connect devices for interactions between humans and technological artefacts (Sethi and Sarangi, 2017). To govern these various protocols, the International Organisation for Standardisation (ISO) which defines the Open Systems Interconnection (OSI) Model can be used. This aims to ensure cohesion between interacting technologies which relay data (Yemini, 1993). Vast quantitates of data then continue to be produced, where there have been advancements in optimally managing data transfer based on these practices to reduce congestion and drive efficiency towards optimal performance configurations (Kunst *et al.*, 2019; Lidong and Guanghui, 2016).

The final, or third layer is the *digital layer*. The digital layer encompasses the storage, analyses and processing of data that comes from the physical layer through the connectivity layer. This allows systems to provide valuable information to users (Lyytinen and Rose, 2006) to automate decisions and changes to achieve efficiency (Sethi and Sarangi, 2017). Within the digital layer, cloud systems are being developed and improved at a rapid pace, enabling new forms of engagement through various platforms (Castelo-Branco *et al.*, 2019). Cloud systems are data driven applications that allows real-time data processing and access to resources and infrastructure without requiring hardware (Oztemel and Gursev, 2018). Cloud systems are replacing standard fixed servers as they are more flexible. This includes storage, computing, networking, data processing and analytics, application development, ML and even fully managed services (Lee *et al.*, 2017). Since these systems are more than just storage, popular options to support the processing of large data clusters has given users the ability to take advantage of Big Data to optimise functions which were previously not accessible due to cost (Lidong and Guanghui, 2016). Big Data is data that is generated in large quantities at a rapid pace. It is typically too expensive to store, manage and analyse using traditional systems (Oussous *et al*. 2018). By using or combining technologies such as AI and cloud systems to gather and process data (including Big Data), critical operations from manufacturing, logistics, storage and client engagement can be efficiently coordinated and adapted based on information that can now be provided in real time at a viable cost (Qin *et al.*, 2016). With 4IR, new, lightweight mobile sensors through robotics can automate tasks through managed networks where AI programming would manage task allocation, with logical timing to manage aspects within a supply chain (Morgan, 2019).

2.4 OPPORTUNITIES AND CHALLENGES FOR A DEVELOPING COUNTRY

Within the developing world, various opportunities and challenges are believed to exist attributable to the 4IR. Literature shows that the African content, despite being the second most populated continent (1.2 billion people), contributes just 3 percent to global Gross Domestic Product (GDP) (Business Day, 2020; Lee *et al.*, 2018). With regards to 4IR, it is said that the continent is behind. The advantage of this is developing countries within this environment can be solving human problems by finding a technology solution to fit the unique challenges posed and develop the needed skills (World Economic Forum, 2017).

To leverage 4IR technologies and drive adoption across the various layers, actors across Europe and America, which are developed regions, are already channelling significant resources to launch programs that proactively shape this industrial change to create relevant value (Liao *et al.*, 2017). The majority of these efforts are focusing on innovation and its associated activities and value outputs. Innovation is an intensive process that involves certain practices such as ideating, sketching, prototyping and modelling toward creating something new or improving something that exists (Ciriello *et al.*, 2019). To innovate though requires certain skills, especially when considering the future of work attributable to the 4IR (Guerrero *et al.*, 2019). Literature on the future of work is constantly expanding, noting that occupations are changing. For example, a study in the United Kingdom of 3 million roles noted that occupations fell from 366 to 160 between 2001 and 2016. Within these roles, social interactions were also significantly reduced (Morgan, 2019). These changes are argued to go beyond specific industries impacting future products and services, business models, markets and associated labour markets (Autor, 2015; Luz Martín-Peña *et al.*, 2018; Muhuri *et al.*, 2019; Sutherland, 2020).

2.5 INNOVATION

Although advances in IS continue to be paramount, the human aspect should not be overlooked (Dragicevic *et al.*, 2019). This is because people, not systems, drive innovation and realise commercial potential (Sousa and Rocha, 2019). Innovation in this sense is said to be vital to achieve the potential benefits of the 4IR, however, the need to create and realise value is argued to be a vital pillar. Technology transfer and brand value through marketing are some of the forms to achieve this (Cunningham *et al.*, 2019).

As organisations innovate, even in the digital sphere, their ability to do so needs to be improved. This can be achieved through further insights generated from advanced analysis based on Big Data (Schwarzmüller *et al.*, 2018). For this reason, digital transformation has become another topic in literature. It refers to the combined efforts of digital innovation to bring actions and practices that change or complement existing paradigms towards value creation (Hinings *et al.*, 2018). For this reason, 4IR and digital transformation are closely tied together. However, capitalising on prospects stemming from digital transformation and innovation is as much about talent as technology (Ibarra *et al.*, 2018). As a result, concerns about skills requirements have never been higher to ensure sustainability. Literature shows that a major variable within the digital and physical innovation landscape is people, as they are innovators, not machines (Derwent, 2019). To do so, critical skills to not only take advantage of technologies but also reduce work force disparity are needed (Sousa and Rocha, 2019). Within this rapidly changing environment then, the adoption of technologies, whether digital or physical, has changed a fundamental aspect of systems and the people who operate them (von Leipzig *et al.*, 2017). Various research articles have attempted to cover skills needed for this paradigm shift (Blayone *et al.*, 2018; Prince, 2017; Rockefeller Foundation, 2013; Worku, 2015).

The changing scenario and transformations that affect business and government also affects academia, as they are tasked with delivering and upskilling people (Schmitz *et al.*, 2017). Fortunately, there is research on enabling skills needed by advancing the linkage of technologies with people to enable positive innovation outcomes. The main functionality and needs required though is the linkages of skills with developing technologies through new and effective strategies, such as cyberinfrastructure and digital scholarship (Thanos, 2014). Within the higher education environments, the need to support users, irrespective of discipline, arises for them to ideate and test their ideas (Colegrove, 2015). This forms part of the innovation system within institutions as vital actors to address change (Bergek *et al.*, 2008). Evidence suggests that technology is a vital enabler of this movement to innovate; however social aspects and policy also play a pivotal role (Bergek *et al.*, 2008). For this reason, it is argued that important mechanisms within higher education institutions are needed to enhance skills needed for the 4IR. This includes innovation ecosystems (Barbakoff, 2019), where technology adoption is key to innovation. As a result, technology adoption theories are reviewed next.

2.6 RESEARCH THEORIES ON TECHNOLOGY ADOPTION AND INNOVATION

With the vast application of technologies, from ICT to smart technologies of the 4IR, the ability of actors to innovate has created a vast potential for expanding the existing body knowledge. It is argued that the most significant drivers of these includes strategy, leadership, skills and effective guides on the successful adoption of such advancing technologies (Bagheri *et al.*, 2015). Leidner and Kayworth (2006) states that the reason why innovation is successful is effective management, a conducive culture and competencies to leverage knowledge, such as the ability to use and apply technology. Notwithstanding, there are several factors that influences technology adoption towards innovation, where several theories exist to enable effective uptake and application (Leidner and Kayworth, 2006).

Originally, due to the nature of this thesis, it was proposed that a grounded theory research strategy be implemented, as a relevant theory did not exist (Strauss and Corbin, 1998). However, after investigation, this proved to be an incorrect assumption. As the reader will note, there are several theories which pertain to relevant studies on developing, adopting and effectively integrating emerging technologies in IS (Bertot *et al.*, 2016). Furthermore, are the levels of applicability of the theories themselves. It is worthwhile to note that when a theory is presented, it is a generalisable statement aimed at explaining a phenomenon, whereas the model is a specific means of applying that theory. Within each theory, several different models can exist (Easterby-Smith *et al.*, 2012). As a result, the researcher found it pertinent to review key models as well as make notes regarding there contextual relevance and application for this thesis.

Actors have various users within the IS they utilise and technologies which can impact this. This in turn means that perceptions and preconceived notions on the technologies and ability to innovate, as well where such innovation can be fostered can have an impact on adoption (Etzkowitz, 2003). Several adoption models exist which goes beyond only considering limiting factors such as perceptions. The reason why these models are chosen is their impact on the social aspects of 4IR technology adoption and skills required to innovate. This can also include a vital aspect of innovation and technology, and that is deriving value (Kruger and Steyn, 2019). This includes the mechanisms that could foster such innovation (Kruger and Steyn, 2020). Another reason for this is a paper by Bagozzi (2007) where the author indicated that adoption models are reaching a point of fragmentation as new models are being created over existing models in various paradigms. As a result, there continues to be a plethora of models developed. For this thesis, not all theories could be reviewed. Rather, based on previous research, it was decided to note those most relevant to the theories that relate to IS, technology adoption, 4IR, development, integration and innovation. With this in mind, the following models were identified and are structured with (1) name, (2) level of analysis, (3) linkages to other theories, (4) description and ending with (5) relevance to the study.

2.6.1 Actor network theory (ANT)

The level of analysis is applicable to individuals and networks. There are two primary linkages to other theories including the social network theory and socio-technical theory. The actor-network theory (ANT) is based on sociology principles. It was developed by Latour, Michel Callon and John Law, who developed this theory to consider people, objects and the organisation they operate in (Doolin and Lowe, 2002). These parts are referred to as actors. A core concept of these actors is they form part of a heterogenous network, which is a network that contains differing elements. Because it is considered heterogenous, it is said to contain both the human and technical elements, which for the purposes of ANT, are treated as inseparable. ANT then claims that the actors (person, object, and organisation) have various elements, where the societal order impacts the effectiveness of the network itself (Bonner, 2013). The network then is said to collapse if one actor is removed. The difficulty in this is separating the identified elements from one another as these can be extensive. As a result, many researchers have been said to struggle with the selection of elements, also known as the problem of selection (Doolin and Lowe, 2002).

Within the field of IS, Doolin and Lowe (2002) argue that with careful tracing, the ANT is well suited to contextual empirical investigations. This is because researchers are said to need to continuously adopt their stance on the role ICT has to play in various organisations. As such, the ANT which is based in the heterogenous network, is considered a work in progress and not a fixed theoretical position. This can improve the understanding of IS, even as specific as software and methods which represent technologies that have influential socio-technologies of management (Doolin and Lowe, 2002). This extends directly into business as noted by Bonner (2013), where a business of certain elements was specifically analysed to determine how the government influenced data sold which impacted legislation years later.

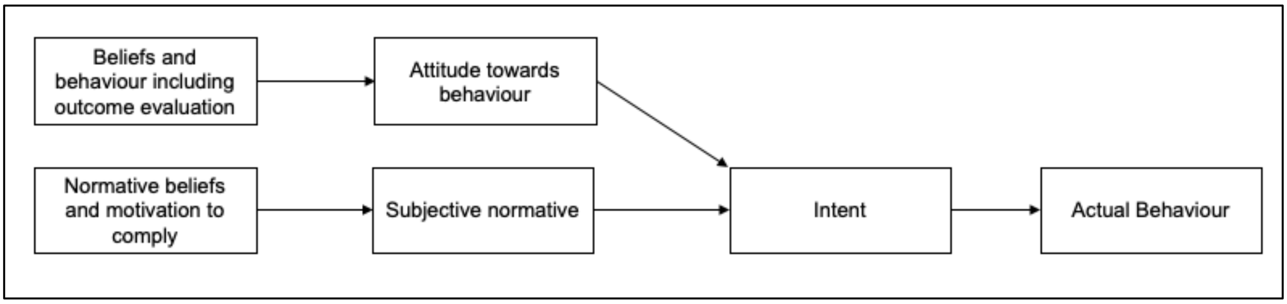
Although this may appear convoluted, the ANT looks to piece together elements of the world the researcher wishes to understand through systematic recordings of sites and documents. This then shows that the researcher needs to find, follow and trace work and actions whilst considering linkages (Bonner, 2013). For this study, there have been forms of innovation using technology despite actors, where they could be removed. Furthermore, the focus is more on the adoption of such technologies and the possibilities that can be achieved through innovation.

2.6.2 Theory of reasoned action (TRA)

The level of analysis is aimed at more an individual level, with other theories including the technology acceptance model, theory of planned behaviour and reasoned action approach.

According to Chang (1998) the Theory of Reasoned Action (TRA), was by Fishbein and Ajzen. It shows that human behaviour is influenced by their attitude as well as the subjective norm of that behaviour. The subjective norm is referred to as the personal belief of what others think about that behaviour (Li, 2020). It aims to explain and predict general behaviour with specific notes to the context in which it is applied. This is because the theory explains that the context in which it is applied will influence the outcome of the actual behaviour. As a result, TRA has seen wide adoption in various fields, including IS and social psychology, as it notes soft skills such as motivation (Sohn and Kwon, 2020a). It must be acknowledged that there are certain underlying assumptions when users adopt and develop ICT and by extension emerging technologies of the 4IR. Based on this, the model is presented in Figure 2-4 that encapsulates the flow of TRA, namely an attitude towards a behaviour and the subjective norm which in general leads to the intent of the action (Chang, 1998). This means that an individual can have certain positive or negative feelings towards a specific behavioural trait, and as a result there are specific consequences that are then evaluated to influence the attitude. These variables then can include the system itself, user characteristics and implementation processes to name a few (Li, 2020).

Figure 2-4: Theory of reasoned action (TRA) model



Source: Adapted from (Chang, 1998).

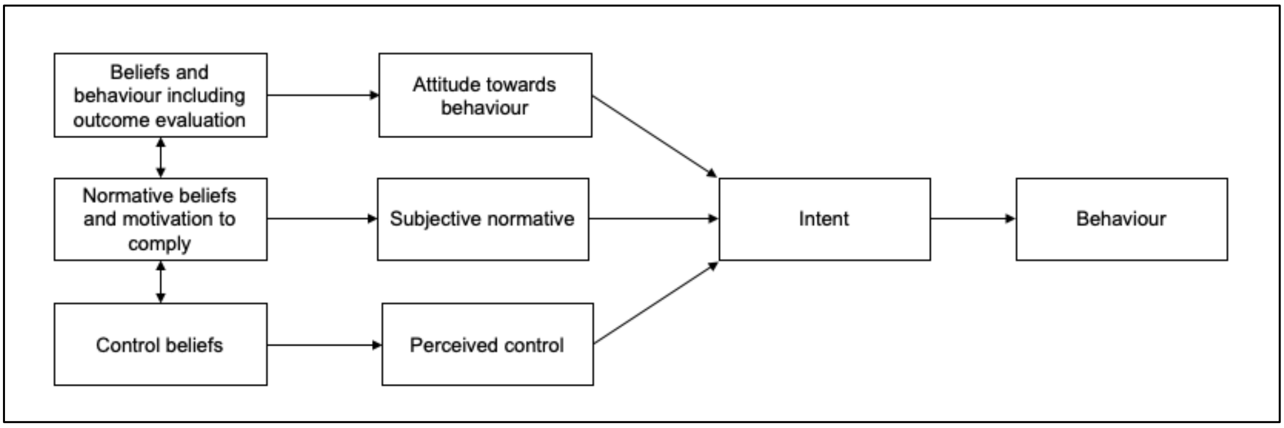
It has also seen usage in ethical behavioural analysis which pertains to certain aspects of this study. From identifying strategies to avoid poor behaviours (leaking confidential data), to adopting new novel technologies such as blockchain (Li, 2020), there is a level of relevance to TRA. Although relevant, this has several limitations, which have been addressed through other models such as the Technology Acceptance Model (TAM) and Unified Theory of Accepted and Use of Technology (UTAUT). This is because attitude and subjective norms do play a part in the successful adoption of technology and influences one's ability to innovate, but there are also other variables (Chang, 1998).

2.6.3 Theory of planned behaviour (TPB)

The level of analysis is applicable to that of an individual and organisation, with linkages to behavioural change. The Theory of Planned Behaviour (TPB) stemmed from TRA as it has added the perceived behavioural control element as noted by Ajzen (2011), as there is a lack of control beliefs and a person’s desire to control. The reason for this extension is the difficulty of identifying the specific action or behaviour which impacts the perceived behaviour control (PBC). The confidence in being able to complete a task impacts the ability of a person to execute that task. PBC refers to the amount of control individuals perceive they have over performed the behaviour. According to Ajzen (2011), the TPB considers the context in which human behaviour takes place to predict and explain those behaviours, which is important to understand complexities of human behaviour. Figure 2-5 notes the additional aspects of TPB which stem from TRA.

Based on the model, the facets of subjective norms and beliefs is not abandoned, rather, the context in which these occurs is considered. For example, according to Chang (1998) normative beliefs and subjective norms could relate to family expectations, however, within an IS context, this could relate to the system and associated management. This means that there will be an effect on motivation, where the behaviour and beliefs should not be overlooked (Venkatesh *et al.*, 2016). This means that people can relate to social groups inside and outside the organisation, which in a developing world context, becomes relevant, as backgrounds can impact the perceived control and thus motivation to innovate using 4IR technologies.

Figure 2-5: Theory of planned behaviour (TPB) model



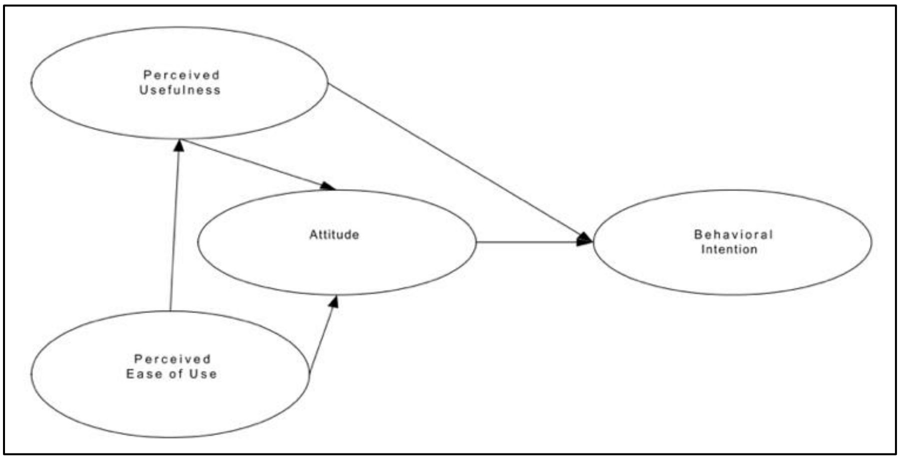
Source: Adapted from (Chang, 1998).

It is important to note that with this general theory, there are various contexts and disciplines to which this can be applied. From losing weight, to attaining a degree, there are various options (Ajzen, 2011). Since the TPB considers context, the importance of this studies context is the specific reasons for technology innovation and development using 4IR starts to emerge, hence why there is a focus on the various possibilities and mechanisms which supported positive outcomes.

2.6.4 Technology acceptance model (TAM)

The TAM model looks to an individual level of analysis. As noted earlier, the TPB theory has ties with the TAM. Founded by Davis (1995), TAM asserts potential adopters' attitudes and expectations towards innovation. This in turn impacts the chances for its adoption (Davis, 1985). According to Straub (2009), there are two concepts stemming from TAM. The first is how innovation is perceived by the potential user or adopter. This relates directly to the Perceived Ease of Use (PEoU) of such innovation's usage, to learn how to use and implement it. The second is its Perceived Usefulness (PU). This relates to how it could improve the user's performance in their personal or work capacity. TAM is presented in Figure 2-6.

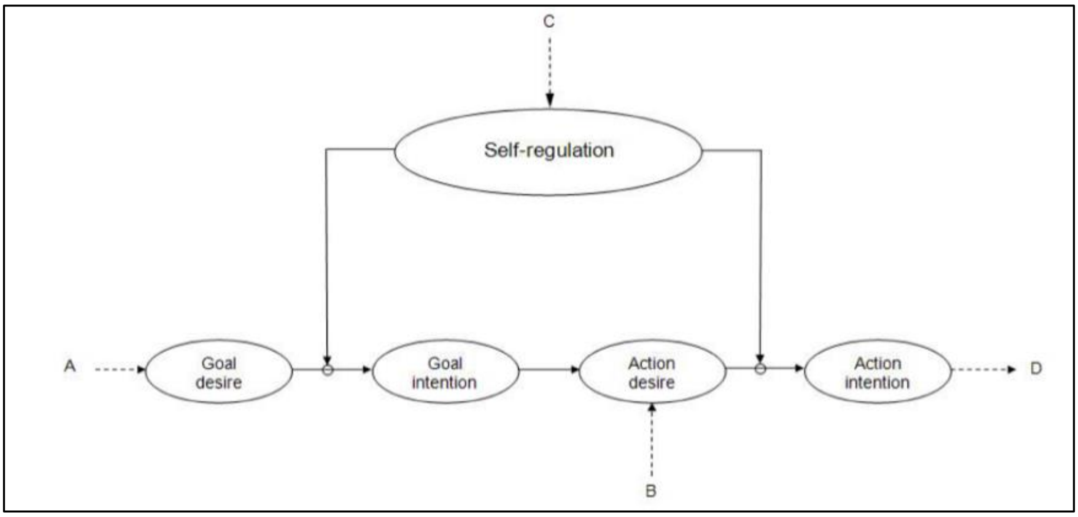
Figure 2-6: Technology acceptance model (TAM)



Source: Adapted from (Davis, 1995).

Of these two elements, Davis (1985) noted that the more useful and relevant the technology, the greater the chance of it being adopted. This in turn could lead to higher productivity and ultimately performance. Important to note is that he argued people would not adopt a technology unless it was perceived as useful, irrespective of how easy it is to learn (Davis, 1985). This was supported later in other studies (Amoako-Gyampah and Salam, 2004; Lee *et al.*, 2003; Straub, 2009), where it was tested in the IS discipline and in schools, businesses and everyday life. TAM then can be used to indicate users' acceptance levels to try new forms of technology, with a focus more on the individual than the organisation (Amoako-Gyampah and Salam, 2004). This directly relates to end-user measurement, adding a social context to ICT and associated emerging technology adoption. TRA and TAM have strong behavioural elements, where there is intent to act and freedom to act, and various constraints in practice (skills, time, environment, resources) impact the freedom to act and adopt (Straub, 2009). Based on this, there was an updated TAM model as shown in Figure 2-7.

Figure 2-7: Technology acceptance model (TAM) in a new paradigm



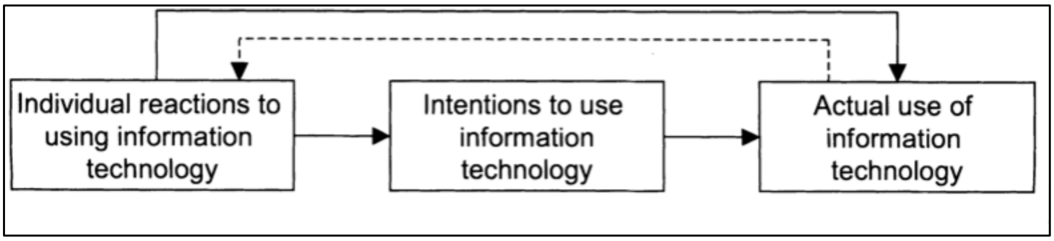
Source: Adapted from (Bagozzi, 2007).

As such, TAM is the PU to adopt a system, where that system is seen as useful. There have been attempts to extend this to introduce various other factors and develop associated models. In a paper by Leidner and Kayworth (2006), the TAM was extended to also factor in the cultural context of the PU and adoption of innovative systems and technology.

2.6.5 Unified theory of acceptance and use of technology (UTAUT)

The Unified Theory of Acceptance and Use of Technology (UTAUT) looks to an individual level of analysis. However, it has been used in organisational contexts. It ties in with TAM, Diffusion of innovation (DOI) and the Deone and McLean IS success model. This theory aims to explain user intentions and subsequent behaviours. The theory looks to four key principles including performance and effort expectancy, social influence and conditions (Sohn and Kwon, 2020a). This then impacts the intention to use the system and base technologies. There are moderators within this construct including age, gender, experience and level of voluntariness to use the system (Venkatesh *et al.*, 2003). This can be seen in Figure 2-8.

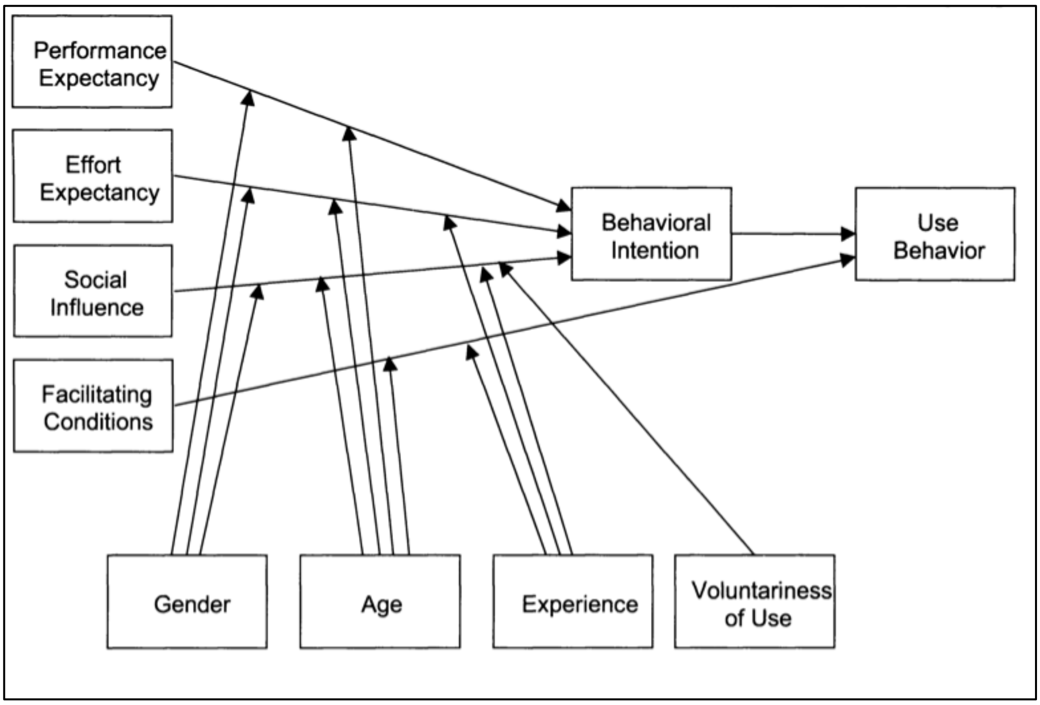
Figure 2-8: Underlying acceptance model for UTAUT



Source: Adapted from (Venkatesh *et al.*, 2003:427).

UTAUT was developed through a review and consolidation of eight models that directly ties into the field of IS where they were used to explain usage behaviour. This included TRA, TAM, Motivational Model, TPB, Model of PC Utilisation (MPCU), Innovation Diffusion Theory (also known as diffusion of innovation) DOI, Social Cognitive Theory (SCT) and a combination of TAM-TPD (Venkatesh *et al.*, 2003). This extensive longitudinal analysis encapsulates various models to deliver a theory relevant to IS, as it considers various behavioural and contextual factors. The outcome of this extensive analysis is shown in Figure 2-9 below, the UTAUT model (Venkatesh *et al.*, 2003).

Figure 2-9: Unified theory of acceptance and use of technology (UTAUT)



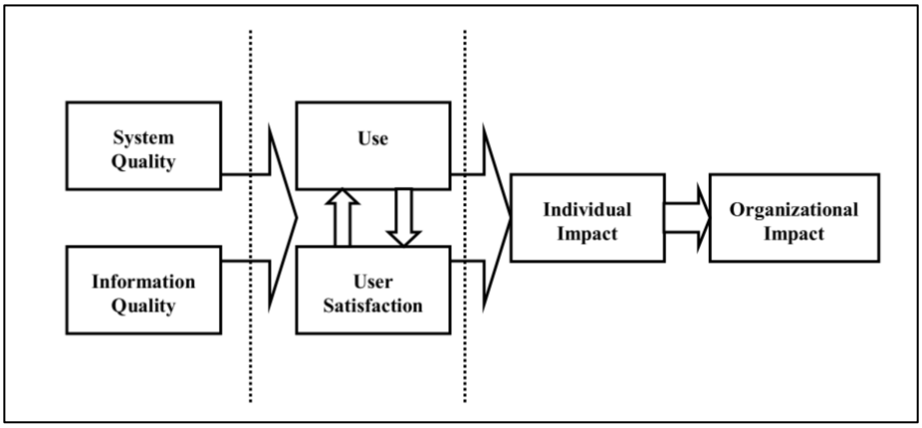
Source: Adapted from (Venkatesh *et al.*, 2003:447).

There have also been arguments noting the limitations of this model. Bagozzi (2007) argues that the model factors in over 41 independent variables for predicting intentions and a further 8 dependant variables for behaviour which could lead to shattered snippets of knowledge. van Raaij and Schepers (2008) noted that certain variables had to be moderated when compared to usage of the TAM due to the grouping and levelling of constructs which could prove problematic. From an IS perspective, UTAUT has the potential to be applied as it considers various aspects of IS and technology adoption (Li, 2020).

2.6.6 Delone and McLean IS success model

The Delone and McLean IS success model looks to both an individual and organisational level of analysis. It ties in with the TAM and UTAUT theories (DeLone and McLean, 2002). This theory is specific to IS which covers various perspectives in the evaluation of IS. There are six main categories classified to create the multidimensional measuring model with independencies in order to identify success categories. Since its development in 1992, there have been further developments to synthesise the newly formed body of knowledge based on this model. As a result, the success component was added to note six interrelated dimensions towards IS success as seen in Figure 2-10 (DeLone and McLean, 2003). This included information, system and service quality, intent to use the system, user satisfaction and the benefits that could be derived (DeLone and McLean, 2003).

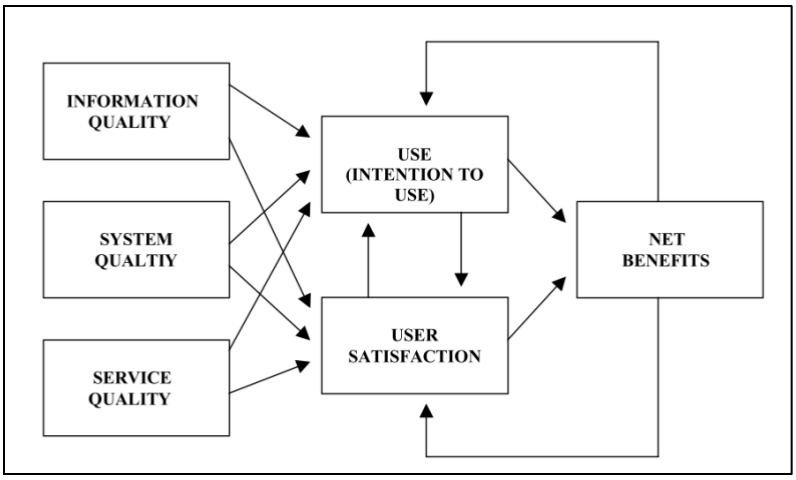
Figure 2-10: DeLone and McLean IS Success model



Source: Adapted from (DeLone & McLean, 1992).

As a result, a system could be evaluated to determine the net benefits of not only the system itself, but the users thereof. After analysis and findings by DeLone and McLean (2002) and Molla *et al*. (2001), an updated model based on various findings was formulated as presented in Figure 2-11.

Figure 2-11: Refined DeLone and McLean IS Success model



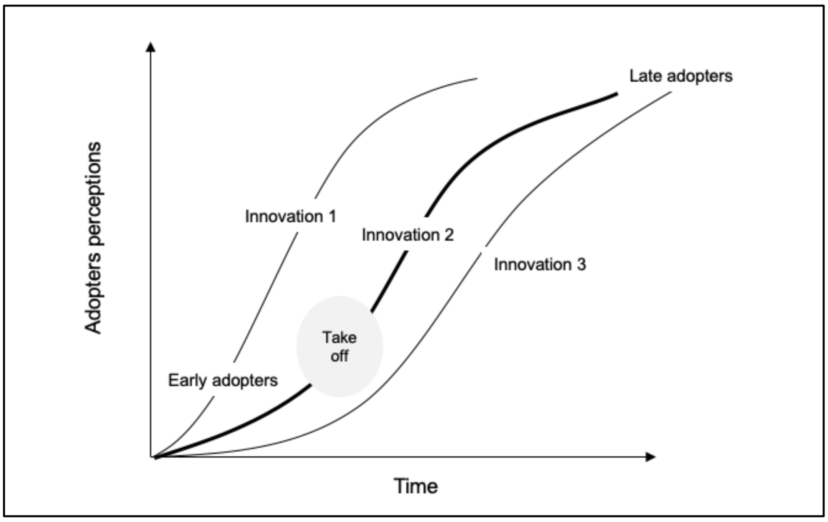
Source: Adapted from (DeLone and McLean, 2003).

The success model then considers actors and their varying opinions on what is defined as beneficial. To develop the net benefits, the context and frame of reference should be defined first. Interestingly, it was noted by DeLone and McLean (2003) that the first model focused on being a useful tool that needed to be tested first. The resulting lack of context was not an oversight, but a choice to test the models' parameters set. The updated model proposes that there are key associations among success dimensions, and the casual relationships should be hypothesised in the context of the study (DeLone and McLean, 2002).

2.6.7 Diffusion of innovations theory (DOI)

The Diffusion of Innovation (DOI) theory can be used to analyse on a group, firm, industry of societal level. It has several links with other theories including TAM, TPB and UTAUT (Rogers, 2003). DOI looks to innovations as being communicated, over a certain time, within a particular system. This system can be social in nature. It was founded by Rogers in 1995 and considers individuals as having varying degrees of innovation adoption, where the population adoption of innovation is normally distributed over time (Rogers, 2003). The level of innovativeness is then determined through segregation based on five categories of innovativeness. This ranges from the earliest to latest adopters of the innovation, which can be technological, method or systems based. These five categories include the following with associated characteristics per Rogers (2003) including (1) innovators, usually educated with multiple sources of information. (2) Early adopters who are popular, educated and lead. (3) Early majority, who take deliberate actions and have varying social contacts. (4) Late majority who have lower socio-economic status and are sceptical. Finally (5) laggers who fear debt and who use close contacts as source of information. This premise though is adopted form Rogers earlier work from 1962, where the Innovation Diffusion Theory (IDT) was introduced. This provided the foundation for the DOI to understand innovation adoption and the factors that influence individuals' choices regarding the adoption or rejection of innovation (Rogers, 2003). Based on this, Figure 2-12 is presented which reviews the flow of adoption assuming normal distribution and iterations of the innovation.

Figure 2-12: Roger's diffusion of innovation (DOI) model



Source: Adapted from (Rogers, 2003).

In order for the adopters to be changed or influenced, there are five stages. (1) Knowledge, (2) persuasion, (3) decision, (4) implementation and (5) confirmation. The knowledge stage looks to establish the existence of the innovation and relating information. This includes the awareness-knowledge (existence of innovation), how-to-knowledge (how to make use of the innovation correctly) and principle-knowledge (defining why the innovation works). To create new knowledge, the individual's attitude must be that to experience and correctly shape this knowledge. The (2) persuasion stage follows the knowledge phase and occurs with the individuals positive or negative attitude towards the innovation. Rogers (2003) states that the degree of uncertainty and those of their peers would influence the adoption. (3) Adoption refers to the *"full use of an innovation as the best course of action available,"* (Rogers, 2003:177) while non-adoption means rejection of the innovation. (4) Implementation is putting the innovation into practice. Technical agents and diffusion occur here, as well as reinvention so as to be modified for adoption. The final stage, (5) confirmation, is where the individual looks to support to confirm their decision to adopt. With this in mind, the adoption curve follows a cumulative path which represents the rate of adoption through these phases. This can be influenced by five key factors, namely relative advantage, compatibility, trialability, observability, and complexity (Rogers, 2003). Relative advantage refers to how much greater or lesser the benefits of the innovation are compared with the alternatives in the market. Compatibility is the fit of the innovation into the potential adopters' processes or work. Trialability is the perceived access to testing of the innovation towards adoption. Observability is the opportunity to see the innovation adoption within the environment by others, driving the adoption curve for others to see and adopt accordingly.

The more difficult to learn and implement an innovation is perceived to be, the less likely it is to be adopted, which is usually due to high levels of complexity as perceived by the user (Rogers, 2003). When looking at IS integration, several changes and factors have impacted models, as can be seen in Figure 2-13 per Baskerville and Pries-Heje, (2003).

Figure 2-13: Roger's diffusion of innovation (DOI) model applied to organisational IS

<u>Source</u>: Adapted from (Baskerville and Pries-Heje, 2003).

Many personal technologies such as smart phones and watches which form part of IoT, and as an extension integrate into our lives as part of 4IR are also considered innovative adoptions. Because of DOI's overlap with TAM, it is likely also vulnerable to semantic theory of survey response. Despite this, the DOI theory of Roger is broad in the scope of its application. This lends itself to being flexible in its adoption across various contexts.

However, it can also be difficult to use a process model towards effective technology adoption as stated by (Straub, 2009).

2.6.8 Overview of theories

To properly investigate this paradigm, a sound understanding of existing models was required. As noted earlier, the researcher assumed that due to the newness of the 4IR, a completely new theory was required. However, during the investigations, it was found that various theories already exist that consider IS, innovation, technology adoption, ICT and the context in which these are adopted. The models are reviewed in Table 2.1, to demonstrate to the reader the theories in place, and aid in indicating why certain models were selected in certain contexts later in the thesis. The table includes the model, level of analysis, description and core constructs.

Table 2.1: Overview of theories for this study

Model	Level of analysis	Description	Core constructs
Actor network theory (ANT)	Individuals and networks	Heterogenous network where actors form part and influence this network	Actors with elements of person, object and organisation
Theory of reasoned action (TRA)	Individual	Human behaviour is influenced by the beliefs and subjective norms	Attitude towards behaviour and subjective norm
Theory of planned behaviour (TPB)	Individual and organisation	An extension of TRA, this has added the perceived behavioural control element	Attitude toward behaviour, subjective norms and perceived behavioural control
Technology acceptance model (TAM)	Individual	Asserts potential adopters' attitudes and expectations towards innovation	Perceived usefulness, perceived ease of use and subjective norms
Unified theory of acceptance and use of technology (UTAUT)	Individual (Several articles have used it on an organisational level)	This theory aims to explain user intentions and subsequent behaviours. The theory looks to four key principles including performance and effort expectancy, social influence and conditions	Performance expectancy, effort expectancy, social influence, facilitating conditions, gender, age, experience, voluntariness and behavioural intention
Delone and McLean IS success model	Individual and organisation	This theory is specific to IS which covers various perspectives in the evaluation of IS. There are six main categories classified to create the multidimensional measuring model with independencies in order to identify success categories	Information, system and service quality, intent to use the system, user satisfaction and benefits
Diffusion of innovation theory (DOI)	Group, firm, industry and societal level	Considers individuals as having varying degrees of innovation adoption, where the population adoption of innovation is normally distributed over time	Relative advantage, compatibility, trialability, observability, and complexity

Source: Adapted from (Ajzen, 2011; Amoako-Gyampah and Salam, 2004; Chang, 1998; DeLone and McLean, 2002; Doolin and Lowe, 2002; Straub, 2009; Venkatesh *et al.*, 2003).

2.7 ETHICS AND TECHNOLOGY

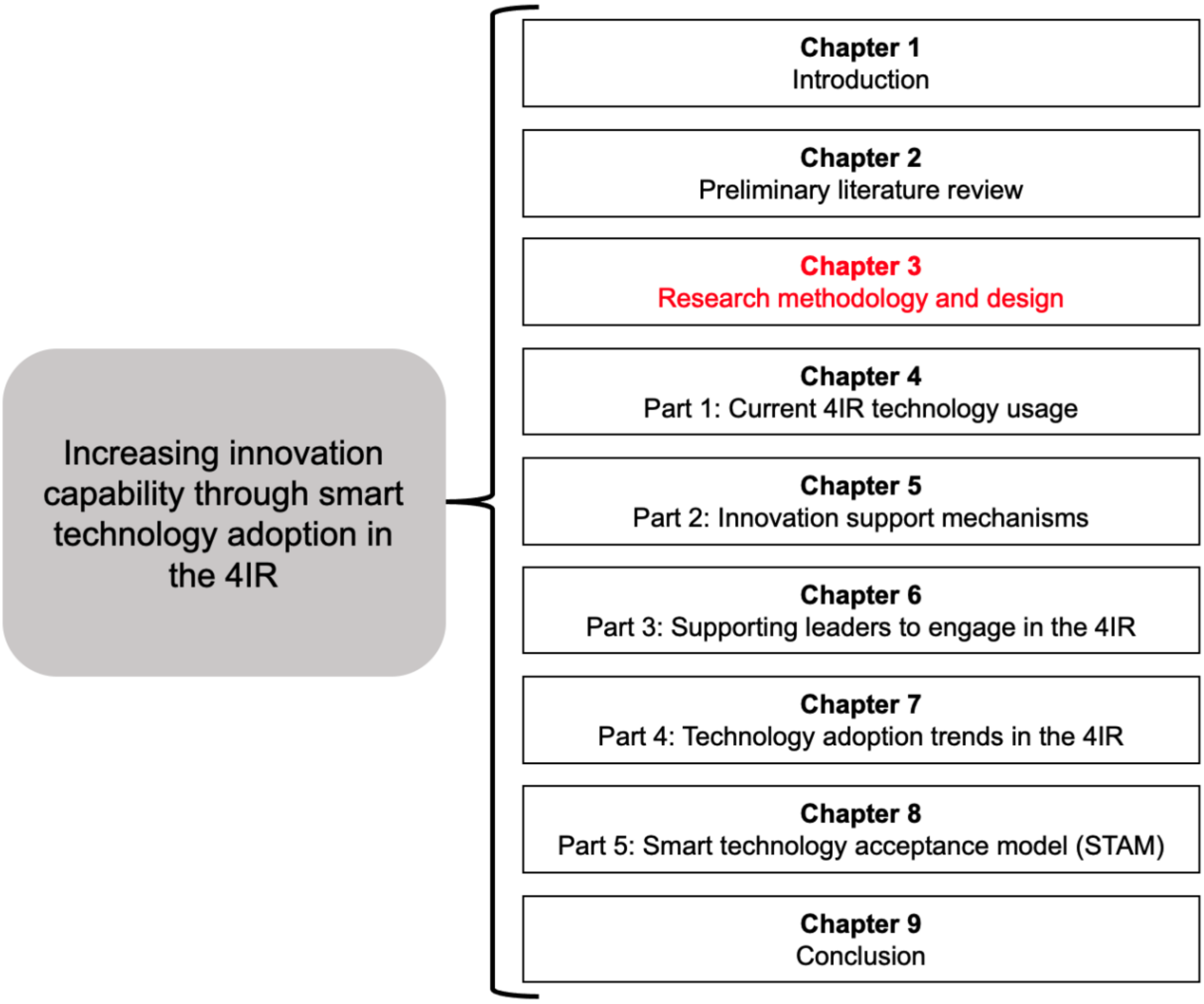
It is not yet clear exactly what the social impact of advanced 4IR technologies such as AI will be. It is said to be an evolving phenomenon, one that has the potential to fundamentally alter the meaning of work and, indeed, our global economic system (Quacquarelli, 2019; Xu, David, *et al.*, 2018). Despite the enthusiasm, potential benefits and increase in usage, challenges remain (Winfield and Jirotka, 2018). In certain instances, these challenges could widen gaps of poverty and unemployment. The effective adoption and governance of smart technology could be one way to mitigate this. This becomes especially challenging in developing economies, where the workforce skills and organisations capacity to adopt technologies has been hampered (Kaivo-Oja *et al.*, 2017). Another apparent issue, or darker side of AI, is the system's capacity to make unfair, or even discriminatory decisions (Rehman *et al.*, 2019). This extends to make or replicate biases and behave in unexpected ways. This becomes highly problematic in sensitive environments which places human safety or well-being at risk. In response to this, pressure is intensifying to make AI systems and their associated algorithms fair and transparent (Winfield and Jirotka, 2018). In so doing, they aim to make them accountable for the decisions made. This is especially true for robotics and physical devices (Keller, 2018). For example, Pepper the service robot autonomously decides which emotion a human is experiencing. However, what if this is done incorrectly because of the race of an individual? In a direct attempt to address this being done openly, the European Union (EU), which is primarily a group of first world countries, has formulated and effectively implements their 1995 Data Protection directive to help individuals right of access or demand knowledge of the logic involved for automated decision-making systems (Kaivo-Oja *et al.*, 2017; Rossi, 2018). However, their associated mechanisms which manifests physical outcomes such as robotics should not be considered in seclusion. Moreover, incorporation of standards into contextually relevant aspects for developing regions is required (Hasselbalch, 2019; Voss, 2016).

2.8 CHAPTER CONCLUSION

This chapter considered previous literature on the 4IR, what it encompasses, including a logical layer structure, what it enables and the rapid advancement it offers business. Within a developing world context, which in general is said to have been left behind, new opportunities were identified that offer needed advancement. In this scope, the future of work skills, automation and the role IS have in this paradigm were also reviewed. To support innovation, the technology adoption theories to do so were reviewed from a theoretical and investigative lens. Finally, a brief overview of ethical considerations was noted. This information was used as the basis to develop the research questions of the thesis as stated in Chapter 1.

In the next chapter, Chapter 3, the research design for each part of the five results areas are addressed. This is followed by the seven articles created to address the research questions. The conclusion, references and appendices are then presented.

3 METHODOLOGY AND RESEARCH DESIGN



3.1 INTRODUCTION

Methodology in research provides a structured approach to achieve a certain goal. Although an area that has caused dismay to many researchers, if well managed, can ensure a coherent and thoughtful overview of what was investigated and how the results were achieved. Within research, the methodology allows a researcher to discover new knowledge or test pre-existing claims in an efficient and reliable manner (Saunders *et al*., 2016).

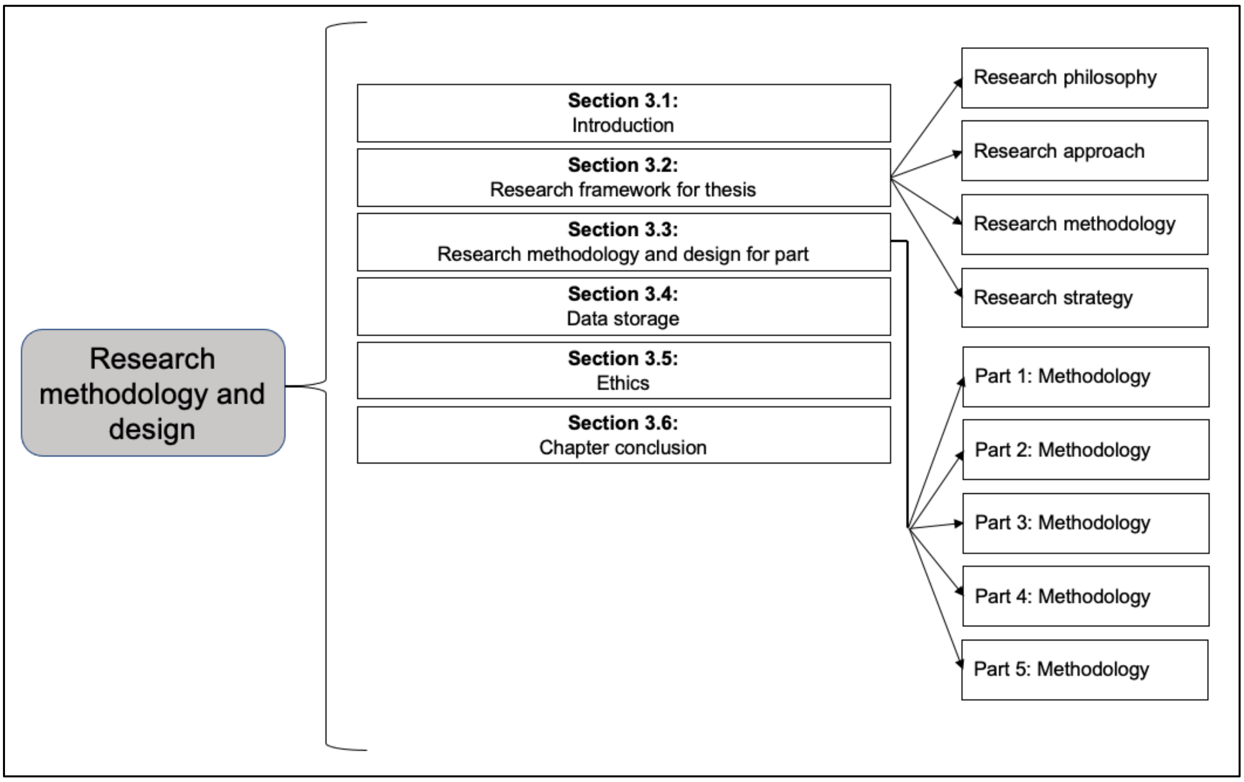
In this chapter, the methodology used for the thesis to address the research questions is presented. This includes the research framework of the thesis that is based on Saunders *et al*. (2016) research onion. The purpose of which is to develop and present to the reader a model that can support the development of innovation capabilities using smart technologies of the 4IR. For this thesis, the conceptual model (STAM) needs to have theoretical applications globally, but for developing regions such as SA, it needs to be empirically tested. The reason for this is to provide a practical guide and needed insights to leverage the 4IR and its possibilities while adding research to the non-western orientated environment. As a result of this, it was decided to break up the investigation into five parts that are presented in article format. Consequently, seven research articles were developed, where each part contains specific articles that addresses one of the research questions of the thesis. In so doing, each part provides a well-rounded answer and insights needed to address each research question. Using this research design approach allows the reader to see how the thesis addresses each research question in the subsequent parts that follow. Thus, the researcher aims to provide a more digestible approach whilst ensuring that the main argument is easier to follow. To this end, each part is presented in turn, showing how the results of each were reached. This is done for the reader to reach a logical conclusion and note the primary contribution of each, and how they integrate to deliver the conceptual model which is presented in Part 5.

The researcher must note, that despite presenting the five-part argument in order, a major concern was raised. This was that there may be a sense of disjointedness in terms of methodological approaches. This chapter aims to address this by clarifying the methodological flow of the thesis, and how each part leads onto another to formulate the conceptual model. To this end, the overall research framework based on theoretical principles is shown first. This contains the research philosophy underpinnings which is explained in detail. Then each parts methodology in turn is reviewed that includes the respective study's data collection, analysis and overall research strategy.

A key characteristic of this thesis is that it provides varying levels of analysis on current occurrences and trends in the South African region pertaining to the 4IR. By applying the research value of each study, the respective contribution of each is shown. A starting point to which is Part 1, that investigates a technology adoption case in the region of SA. Additionally, the thesis reviews tangible mechanisms in the region that can used to achieve this, which is addressed in Part 2. The researcher mentions that these instances are not short-term academic experiments, rather, they offer sustainable channels and tools that align with successes internationally. Moreover, it offers insights into such mechanism's usages even during the pandemic. Part 3 offers the reader a case to support leadership, as this was identified as crucial in Part 1, Part 2 and the literature review. While investigating Part 1, Part 2 and Part 3, technology adoption remained pivotal in assessing the effectiveness of how smart technologies are used, even in the emerging 4IR paradigm. However, with the varying levels of analysis and plethora of mature literature, it was noted that current trends on models and constructs on varying levels remained unclear. This led to the development of Part 4 that used a systematic literature review to provide needed insights from a global perspective. Part 5 can be considered the primary contribution, as it encompasses a larger assessment and the development of the conceptual model that can be used by leadership. The need of which was noted in Part 3.

Another defining characteristic of this study is the use of technology adoption principles and development of models. Part 1 produces a conceptual framework based on the TAM model. Part 2 produces a support mechanism model based on the TAM and UTAUT model. Part 3 applied the TAM and UTAUT2 model. The researcher, following the action research approach developed their understanding and application of these models. From this progression, the need to identify what global trends in terms of model applications was occurring, leading to Part 4. Part 5 uses this knowledge to produce the conceptual model, but also empirically test its validity. The overview for Chapter 3 is presented in Figure 3-1, guiding the reader on the process followed for the overall thesis. To this end, it demonstrates that sound principles were used to ensure that a coherent argument was formulated, based upon the need to address the research questions.

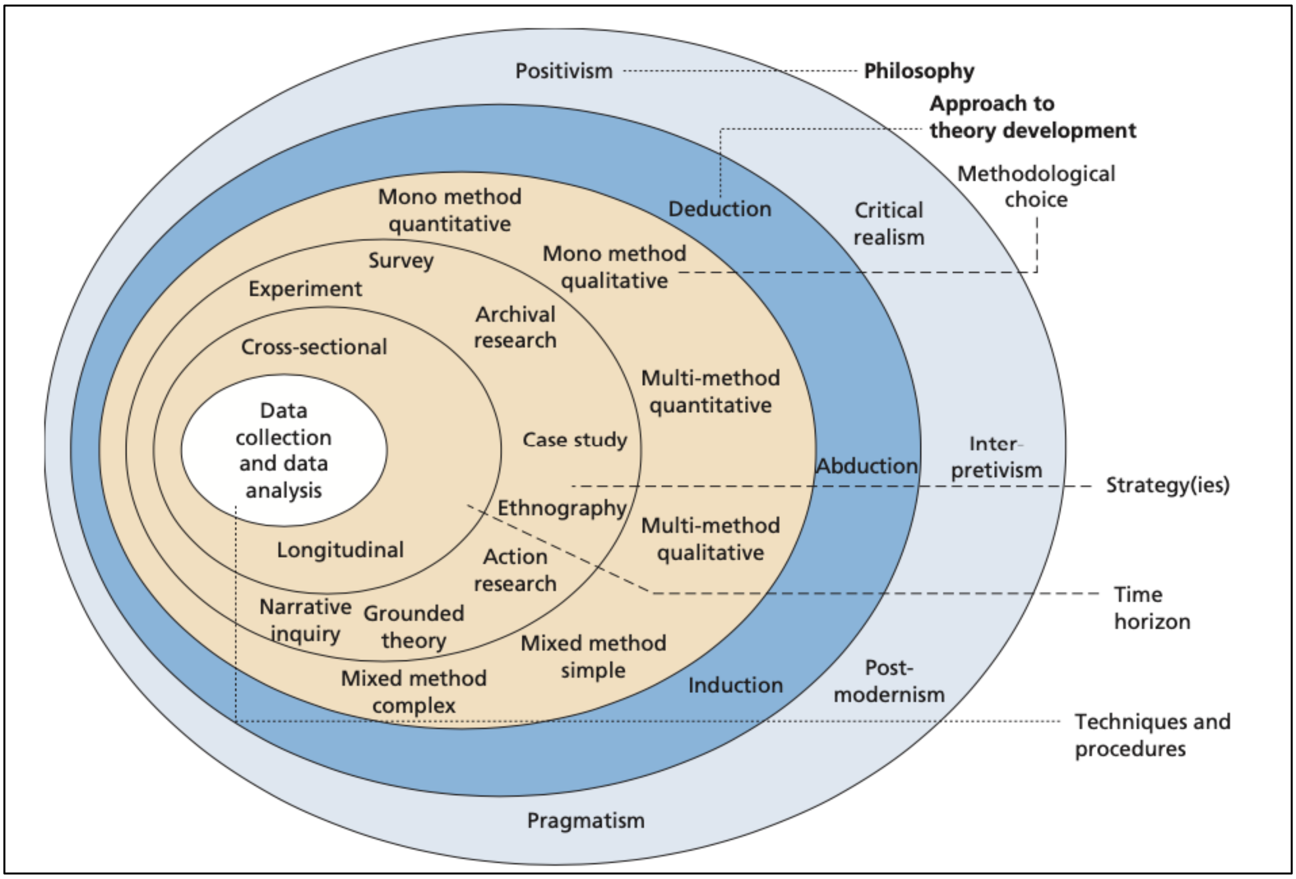
Figure 3-1: Overview of chapter 3



3.2 RESEARCH FRAMEWORK FOR THE THESIS

There are several facets associated with an effective research methodology. To tie concepts together in a coherent output which can add value, many researchers look to a research framework. Following Saunders *et al*. (2016), this thesis uses the research onion, as each layer of the onion integrates with the next to create a formal structure. It can be argued that the elements, or principles used within a research framework have different focus areas. However, they are related to one another. As such the appropriate selection impacts the overall outcome of a study. Consequently, a holistic viewpoint is taken, and each layer leads to the core of the research, ultimately, to address the research problem as shown in Figure 3-2. This includes the research philosophy adopted, which in turn impacts the approach to theory development. For this thesis, there is one overarching research philosophy. The subsequent methodological choice and research strategy for the thesis used to develop the framework is then shown (Saunders *et al.*, 2009). However, the reader will note that each part is addressed on its own merits in terms of the approach identified and how findings of each article were formulated to address each respective research question.

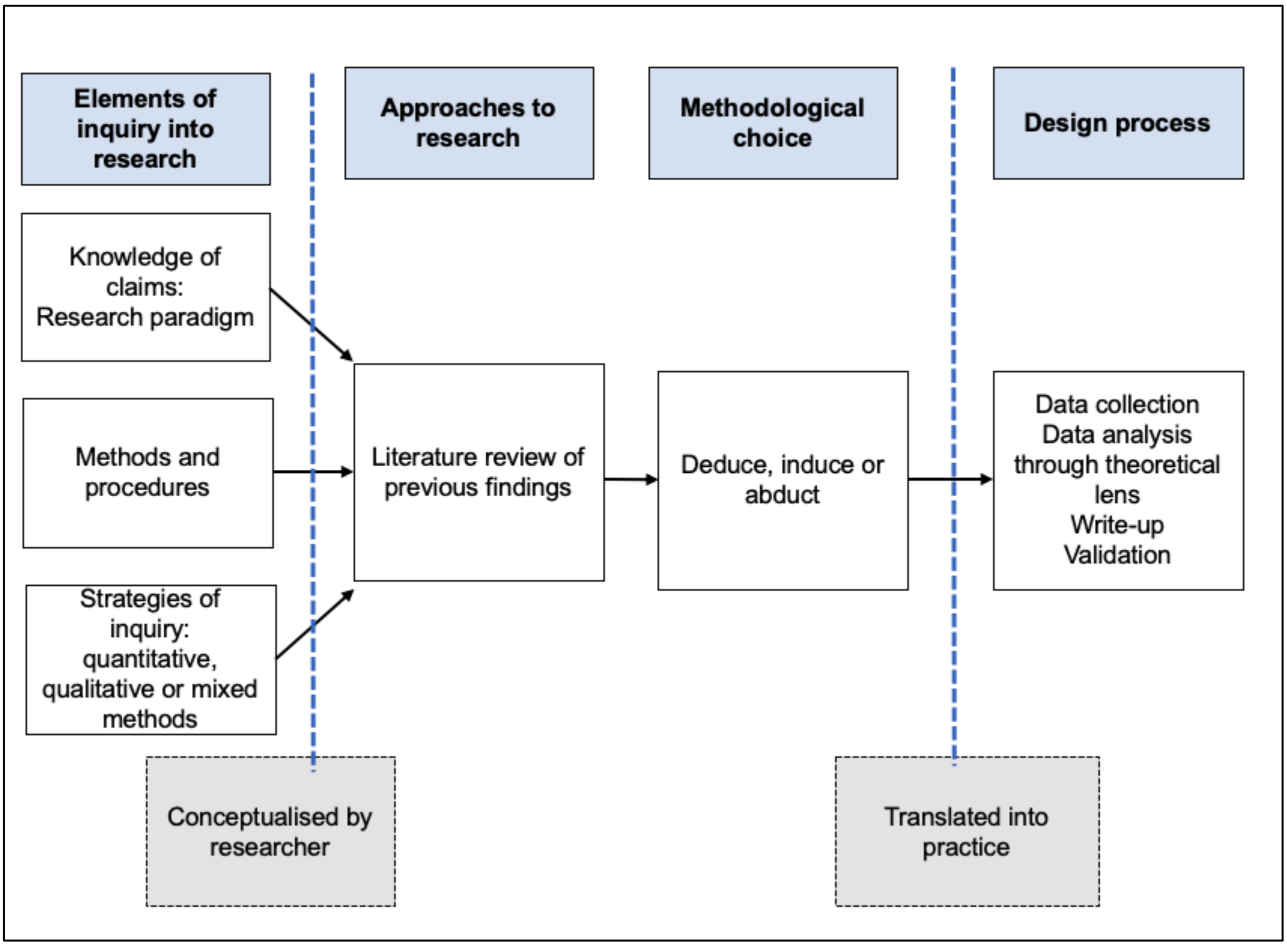
Figure 3-2: Research onion framework



Source: (Saunders *et al.*, 2016).

Figure 3-2 demonstrates logical principles which together form a research framework. However, arguments remain regarding the terminology between scholars' regarding frameworks, where authors differ on meanings. Crotty (1998) states that researchers encounter arrays of methods, methodologies, frameworks or concepts. This could mean that there is no articulated method available to researchers to structure or order their research. Based on this, this thesis accepts that the research onion proposed acts as a logical guide to create a coherent research methodology. It is accepted that alternative frameworks do exist that can be used to suit research, where one element informs another. These are not argued to be less effective in any way, rather, that the framework selected eases the understanding for the researcher and by extension, the reader (Sreejesh *et al.*, 2008). This is because pre-designed frameworks have structural integrity and are considered academically sound (Saunders *et al.*, 2016). This is further supported by Creswell and Plano (2007). An adaptation of this is applied to this thesis, resulting in a logical strategy as shown in Figure 3-3, where the researcher aims to conceptualise thoughts and translate this in practice.

Figure 3-3: Strategy of inquiry and methods leading to the design process



Source: Adapted from (Creswell and Plano, 2007; Feilzer, 2010).

Based on the above figures, there are logical layers which follow one another for this thesis. Each is dependent on the next and all form part of the research onion with the goal to produce a sound research methodology. The first part of this framework is the research philosophy which is discussed next in detail.

3.2.1 Research philosophy for the thesis

To address the research questions, and as stated in Chapter 1, this thesis adopts a *pragmatic philosophy, or pragmatism*. The reason for this is that it allows the articulation of the researchers' beliefs about the reality of this study. The paradigms theoretical framework belief system focuses on practical and applied research and allows for the integration of different perspectives to help interpret data (Peffers *et al.*, 2018). With this ability, the focus is on addressing the research questions. As a result, the researcher can focus on the questions, and not on the restrictive nature of other paradigms (Biesta, 2010; Saunders *et al.*, 2009).

With regards to alternative paradigms such as positivism, although a sound philosophy, the researcher contended that it does not apply to this thesis, as there are varying primary cause-effect relationships between phenomena to be determined. In this instance, prediction in terms of certainty is not the aim. Moreover, because of the plethora of variables which could impact the thesis because of the complexity and idiosyncrasies of people who innovate in various environments, a heavily experimental paradigm would not have been suitable (Rehman and Alharthi, 2016; Saunders *et al.*, 2009). The interpretivism paradigm could have been a relevant paradigm for this study as well, as the socially constructed realities are seen as created (Goldkuhl, 2012). This is because the data and analyses are done through the 'lens' of the researcher. With the goal of interpretivism to understand social phenomena in their context, it further related to this study (Walsham, 2006). However, a limiting factor in this paradigm was the focus on varying data points, making this philosophy less than optimal from the researcher's perspective. Based on these arguments, the researcher adopted the pragmatic philosophy throughout the thesis.

In this regard, the reader should be made aware that a research philosophy rests on four key principles. Including the "ontology", which refers to the nature, or beliefs of our reality. The "epistemology", which refers to the process by which knowledge is acquired and validated, and in this sense, refers to what constitutes acceptable knowledge. The "axiology" is the role the researcher plays in the research itself (Saunders *et al.*, 2009). For this study, the pragmatic approach was found to be most relevant, as the focus point is answering the research question. Table 3-1 summarises the four principles of the research philosophy selected, making notes and inferences of the study to each respective principle.

Table 3.1: Overview of the pragmatism research philosophy applied to this study

Principle	Pragmatism Philosophy
Ontology	For the pragmatist research philosophy, this is usually an external view, which exists through human action. This symbolic realism looks more to the human experience, considering the associated actions and changes. In terms of belief, it aligns with the researchers focus on the research question. It is suggested that it is more appropriate for a pragmatist to think of the philosophy adopted as a continuum rather than opposing views. For the study, it considers the problem and domains of solutions.
Epistemology	The knowledge that is considered valid within pragmatism is not restricted to explanations (a fundamental form of positivism) or understanding (a critical form of interpretivism). However, prescriptive, normative and prospective forms of knowledge are considered vital to provide guidelines, suggest likelihoods or exhibit values which aligns with this thesis. In essence then, the thesis is concerned with problem resolution.
Axiology	The researcher is engaged within the change and is involved in the inquiry. As such, the researcher is in some way part of reality to create knowledge for a controlled change of that reality. For this study, both an objective and subjective point of view of the situation can be adopted for the situation. In this thesis, the view taken depended on the respective part. However, the primary agent to solve the problem was the researcher.
Data collection technique	Aligning with the pragmatism paradigm, a multi-method (simple design) is used to address the research question. This was one of the first starting points in selecting this paradigm, as there is not a restriction based on the philosophy, and that the researcher can be involved in the research to create valuable outputs and address the question at hand.

Source: Adapted from (Biesta, 2010; Dewey, 1931; Goldkuhl, 2012; Morgan, 2014; Saunders *et al*., 2009).

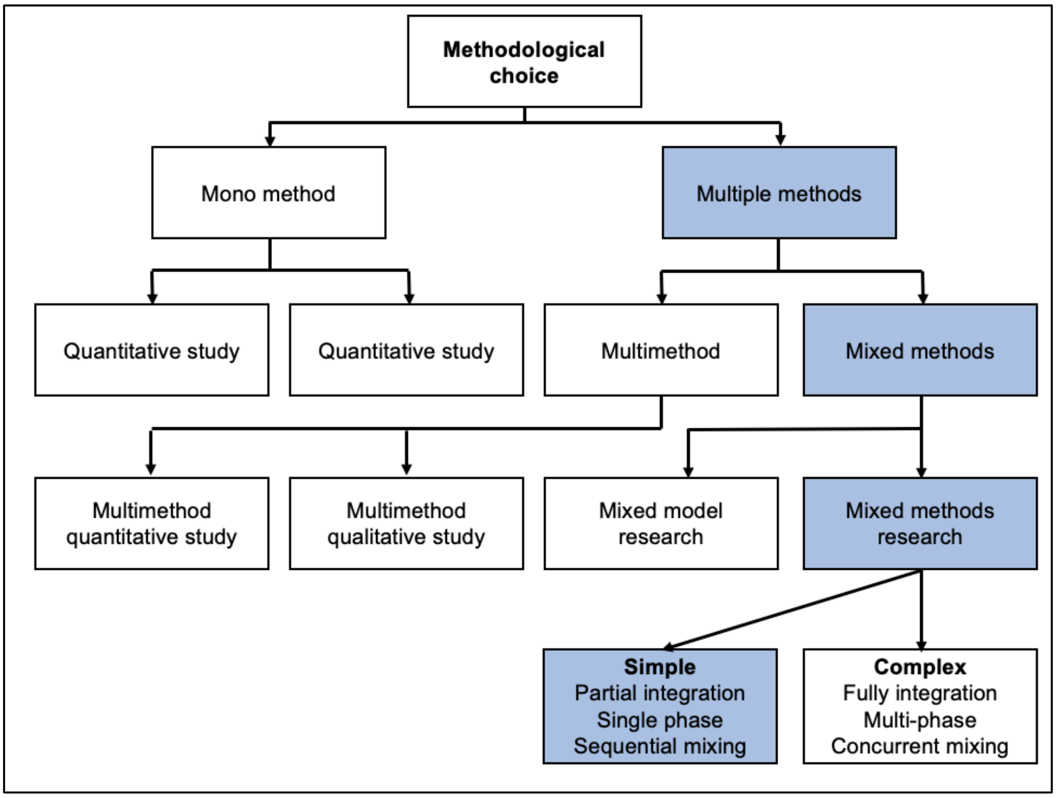
3.2.2 Research approach for the thesis

First and foremost, following the pragmatic research philosophy, where the focus is addressing the research questions, there are specific research approaches applied to each respective part. For example, the case studies look to specific examples towards a more generalisable approach. In Part 5 however, the study is based more on the deductive approach. Consequently, for the overall thesis, the *abductive* research approach is applied. This is attributable to the premises used to create testable conclusions and move towards theory development. Furthermore, unlike deduction that moves from theory to data, or induction which moves from data to theory, abduction effectively combines these two approaches as is the case in the thesis. As a result, it goes on the principle that an observation is identified and then a plausible theory is developed using data. Although the overall thesis follows a strong deductive approach, where there are investigations of theory that are then tested with data, there are practical considerations required for the region where the model is tested, making the abductive approach more applicable. Furthermore, it aligns strongly with the philosophical underpinning applied to the thesis.

3.2.3 Research methodological choice for the thesis

For the thesis, a *simple mixed method* is used. The reason for this is to answer the research questions posed and combine the resulting articles to create the innovation framework. Case studies adopted use primarily qualitative data. However, in certain instances, technology adoption principles used quantitative data to ensure effective synthesis of results. As a result of this, Figure 3-4 is presented, showing the flow of methodological choice to obtain the needed data based on Creswell and Plano (2007) for the overall thesis.

Figure 3-4: Methodological choice for this thesis



Source: Adapted from (Saunders *et al*., 2016).

3.2.4 Research strategy for the thesis

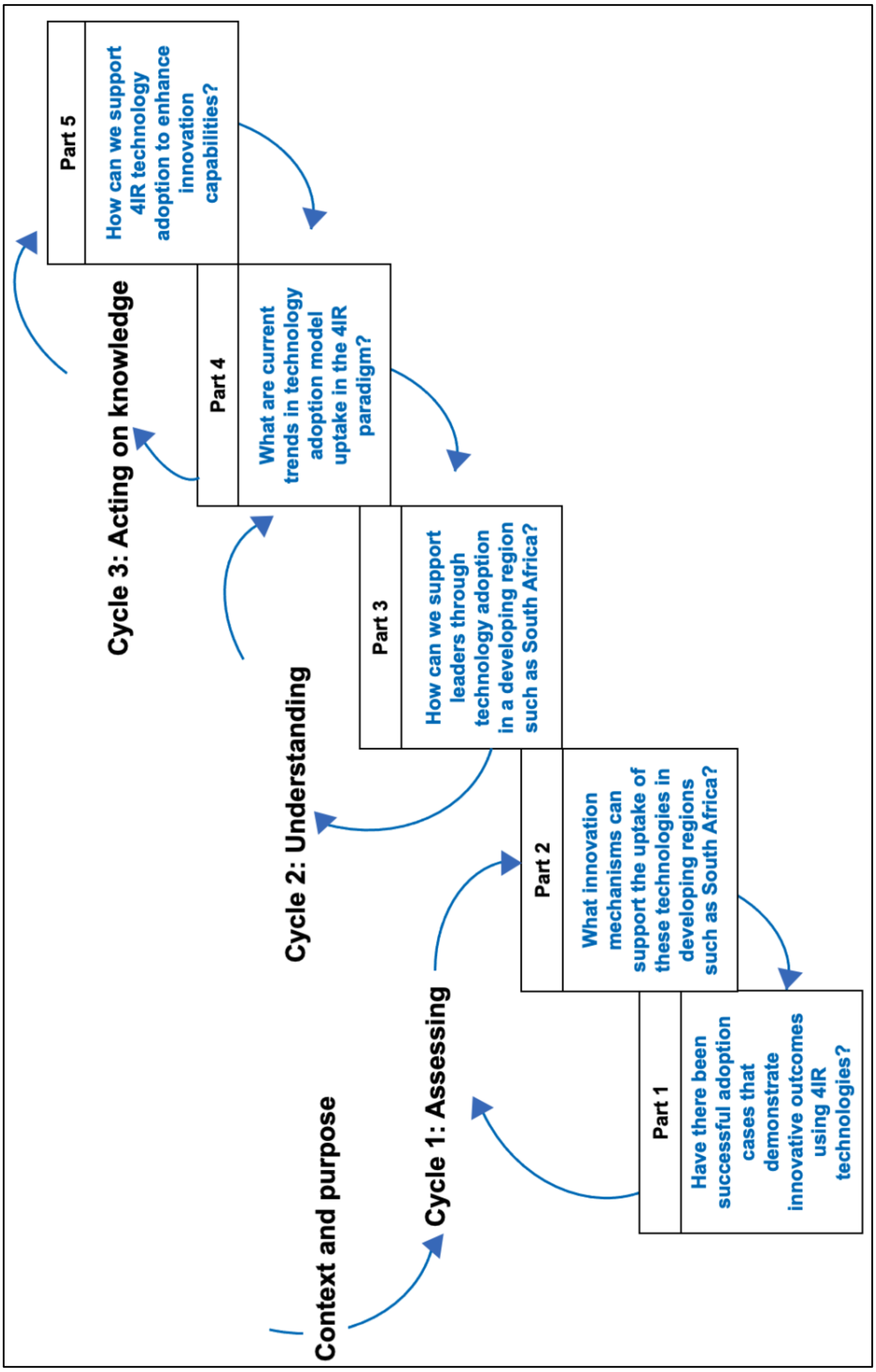
The research strategy selected for this study, as guided by Saunders *et al*. (2016) research onion is *action research*. The reason for this is the iterative processes it facilitates, and the development of practical solutions. This aligns with the purpose of this thesis, which is to develop insights through several contributions to support leaderships understanding in academia, government and business on the 4IR and smart technologies it brings.

Action research itself is unique to IS, as research informs practice and vice versa. The aim of which is to effect change and intervene in a problematic area. In this thesis, supporting innovation using emerging technologies that stem from the 4IR paradigm. There are 16 action research methods overall. For this thesis, the Network of Actions (NoA) was used, at it aligned most to the overall thesis's strategy. The strongest reason for this action research approach was that the paradigm shift is constantly changing, and sustainable solutions is required (Davison *et al.* 2021).

To do so, the thesis is built on contextual data from multiple sources, where each of the five parts provides information to address the respective research question as shown in Figure

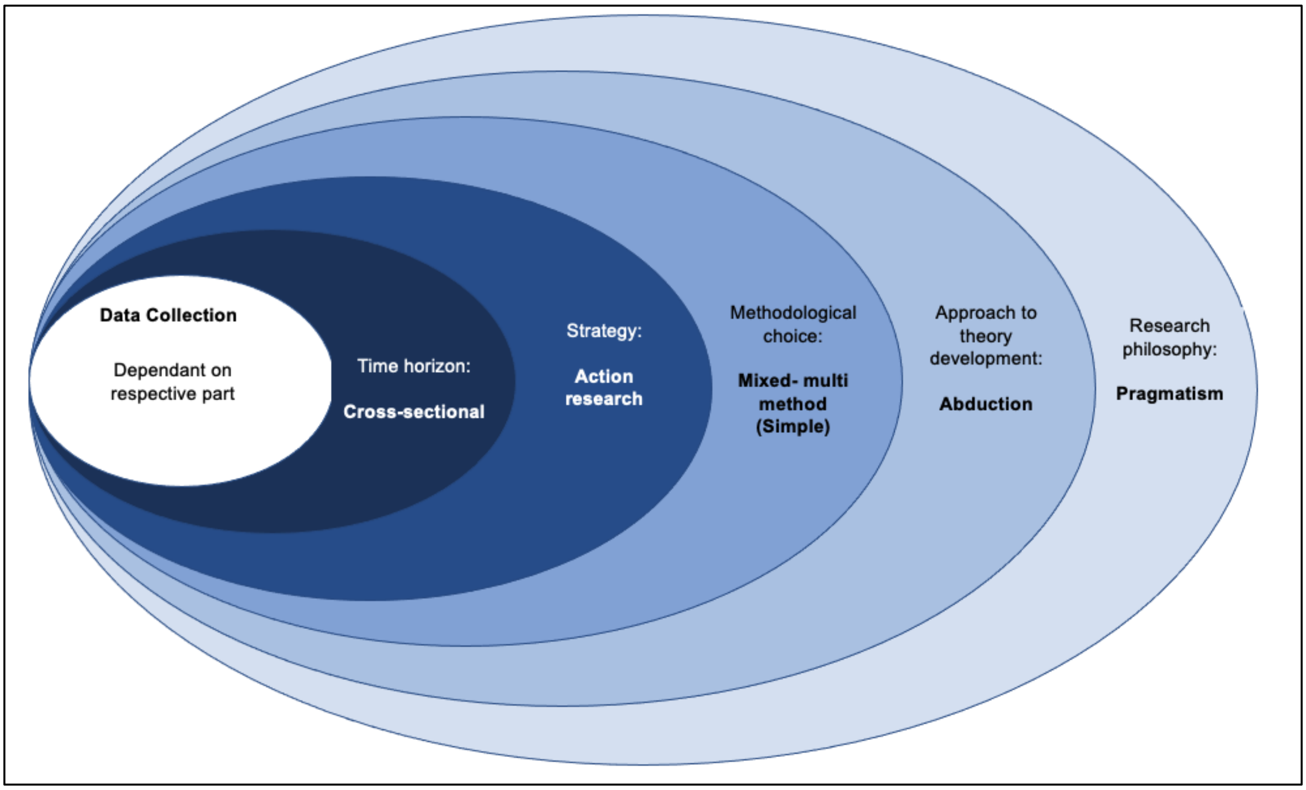
3-5. The first step as such is developing the research question. After which, aligning with action research, is diagnosing current issues or identifying possibilities which Part 1 addresses. Part 2 assesses possible solutions, in this instance, support mechanisms to innovate within the 4IR. Part 3 assesses the action to support leadership in this regard. From this action research, a gap was noted, and that was determining which of the theoretical trends in the 4IR are mostly used, as well as their application. This resulted in the development of articles in Part 4. From this, Part 5 combines global trends to develop the conceptual model. This is then tested in SA empirically. At the basis of this model is technology adoption and associated theories that have seen significant uptake and application in this paradigm (Vega and Chiasson, 2019). The reader may note that all parts remained contextually applicable to the region per the strategy selected.

Figure 3-5: Research strategy process based on action research



With the action research strategy selected, an iterative process from one to the next is facilitated towards the development of a conceptual model. Since it is tested in SA, it factors in the context of its applicability in a developing world region. The resulting research framework used to achieve this is presented in Figure 3-6.

Figure 3-6: Research framework part 1 based on the research onion

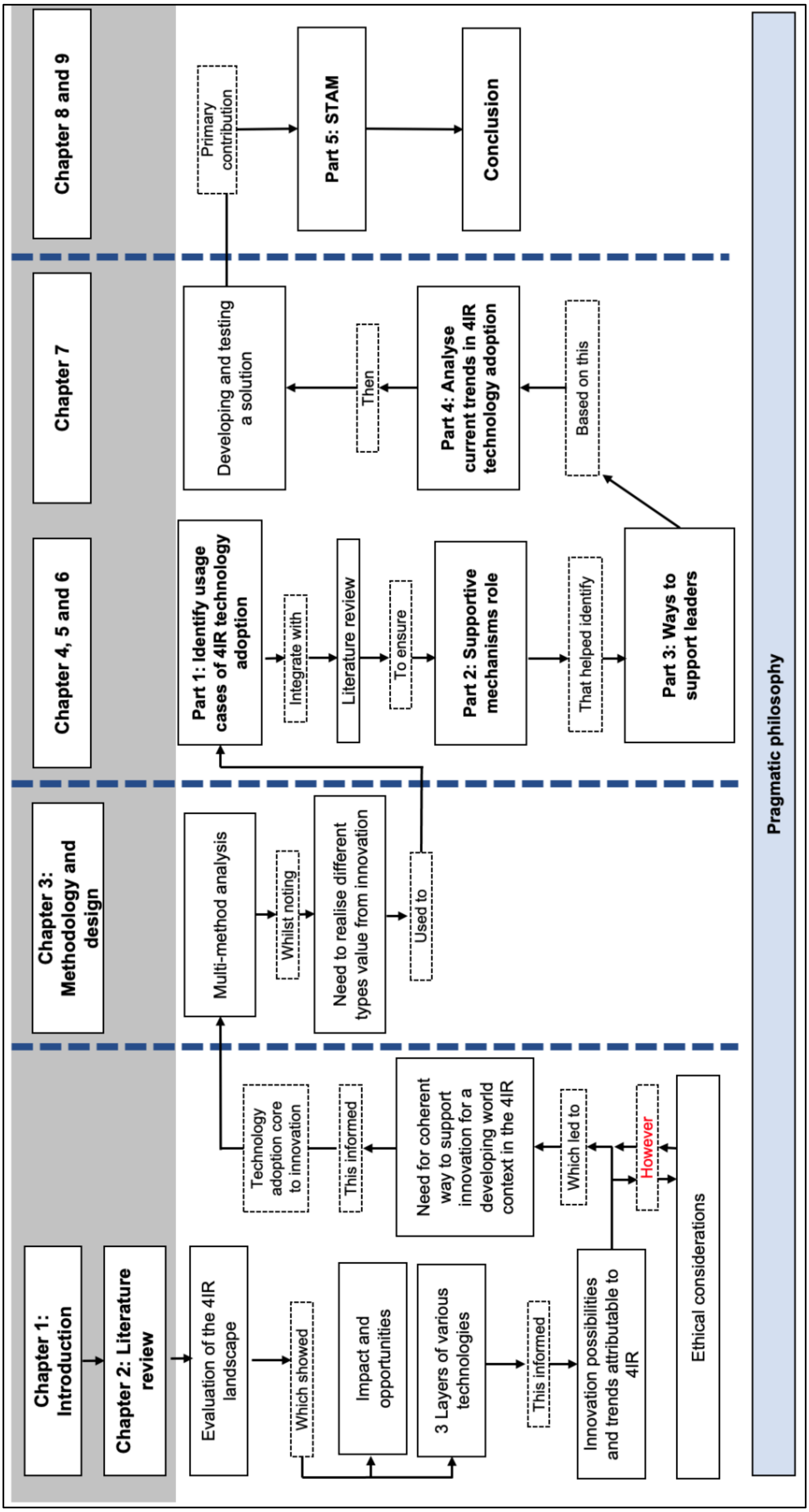


Source: Adapted from (Saunders *et al*., 2016).

3.3 RESEARCH METHODOLOGY AND DESIGN FOR EACH PART

The research framework of the overall thesis aligns with Saunders *et al*. (2016), where each subsequent layer impacts the next. In this thesis, Chapter 1 provided an overview of the research, justification and research questions. This was based on existing literature presented in Chapter 2. To address the questions and deliver relevant findings five parts are formulated to address the research questions. Each respective part applies the pragmatic philosophy, however, to address the questions each considers the research approach, methodological choice, time horizon, data collection and analysis on their own merit. To determine each part, action research was used. However, this is not to say that each part used this research strategy. Instead, this was the larger holistic strategy applied to the thesis to lead to the development of the conceptual model and determine how the parts interconnect, following an iterative and emergent strategy. As a result, the overall flow to develop the parts in turn is shown in Figure 3-7. Each subsequent parts methodology to address the research question is presented next to show the reader "how" the associated research question is answered.

Figure 3-7: Research design with respective parts


Chapter 1: Introduction
Chapter 2: Literature review
Chapter 3: Methodology and design
Chapter 4, 5 and 6
Chapter 7
Chapter 8 and 9
Evaluation of the 4IR landscape
Which showed
Impact and opportunities
3 Layers of various technologies
This informed
Innovation possibilities and trends attributable to 4IR
Ethical considerations
However
Which led to
Need for coherent way to support innovation for a developing world context in the 4IR
This informed
Technology adoption core to innovation
Multi-method analysis
Whilst noting
Need to realise different types value from innovation
Used to
Part 1: Identify usage cases of 4IR technology adoption
Integrate with
Literature review
To ensure
Part 2: Supportive mechanisms role
That helped identify
Part 3: Ways to support leaders
Based on this
Part 4: Analyse current trends in 4IR technology adoption
Then
Developing and testing a solution
Primary contribution
Part 5: STAM
Conclusion
Pragmatic philosophy

3.3.1 Part 1: Methodology

Research question Part 1: Have there been successful adoption cases that demonstrate innovative outcomes using 4IR technologies?

The nature of this research question facilitates both qualitative and quantitative data analysis. The question aims to determine if there is actual adoption of 4IR technology and what outcomes they had, in this instance, innovation. For the thesis, as stated in Chapter 2, innovation is more than idea, and there needs to be value derived from a concept for it to be considered innovation. In this sense, technology transfer through IP, copyright, research enhancement or business development.

Per action research, it was the first step in the iterative process. In this regard, the first article investigates technological applications as well as the outcomes. However, it is limited to one adoption case. To this end the study captured the processes used with specific smart technologies. It was noted that the application of the technologies within the study was dependent not only on the usefulness or stage of the technologies maturity, but also how they would integrate into existing systems. The context of the study was a key point in addressing a gap in literature, which was a developing regions usage and application towards innovative outcomes. The case assessed supported smart agriculture to achieve potential economic benefits. The reason for this industry is that it is one of the areas of interest to be supported by government, and its importance for human survival.

1.1.1.1. Part 1: Research article 1

As stated previously, the article is entitled "*Assessing Entrepreneurs Who Utilise Smart Technologies of Industry 4.0 to Develop Needed Business Intelligence*". It notes that business intelligence has been enabled in several ways with smart technologies of I4.0 towards improved efficiencies and value creation. The outcome of which addresses the research question, in that yes, there have been successful adoption of 4IR technologies in the region, and that the outcomes have tangible benefits. Although limited to one case, this is not to say that there is not a variety of cases on such adoption. However, what the article provides is a practical usage case, using 4IR technologies, specifically to innovate. At the basis of which is technology adoption. In this study, it was noted that to enable this, a supportive mechanism was used, leading to the second part of the thesis's investigations.

The *research approach* for this study was abductive. The *methodological choice* that resulted from this was a mixed method, as two data sources are used to formulate the resulting conceptual model. The *time horizon* for the article was cross-sectional pertaining to 2020. The *theoretical underpinning* for the study was the TAM model.

Article 1: Research strategy

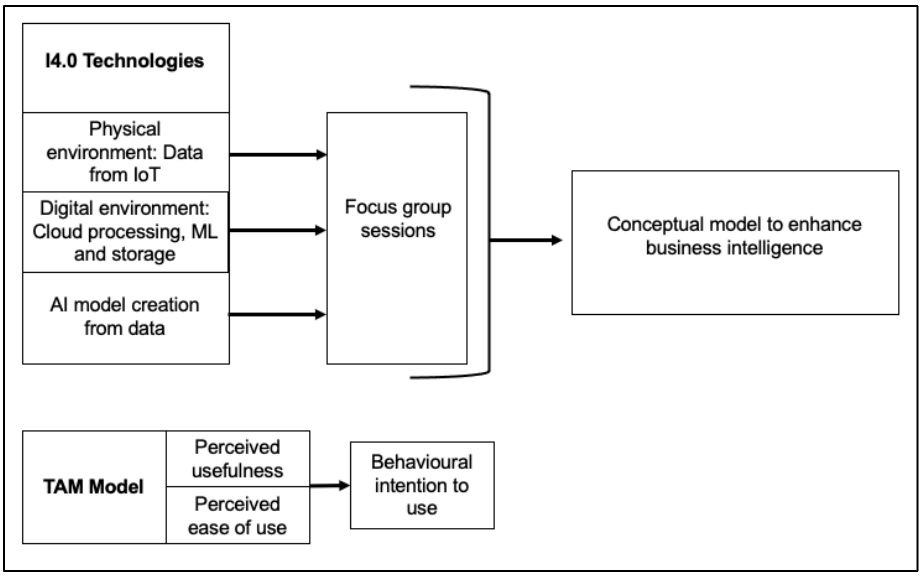
To begin to address this gap this study uses a case study approach based on *Dalmarco et al*. (2019), Liu *et al*. (2018) and Luthra *et al*. (2020). The case study itself focuses on how a bounded entity in SA used smart technologies of I4.0 to enhance business intelligence within the agricultural sector. Core to which were the entrepreneurs who collaborated with an academic makerspace to leverage the described technologies of the literature review, hence the reason for this specific case. The applications of technologies included livestock health and movement.

Data collection and analysis

To attain the required data, the case study triangulates data from mixed sources (Luthra *et al*., 2020). The first method applied was data collection using smart technologies of I4.0. This was quantitative data from IoT devices, drones and thermal imaging technologies. The quantitative data itself included images as well as metadata such as temperature, location, date, time and user. The second set of data was qualitative data, which was attained from semi-structured focus group sessions with 24 entrepreneurs. This was conducted following the development and deployment activities of the technologies in the makerspace environment.

Using the data collected from the first method, an AI could be developed. Designing of the system to support decision making is one aspect of this study. The data from the focus groups provided insights into activities and key functions that enabled the adoption and subsequent outcome of using smart technologies. To do so keywords were logged and tracked within the parameters of activities, noting trends and functions that enabled the outcomes and adoption of the technologies. The overview of the methodology for article 1 is shown in Figure 3-8.

Figure 3-8: Overview of article 1 research methodology



3.3.2 Part 2: Methodology

Research question Part 2: What innovation mechanisms can support the uptake of smart technologies in developing regions such as South Africa?

The research question stemmed from Part 1 but was also underpinned by Kruger and Steyn (2019), who provided an analysis of the innovation ecosystem in the region. However, what was an area for further research was investigation into the specific mechanisms to do so. Furthermore, a key aspect to addressing this question was the researcher's role in an existing innovation mechanism. To this end, there was access to examples, but also how technologies of the 4IR were used to create innovative outcomes. A further facet, as mentioned in earlier chapters, is that academia is being pressured to deliver skilled graduates, support relevant upskilling of existing employees towards an ever-changing future of work, as well as drive research outputs. At the core to which in the South African region is supporting and enabling such activities in universities. For this reason, the thesis developed Part 2 to address the research question.

The research design itself called for practical insights that also aligned with action research, as from Part 1. It was found that such supportive mechanisms do exist, but more insights are required. Moreover, how they are using smart technologies to not only engage in the paradigm, but also create innovative outcomes through the various technology transfer methods.

To address this, efforts were undertaken to assess the mechanisms while focussing on specific instances to answer the research question. During these efforts however, the global COVID-19 pandemic hit. Despite this, the innovation mechanism in question where the researcher was based continued to operate. Consequently, the usages of such mechanisms, in the context of a global pandemic could be identified, noting their additional role in larger institutions to be able to pivot quickly. This is what the second article of Part 2 adds to the findings. The third article pertaining to Part 2 further addresses the research question as it provides insights into 4IR technologies, but also the way in which they integrate through varying levels of analysis. Moreover, it provides what can be deemed alignment for international trends and a conceptual model that identifies functions for needed skills development.

1.1.1.2. Part 2: Research article 2

The article entitled "*Innovation Environment's Role in Supporting Industry 4.0 Technology Adoption to Address Effects of COVID-19*" provides practical insights on how to support smart technology adoption within a developing world context. Even in the instance of a pandemic. To address this previous literature on I4.0 technology, the role of innovation environments and theoretical principles of technology adoption is reviewed. To address the research question for this part, a practical case from an academic makerspace based in a South African university was then assessed. *The research approach* for this study was inductive*. The methodological choice* that resulted from this was a mixed method that included documented activities and direct observations by the researcher. The *time horizon* for the article was cross-sectional pertaining to the year 2020. The *theoretical underpinning* was a combination of the TAM and UTAUT models.

Article 2: Research strategy

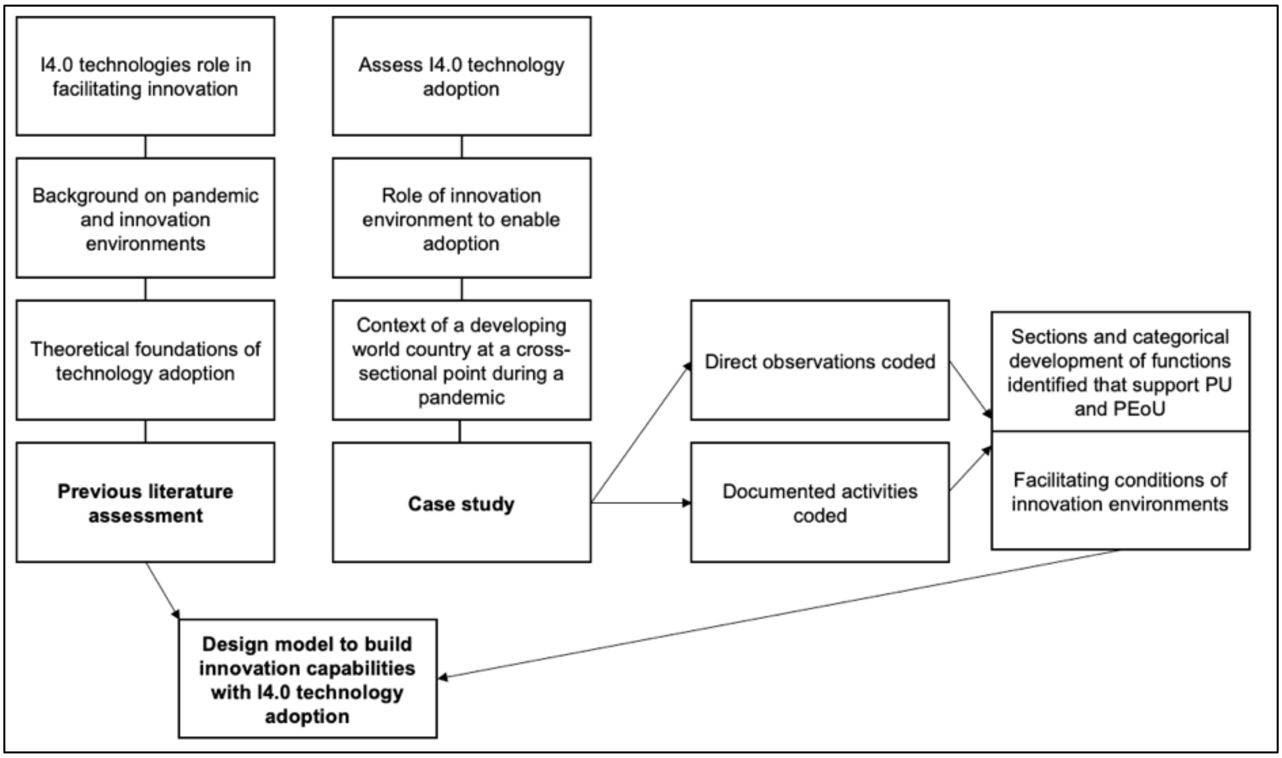
The research strategy for this article was a case study. This was attributable to the research calling for an in-depth review of a specific phenomenon. The phenomenon itself was investigating how to streamline novel technology adoption. This pertained to an organisation within the developing world of SA. The reason for only one case assessment was that the environment offered insights into strategic collaboration activities as other innovation environments were sourced to deliver the solutions. With these insights, the case can be argued to have provided time-relevant insights into the activities of the study (Yin, 2017).

Data collection and analysis

To achieve this, the academic makerspaces activities that enabled rapid response and possible reasons for its innovation capabilities were directly observed with documented findings added. To analyse this, coding was used to log reports, documented achievements, news items, processes from observations, field notes and publications. This state of coding was used until categories emerged to present findings that could be used to create the model.

As per (Fram, 2013), inductive coding was used based on the constant comparative method to identify patterns and organise it into logical sections. This constant comparison allowed the researchers to reach a point where theoretical saturation for this case was obtained, and no additional coding within the studies parameters were noted. In other words, the categories were developed with properties and dimensions identified during the start of the pandemic. Using this method, essential practices that supported PU and PEoU could be identified. Moreover, how an innovation environment can enhance facilitating conditions towards improved adoption, if at all could be determined. The articles methodology is shown in Figure 3-9.

Figure 3-9: Overview of article 2 research methodology



1.1.1.3. Part 2: Research article 3

The third article for the thesis pertaining to Part 2, entitled "*Improving Innovation Capabilities in Developing Countries through 4IR Technology Adoption: The Supportive Role of a Makerspace"* aims to provide practical insights through a conceptual framework on the supportive role an innovation mechanism such as a makerspace has in a university to enhance 4IR technology adoption of users.

To obtain this data and observe activities, as mentioned earlier, the researcher of this thesis was based in the makerspace itself during the study. The researcher was directly involved in tracking outcomes of such activities, in this capacity allowing for the observations and access to processes of users. Where activities produced valuable outputs, the core functions that facilitated this were noted and tracked as mentioned. Accordingly, by using a purposeful approach to selecting relevant projects, representative cases and associated core functions could be developed towards a conceptual framework based on the draft created from literature (Saunders *et al.*, 2016; Urban and Chantson, 2017).

The *research approach* was abductive. The *methodological choice* that resulted from this was simple mixed method, as two data sources are used to formulate the resulting conceptual model. The *time horizon* for the article was cross-sectional, spanning over six months, ranging from July to December 2020. This time horizon was a specific comment made by a reviewer, noting that the study offered a snapshot of activities and not constant comparisons. This was done to identify the processes towards innovation outcomes within an academic semester in the region. Although activities in certain instances have been seen to produce outcomes quickly, in the space for research projects, the outcomes take time to materialise. The *theoretical underpinning* is the UTAUT model.

Article 3: Research strategy

This study investigates an academic makerspace as an innovation mechanism through case study methodology. This is to identify how it can support technology adoption towards the development of innovation capabilities of its users. The case study method allowed for an in-depth view of the environment that engages academia stakeholders (Bai, 2018). The case itself pertains to a specific area of enquiry, aligning with Gregor (2006:613), in this instance, the first academic makerspace in SA based in a university. The makerspace assessed is in one of the three capital cities of SA called Pretoria, the administrative capital.

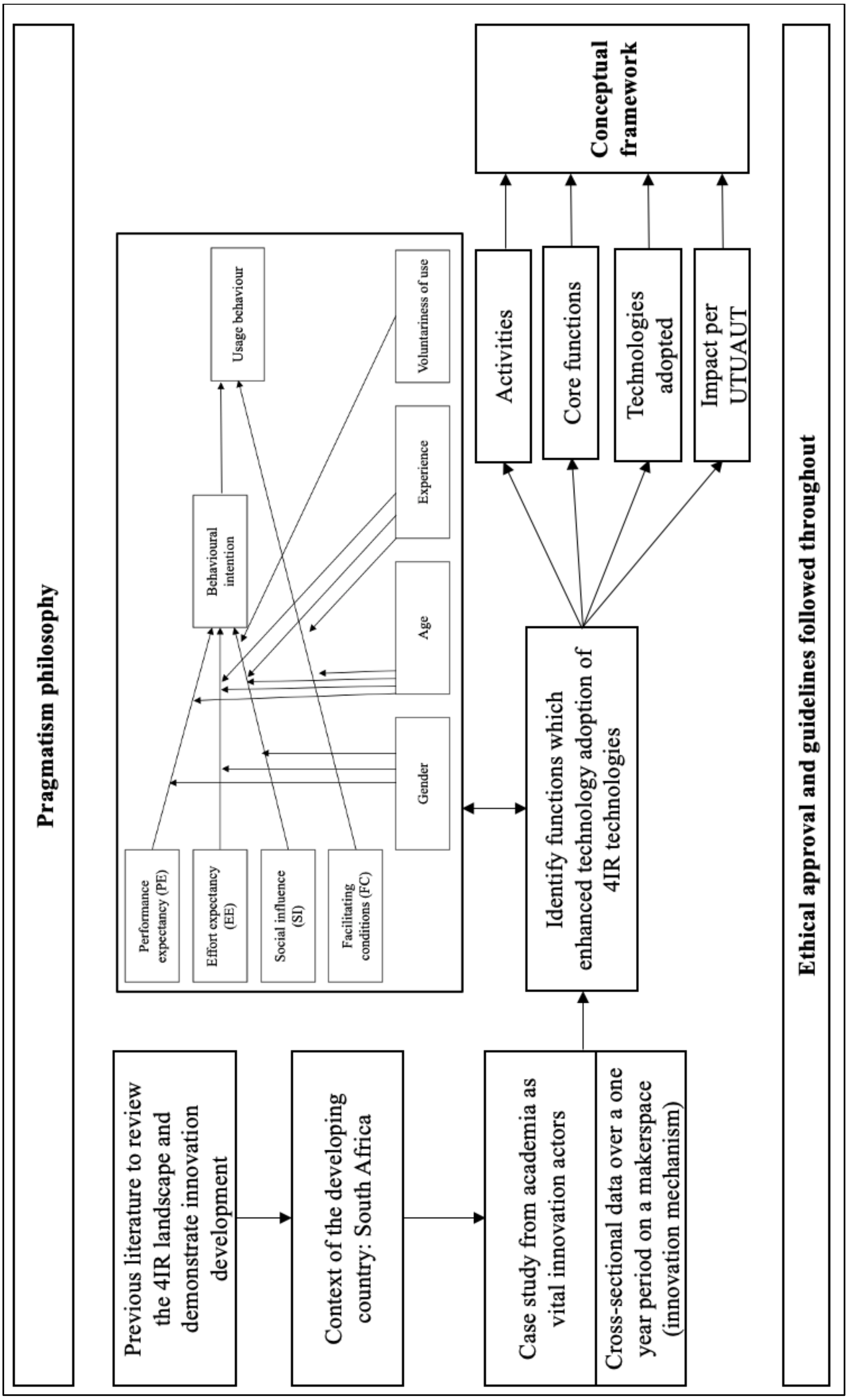
Data collection and analysis

Data collected pertained to the activities identified that supported technology adoption of users that was tracked through a project management tool. Only outcomes that were documented such as success cases in news items, reports, achievements, publications and deliverables were included to ensure the activities identified had tangible outputs. From the data, categories emerged and were noted until such a stage that all needed information per Fram (2013) was collected. This allowed for the identification of patterns to organise them into logical sections. To achieve this, constant comparisons throughout the study was conducted until a saturation point could be reached. For example, where a user adopted a smart technology or combined them, then the technologies and activities were noted. However, this was only logged where an outcome such as publication, MVP or product prototype was achieved to ensure only activities that supported outputs that materialised were logged.

It must be noted that despite the apparent homogenous population in terms of users, such as researchers, lecturers, undergraduate and postgraduate students within a university, the researcher accepts significant differences in the family backgrounds, cultures, ethnicity, sexual orientations, age, interests and field of study exist (Davison and Martinsons, 2016). These were not explicitly noted to protect the users and align with ethical guidelines obtained from the institution’s ethics board.

The document artefacts from a project tracking software used in the environment were used and analysed to produce the needed insights. The overall research methodology for article 3 is shown in Figure 3-10.

Figure 3-10: Overview of article 3 research methodology



3.3.3 Part 3: Methodology

Research question Part 3: How can we support leaders through technology adoption in a developing region such as South Africa?

Using the Figure 1-2, and the associated action research strategy for the thesis, the technology adoption cases and mechanisms to support adoption have been reviewed. In this regard, the thesis noted from these findings that yes, there are technology adoption cases in the 4IR. Secondly, there are innovation mechanisms to support such uptake. The subsequent question and area for research was how we can support leaders using these insights, addressing the third research question.

1.1.1.4. Research article 4 for part 3

The article entitled "*Supporting Leaders to Engage in the Fourth Industrial Revolution through Technology Adoption Principles: Perspectives from a Developing Country"* used an abductive *research approach*, with a focus on interpreting the results to prescribe future actions. The consequential *methodological choice* that resulted from this was a mixed method, where quantitative data from surveys and technology usages was assessed. The *time horizon* for the article was cross-sectional pertaining to 2020. The *theoretical underpinning* was the TAM and UTAUT2 model.

Article 4: Research strategy

For this study, the action research approach was selected to develop a method to test constructs such as PU, PEoU, facilitating conditions and BI to create value on a representative sample (Ågerfalk, 2013). Moreover, the reason for an action research approach based on TAM and UTAUT2 is that the design and action relate to the nature of this study, which is prescriptive (Cassell *et al.*, 2018). This approach allowed for testing of theoretical principles. This was to determine if such methods support value creation for leaders to leverage benefits of 4IR technologies (Saunders *et al.*, 2016). Using the action research principles an artefact could then be developed based on previous studies and findings. Part of this was that there needed to be an introduction to leaders to enhance their technical abilities to adopt smart technologies (Sohn and Kwon, 2020b). This was tested in 2019 with only IoT being considered as a smart technology (Turpin *et al.*, 2020). Usage examples and practical applications in this regard were presented face-to-face with notes made for future efforts.

Data collection and analysis

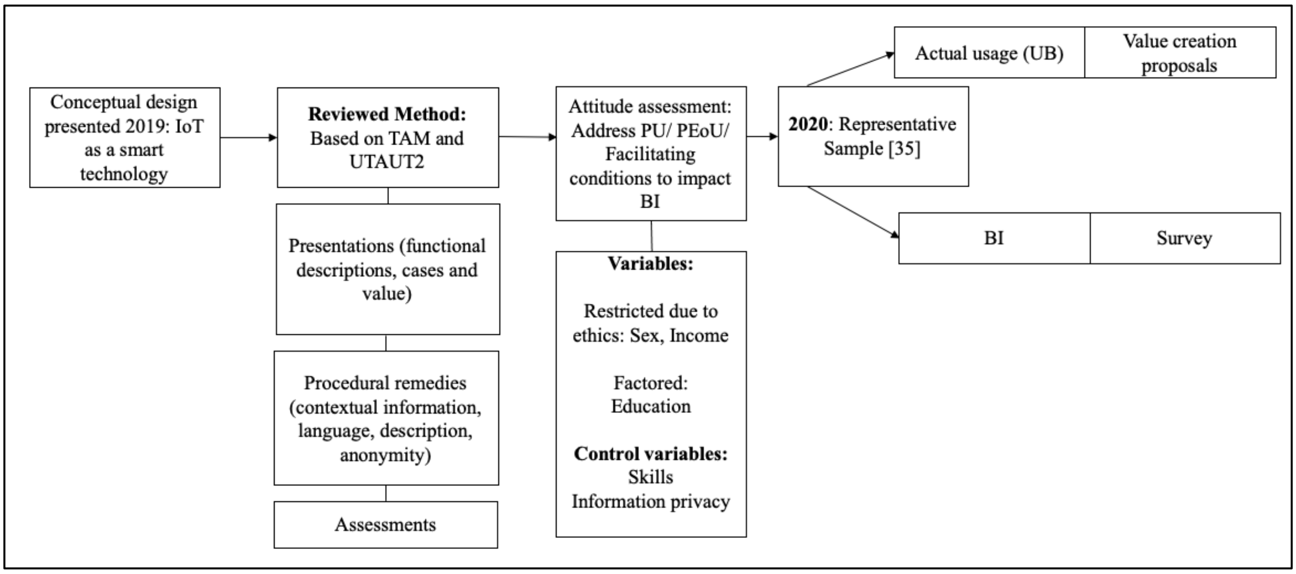
Micro level user data was required to determine if the introduction of smart technologies based on key constructs from theory supports leaders for them to engage in the 4IR.

However, preferential data of a large leader's group across multiple industries is difficult to attain. The sample itself applies to 35 industry leaders enrolled in a master's level information systems program at a university which focuses on strategizing and making technology relevant for business success. They were identified as they all have a direct role in technology and management, as well as a leadership aspect within a job function (Walsham, 2006). This also allowed for various industry roles to be factored into the sample. The reason for this sampling frame was that they are graduates of higher education. Furthermore, the university they enrolled in is based in the administrative capital which has several innovation support mechanisms towards innovating using technologies of the 4IR.

Subsequently, two methods of data collection are used. The first is the usage of the survey method based on a 5-point Likert scale. Beforehand, functional descriptions, case studies and examples of intelligent or smart technologies were introduced to demonstrate use, usage cases and value. This was first done as a validation exercise in 2019, to determine inefficiencies in presentations, guidance and methods. This exercise was however limited to only IoT as a smart technology. Overall, the survey was used to determine the effectiveness of using technology adoption constructs (independent variables) in supporting leaders' behavioural intentions to engage with smart technologies of the 4IR. The second set of data is assessment of the actual usage of technologies by the sample of leaders who presented cases. To do so leaders were assigned a group task which required them to master, apply and present their smart technology integration cases towards value creation. This was to note the adoption of 4IR technologies specifically AI, ML, IoT and Blockchain from 7 groups with 5 leaders in each.

Factor analysis was used to identify underlying factors within the data set, where factor loading was used to assess correlation coefficients for the variables. The overall research methodology is shown in Figure 3-11.

Figure 3-11: Overview of article 4 research methodology



3.3.4 Part 4: Methodology

Research question Part 4: What are current trends in technology adoption model uptake in the 4IR paradigm?

The action research approach identified various areas and answered questions pertaining to technology adoption cases, mechanisms to support such adoption and ways to support leaders in adopting smart technology. This was based on investigations that demonstrated how several disciplines and thousands of studies have used, developed, and supported technology adoption theories to guide industry and support innovation. However, within the last decade, the 4IR has caused a paradigm shift, resulting in new considerations, affecting how models are used to guide smart technology integration. Notwithstanding, in all the articles formulated to this point in the thesis, the technology adoption underpinnings were assumed.

1.1.1.5. Article 5 and 6: Part 4

Consequently, there was a need to determine which technology adoption model, or models, are primarily used when assessing smart technologies in the 4IR construct. The fifth article was then formulated, entitled "*Which Model is Best? A Systematic Review of Technology Adoption Model Trends for the Fourth Industrial Revolution*". A future research aspect identified was the need to investigate additional constructs that were impactful whilst considering the level of research they were applied to. The subsequent paper focused on organisational levels of assessment.

The sixth paper entitled "*Assessing Technology Adoption Constructs That Enable Organisations to Navigate the Fourth Industrial Revolution: A Systematic Review*" was then formulated. The reason for starting with an organisational level of analysis was that it was found that there is pressure on business to reassess their models, strategies, systems and needs of their users. Several proposed frameworks to identify and predict variables to navigate such new technological complexities were identified. Nevertheless, the models themselves have been expanded and applied in different contexts to determine the applicability of new technologies and the behaviour of users to support innovation development needed for organisational competitiveness, including that of the 4IR.

Considering these insights, the articles, although having a different focus area, utilised the same research methodology. For the ease of the reader, they were combined to reduce duplication. In order to provide a holistic level of insights, where the 4IR is a global paradigm the abductive *research approach* was used. The *methodological choice* that resulted from this was a mono-method. The *time horizon* for the article was cross sectional, taking a specific inquiry date in 2022. The *theoretical underpinning* did not relate to technology adoption, rather, the assessment thereof.

Article 5 and 6: Research strategy

For both article 5 and 6, a Systematic Literature Review (SLR) based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) principle to explore existing literature whilst ensuring non-replication and transparency. Both articles also adopt Rad *et al*. (2018), where different databases and a well-defined review protocol were used to produce relevant findings.

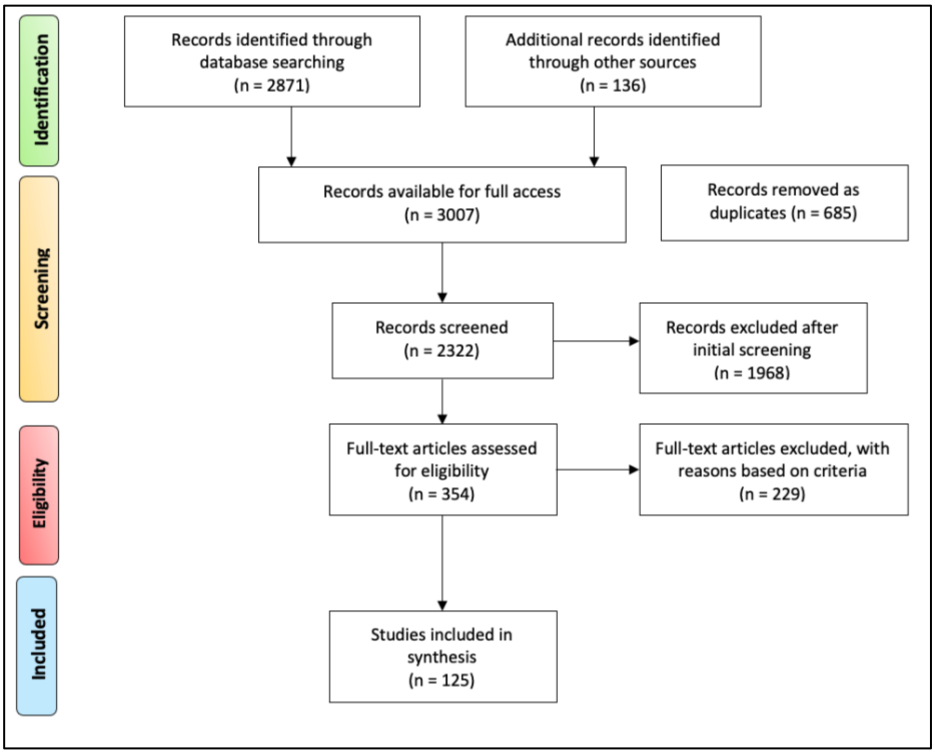
Data collection and analysis

To collect the data, the search strategy per PRISMA was used to identify relevant research papers. Due to the large extent of research disciplines and associated contexts of the 4IR, including concepts of I4.0 and extensive literature of technology adoption, the limitation of disciplines was not ideal. To develop a narrative and identify associated insights encompassing the 4IR's extensive scope, search strings, specific terms and keywords, including certain synonyms and nuances of the new industrial movement were used. The searches were done on publications published in English with multiple queries executed on the title, keywords, abstract, date of publication, and the type of publication. This was applied to 9 databases, including EBSCOhost, Emerald Insight, ProQuest, IEEE Xplore, Google Scholar, JSTOR, SAGE, ScienceDirect and SCOPUS, for extensive and broad coverage of relevant sources.

Moreover, to align with the study's construct, purpose-built databases which integrate AI were also used to ensure a broad scope of application. In this study, Dimensions was used. Finally, cross-referencing was conducted between the relevant articles not to overlook relevant literature (Bai, 2018). The rationale behind this is that when two articles are frequently co-cited, the commonalities between them allows the identification of clusters which could enable researchers to understand knowledge base, intellectual structures and current scientific studies (Oliveira and Martins, 2010).

The third stage was assessing and selecting articles based on exclusion and inclusion criteria. The fourth stage was to review downloaded articles to ensure eligibility and quality. After the quality assessment, the articles were coded. The full text of the article bibliographic data and additional parameters not included in metadata were extracted to an Excel file (2021 version 16.54). Using this allowed the categories of the core model or theory used, study context, methodology, level of analysis, smart technology, adoption assessment level and purpose of the study to be assessed. The model extensions were then sub-categorised. Additionally, publication date, country of author, author affiliations, country of study, country of publication, open access (OA) status, database, and citation count were synthesised to aggregate evidence from the studies identified. The overview of the PRISMA model applied to the fifth article can be seen in Figure 3-12.

Figure 3-12: Article 5 PRISMA flowchart



3.3.5 Part 5: Methodology

Research question Part 5: How can we support 4IR technology adoption to enhance innovation capabilities?

The literature review noted that there are several uncertainties brought on by rapid changes of 4IR. This alongside the global pandemic, has caused concerns amongst leaders about how to navigate subsequent impacts in business, academia and government. However, the paradigm itself is complex due to the combination and interconnection possibilities between physical and digital technologies. The thesis until this point noted that the articles uncover various facets to address this. However, the primary research question needs to be addressed. This study aims to address this by reviewing critical constructs in the adoption of smart technologies of the 4IR on an individual level to develop innovation capabilities.

1.1.1.6. Article 7: Part 5

To deliver on the main contribution, the *research approach* used was based strongly on a deductive approach, where there was movement from the general, the synthesis of literature, to the specific, data collection and testing. The *methodological choice* was a mixed method. The *time horizon* for the article was cross-sectional, pertaining to 2022. The *theoretical underpinning* was formulated in the study using a SLR. The resulting model, STAM was based on TAM and UTAUT.

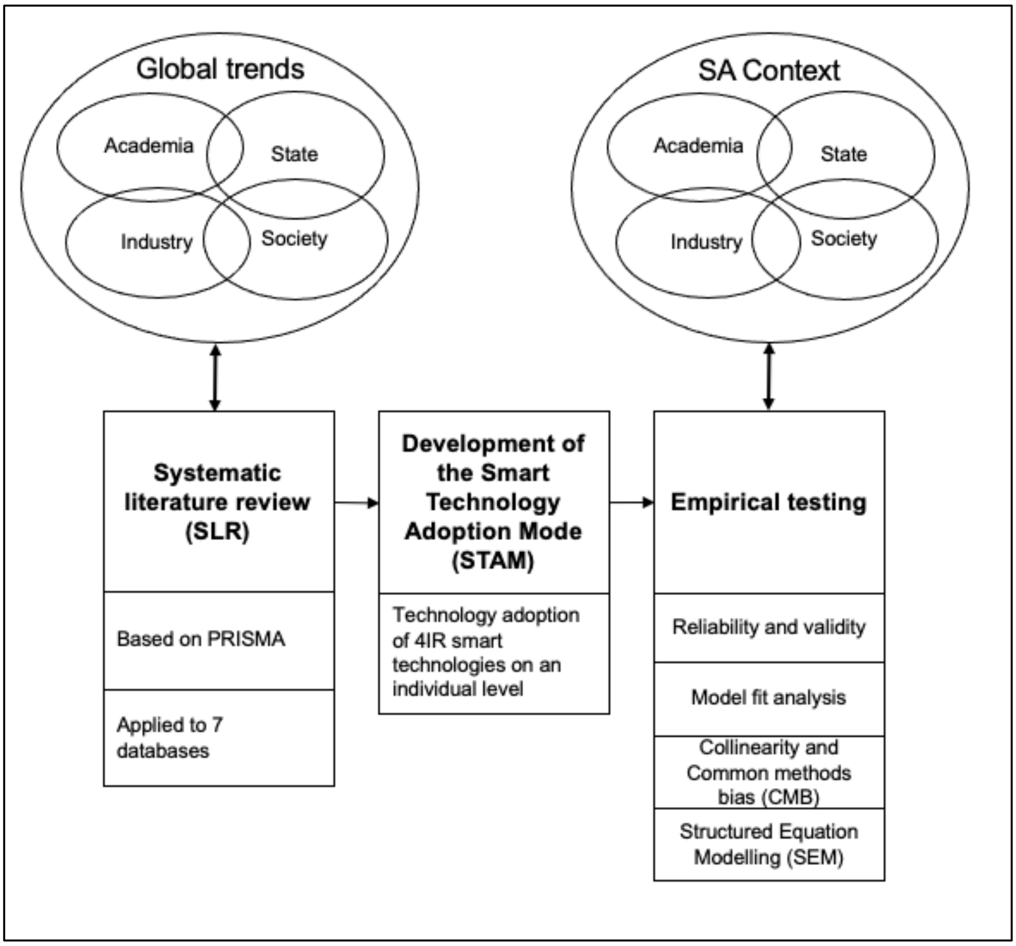
Research strategy for part 5

The final article used a combination of approaches to formulate a relevant model as well as test it empirically. This aligns to the overall action research of the thesis. However, it is the final stage of the research. Consequently, a construct assessment need stemming from article 5 and 6 was noted. The first approach then was a SLR to identify constructs of models on an individual level. Secondly, using these insights a model that encompasses the smart technologies of the paradigm could be formulated. However, to ensure its relevance and application to SA, a developing region, and address the primary research question, it needed to be empirically tested.

Data collection and analysis

Per the strategy of the article, two data collection points were used. The first of which was an SLR. For the reader, this was already covered in the previous section for article 5 and 6. The second part of the data collection involved empirical testing. To do so, a questionnaire-based survey tool, using the themes and trends identified from the previous literature was used. The resulting STAM from the SLR was empirically tested in SA. The non-probability, representative sampling approach was applied to identify an appropriate sample size with suitable characteristics. The questionnaires were distributed on the Qualtrics platform. The measurement items were then assessed using SPSS Amos Version 28.0.0.0 (190) to note demographics, followed by reliability and validity tests, model fit analysis, collinearity tests and the common methods bias. The hypothesis was then assessed based on Structured Equation Modelling (SEM). An overview of the research methodology for the final article is shown in Figure 3-13.

Figure 3-13: Overview of article 7 research methodology



3.3.6 Article status overview

At the time of writing, the articles had been submitted for review. Table 3-2 reviews the article title, the part of the thesis it pertains to, and the status of the submission.

Table 3.2: Overview of article submissions and status

Article number	Part of thesis	Article Title	Journal submitted to	Status
1	1	A Practical Case on Adopting Smart Technologies of Industry 4.0 to Develop Business Intelligence	Communications in Computer and Information Science (CCIS) proceedings	Accepted
2	2	Innovation Environment's Role in Supporting Industry 4.0 Technology Adoption to Address Effects of COVID-19	International Journal of Innovation and Technology Management	Accepted
3	2	Improving Innovation Capabilities in Developing Countries through 4IR Technology Adoption: The Supportive Role of an Academic Makerspace	Research Policy	Awaiting feedback

4	3	Supporting Leaders to Engage in the Fourth Industrial Revolution through Technology Adoption Principles: Perspectives from a Developing Country	Information Systems Frontiers	Awaiting feedback
5	4	Which Model is Best? A Systematic Review of Technology Adoption Model Trends for the Fourth Industrial Revolution	Technology in Society	Not accepted, editorial office recommended transfer to Technological Forecasting & Social Change
6	4	Assessing Technology Adoption Constructs That Enable Organisations to Navigate the Fourth Industrial Revolution: A Systematic Review	Telematics and Informatics Reports	Journal noted they do not have reviewers to process article, awaiting transfer
7	5	Assessing Individual Constructs to Leverage Possibilities of the Fourth Industrial Revolution: Development of the Smart Technology Acceptance Model (STAM)	Telematics and Informatics	Awaiting feedback

3.4 DATA STORAGE

Data storage of the thesis data is vital importance, as it supports the research study and ensures reliability and validity. The data itself pertains to systematic studies, but also people. Consequently, it can be considered sensitive in nature. As such, the data obtained is managed in two phases. During the first phase, where data collected that included field noted from observations, materials, literature analysis, survey data or project specifications was kept securely on a password protected laptop. This laptop also has an encrypted hard drive to ensure that unwanted access was limited as far as possible. Whilst on the laptop, the data was then analysed. The outputs and data sets after the study are to be securely stored in a data cloud of the institution for quick reference by the researcher. This will be password protected. On finalisation of the thesis, the anonymised data will be kept on the institutional repository assigned for a period of 15 years. To assist in this regard, a data management toolkit was used. This was referred to as a Data Management Plan (DMP).

3.5 ETHICS

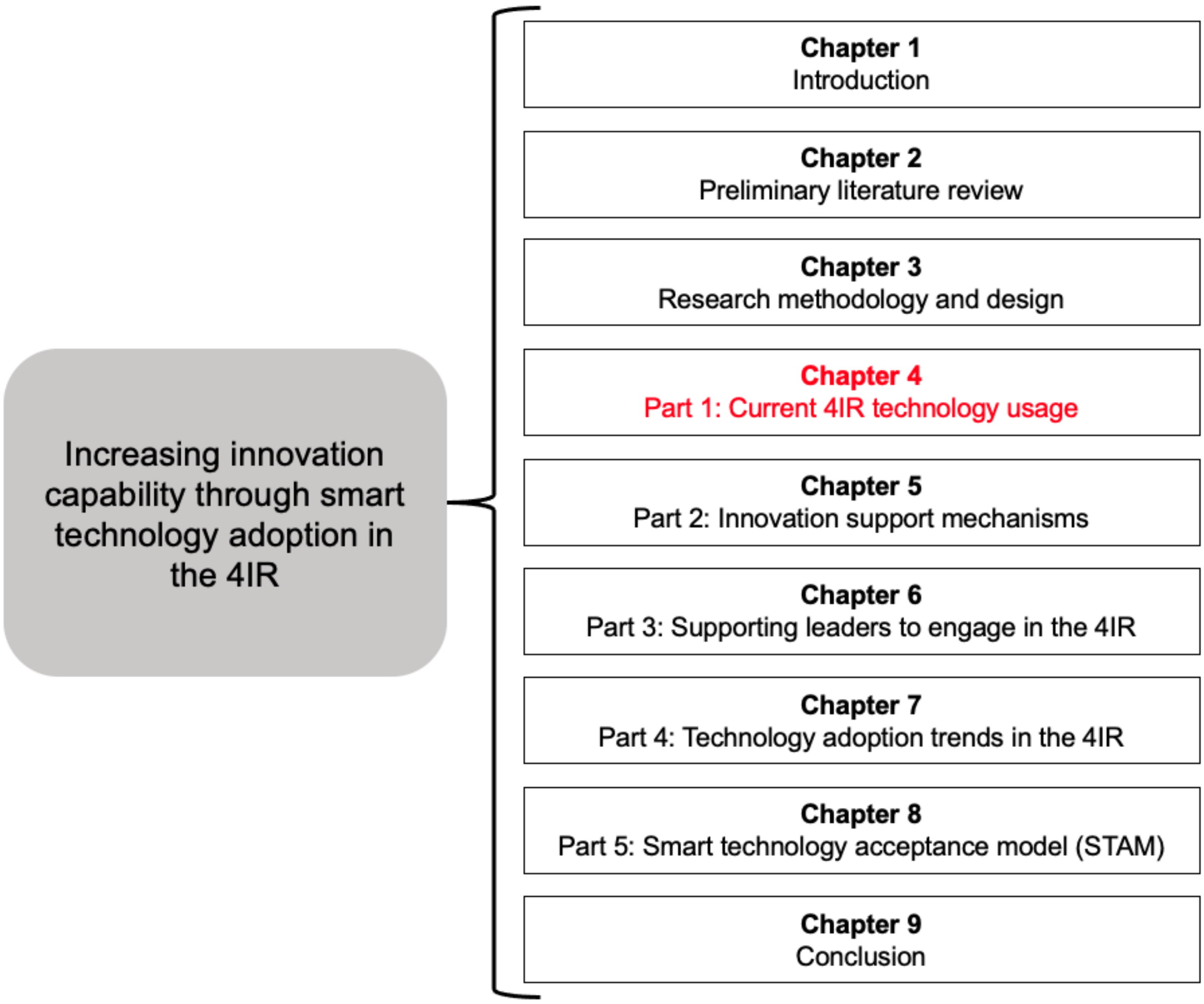
Based on the research methodology of the thesis, there are several ethical considerations present. For this thesis, the data obtained from the various sources is analysed and presented based on the university's guidelines and committees' requirements. All data remains anonymous and stored securely. Where applicable, all participants were informed of ethical guidelines, as well as the fact they can withdraw at any stage without repercussions. The researcher while exploring, examining and describing findings and conducting the collection and analysis for this thesis was done with clear ethical principles. This included consistently obtaining informed consent, prior approval and constant permission to conduct the research. Moreover, each research articles ethical considerations are specifically addressed, except for the SLR articles. Although the SLR could be considered as non-invasive, the research therein still requires certain principles to be followed, as such, ethical clearance was also obtained and applied for article 5 and 6 respectively. As such, the researcher acknowledges ethical considerations are of utmost importance, and notes to the reader that guidelines were followed, not only to ensure adherence to rules, but to have a clear moral conscious on the research that was conducted. Fortunately, this research focused on driving and supporting innovation using technology, and not focus on the several barriers of the region. See **Appendix A** for ethical clearance obtained.

3.6 CHAPTER CONCLUSION

In this chapter, fundamental principles that align with research principles that were applied to this thesis were reviewed. This included reviewing the research framework of the thesis. In this regard, the overarching methodology was reviewed, as well as each contributing parts articles methodology. In this sense, the action research strategy, using its iterative steps was shown to address each research question leading to the primary research output. Within each part, the articles methodological choice, method, time horizon and research strategy were presented. The data collection and analysis techniques with an overview of this was then presented. Finally, the ethical considerations were addressed.

The next chapters encompass the primary contributions of this thesis through five sequential parts. In each part the article is presented with brief introductory notes, as the sequential flow has been shown in Chapter 1 and Chapter 3. After which the thesis conclusion, references and appendices is presented.

4 PART 1: 4IR TECHNOLOGY USAGE



4.1 INTRODUCTORY NOTES

Research question Part 1: Have there been successful adoption cases that demonstrate innovative outcomes using 4IR technologies?

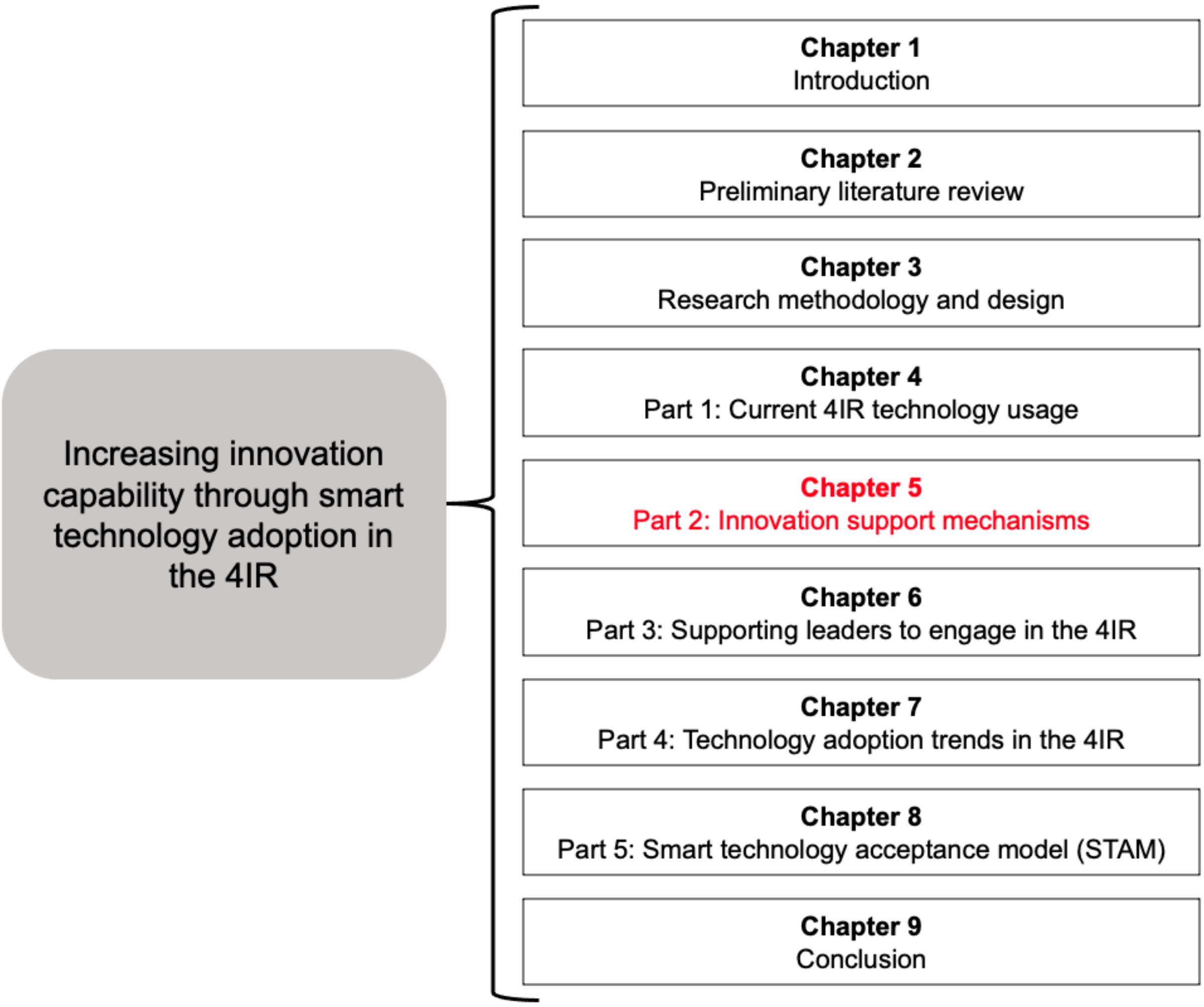
As the initial part of this thesis, the aim was to investigate a contextually relevant technology usage case. The purpose being to determine if there are smart technologies being used, what kinds of value can be developed from them and the stakeholders involved. The researcher while conducting the preliminary investigation, presented in Chapter 2, noticed that "traditional models" to improve or create new forms of value with smart technologies, including business intelligence has focused on developed regions, leaving limited indigenous examples. Perhaps not an oversight, as several models do exist confirming tacit understanding that local systems and mechanisms do support innovation development. This study tries to address this through the specific usage case identified and subsequently investigated.

The overall contribution and efforts are presented, as with other parts, in article format. To this end, each article presented is done to the journal's standards and styling. The references, appendices, figures and tables are all also kept with each article to support the reader to navigate the thesis and relate each articles content to the respective part presented.

On the onset of the investigation, the researcher noted that there are several opportunities that can be grasped if smart technologies can be effectively combined or integrated into existing systems. In this particular instance, the formulation of business intelligence to drive productivity, efficiency or even create new forms of value like never before. It was noted that such intelligence can assist leaders in making more accurate, timely and smart decisions to increase profitability, productivity and effectiveness of business operations. The results show that there is a definite cycle followed with the aim to innovate and create needed business intelligence. Importantly to the study, was its context and the sector this was developed in. In this sense, the article addresses the first research question. The findings from this chapter were used to inform Part 2, which was the supportive mechanism that supported the efforts of the case assessed.

Reference article 1: Kruger, S. & Steyn, A. A. (2022). A Practical Case on Adopting Smart Technologies of Industry 4.0 to Develop Business Intelligence. Submitted for review to the 12th International Development Informatics Association Conference (IDIA), August 2022. The submission was accepted to be processed in the Springer's Communications in Computer and Information Science (CCIS) proceedings volume **Appendix B**.

5 PART 2: INNOVATION SUPPORT MECHANISMS



5.1 INTRODUCTORY NOTES

Research question Part 2: What innovation mechanisms can support the uptake of smart technologies in developing regions such as South Africa?

During the investigations from Part 1, that demonstrated that technology adoption is occurring, the researcher identified a core aspect in the development of skills and introduction to smart technologies, which was an innovation mechanism. These concepts led to Part 2. This chapter investigates these mechanisms in depth, and the role they can have in supporting smart technology adoption. Conceptually, they are not new to universities or business. However, the researcher noted that they could promote needed uptake of technologies and several other functions in the 4IR paradigm. Moreover, as the researcher was based in such an environment, needed data could be accessed to meet the needs of the thesis.

Consequently, the researcher sought to investigate such mechanisms or environments as infrastructure to support innovation development. However, during the investigations, the COVID-19 pandemic hit, shocking existing paradigms on a global scale, where several countries were left scrambling to manage numerous adverse effects. This included changing several dynamics not only in such innovation environments, but universities as well.

Despite this, large-scale adoption of technology was occurring, as it enabled innovation across economies to address challenges of the pandemic. This was achieved through a global community movement that leveraged rapid advances of smart technologies, specifically AM, towards the next generation of manufacturing. Part of which was a makerspace. Consequently, the researcher sought to investigate the practices that supported adoption in this mechanism, or "space". The findings from this are presented in article 2, which showed that the adoption of smart technologies depends on evident constructs as specified in the TAM and UTUAT model, which were shown to have applications in the field of I4.0 and by extension, the 4IR. Moreover, a conceptual framework was developed to note how makerspaces can act as innovation mechanisms to support adoption levels of 4IR technologies to develop innovation capabilities. Part of this is that makerspace's themselves can evolve to offer more relevant and needed functions, even in universities, such as those stemming from DIHs.

Reference article 2: Kruger, S. & Steyn, A. A. (2022). Innovation Environment's Role in Supporting Industry 4.0 Technology Adoption to Address Effects of COVID-19. Accepted in the International Journal of Innovation and Technology Management, May 2022.

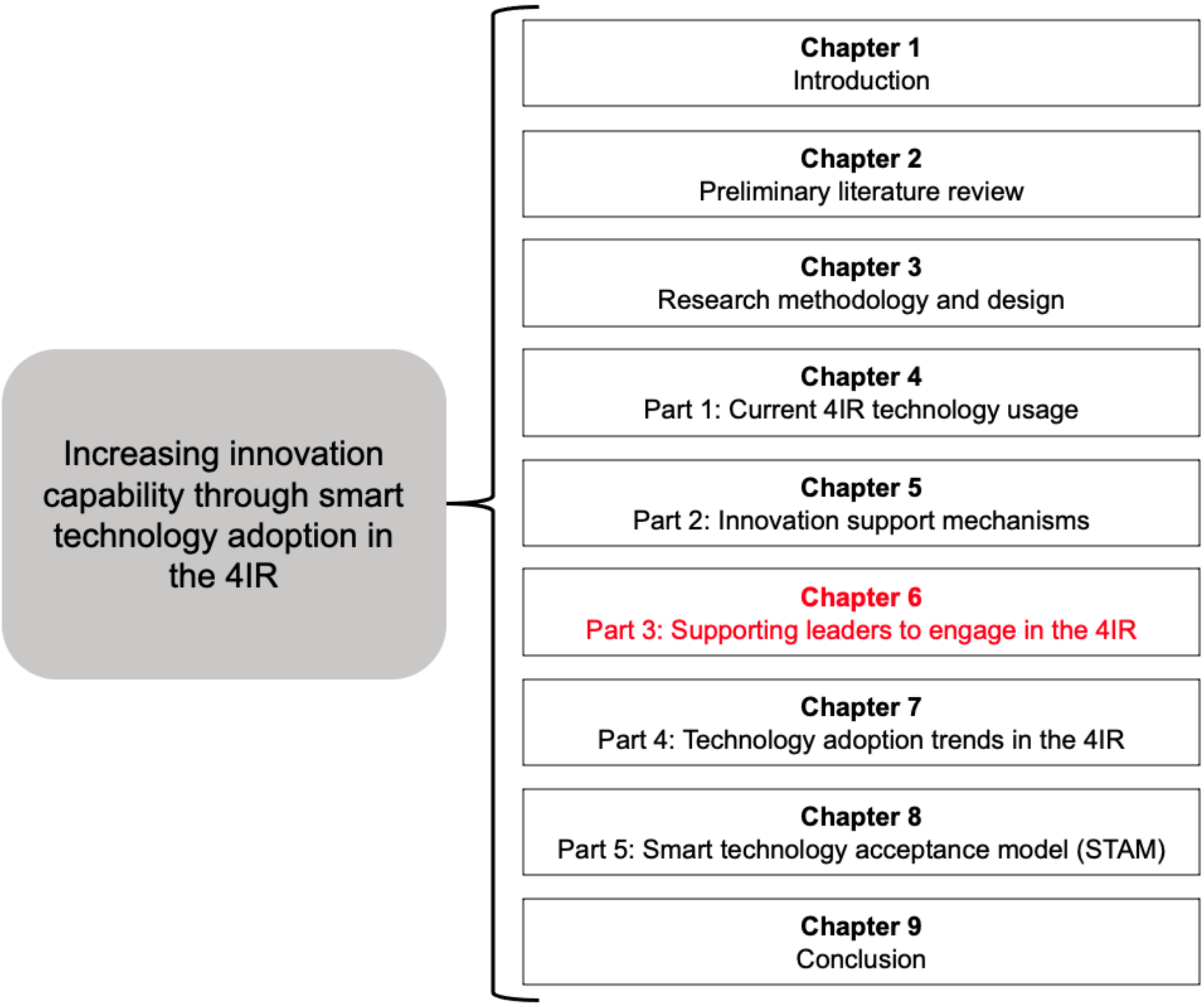
During these investigations though, the researcher wanted to provide further insights into what could be constituted as core services to users of such mechanisms. As a result, a secondary article for this part was developed. At the basis of the assessment was the

UTAUT model. The findings align with article 2, in that innovation mechanisms such as an academic makerspace could act as a strategic tool in developing regions universities to stimulate innovation and skills development to leverage opportunities of the 4IR. As a result, the research question is answered. Both articles are now presented, followed by Part 3.

Reference article 3: Kruger, S. & Steyn, A. A. (2022). Improving Innovation Capabilities in Developing Countries through Enhanced 4IR Technology Adoption: The Supportive Role of a Makerspace. Submitted for review to the Research Policy journal, April 2022. The submission notice can be seen in **Appendix B**.

As with Part 1, both contributions are in article format. To this end, each articles presentation is done to the journal's standards and styling. The references, appendices, figures and tables are all also kept with each article to support the reader to navigate the thesis and relate each articles content to the respective part presented.

6 PART 3: SUPPORTING LEADERS TO ENGAGE IN THE 4IR



6.1 INTRODUCTORY NOTES

Research question Part 3: How can we support leaders through technology adoption in a developing region such as South Africa?

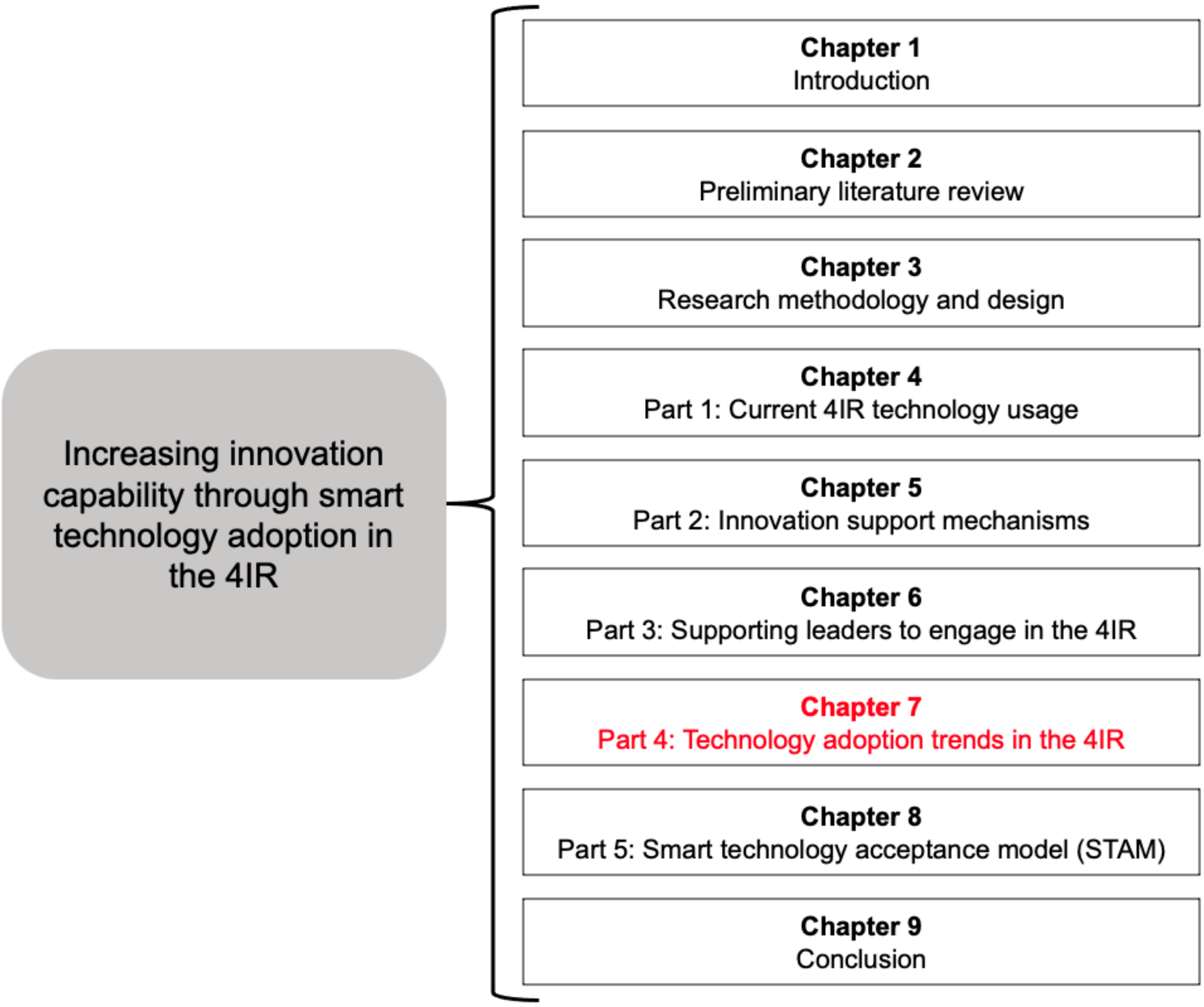
To this point, the researcher investigated technology adoption occurring in the 4IR within SA and supportive mechanisms to achieve this. However, the target audience for this thesis is leaders. Moving from these two parts, the researcher then investigated ways to support leaders in the 4IR due to their potential to leverage smart technologies to positively impact SDGs such as fair work and economic development.

In the article that follows, an artefact was developed based on key elements and constructs of technology adoption theories that have been used to assess the adoption of technologies which stem from the 4IR. By supporting leaders, larger impacts can be achieved as they influence strategy and implementation of technologies towards innovation of that of organisations. The theoretical underpinnings applied to this study was the TAM and UTUAT models, where linkages were postulated based on skills towards engagement in the 4IR. Consequently, the research question is addressed, with a specific case provided within SA.

Reference article 4: Kruger, S., Steyn, A. A. & Turpin, M. (2022). Supporting Leaders to Engage in the Fourth Industrial Revolution through Technology Adoption Principles: Perspectives from a Developing Country. Submitted for review to the Information Systems Frontiers journal, December 2021. The submission notice can be seen in **Appendix B**.

As with Part 1 and Part 2, the contribution of Part 3 is presented in article format. To this end, the articles presentation is done to the journal's standards and styling. The references, appendices, figures and tables are all also kept with the article to support the reader to navigate the thesis and relate each articles content to the respective part presented.

7 PART 4: TECHNOLOGY ADOPTION TRENDS IN THE 4IR



7.1 INTRODUCTORY NOTES

Research question Part 4: What are current trends in technology adoption model uptake in the 4IR paradigm?

In conducting Part 1, Part 2 and Part 3, the researcher acknowledged that the underpinnings may appear inconsistent. Although they are sound and mature in the field of IS, within the context of the 4IR, a consistently used model, or models, was unclear. The purpose of this part of the study was to address this by determining which technology adoption model, or models, are primarily used when assessing smart technologies in the 4IR construct. It is not to investigate the rigour of existing models or their theoretical underpinnings, as this has been proven.

The researcher developed the fifth article for this thesis to formulate needed insights. First and foremost, the analysis confirms that TAM remains the predominantly used model. However, 105 of the 125 models extended their theoretical underpinnings indicating a lack of maturity. Additional information that was provided was author countries, their institutions, but also, where the studies themselves were conducted. The citation count, sample size of the articles reviewed, research methods, subject areas and the smart technologies within these papers were also extracted. The linkages to the models, subject areas and technologies were then introduced. Subject areas were noted due to the interdisciplinary nature of the 4IR. The aim of which was to provide a comprehensive outlook on this paradigm.

Reference article 5: Kruger, S. & Steyn, A. A. (2022). Which Model is Best? A Systematic Review of Technology Adoption Model Trends for the Fourth Industrial Revolution. Submitted for review to the Technology in Society journal, July 2022. The submission notice can be seen in **Appendix B**.

However, while conducting the review, the researcher identified a gap, or lack of specification in the primary research question. This was that the level of analysis, which plays a significant role in selecting the correct model was lacking. As a result, a second article for Part 4 was developed. This focused on organisational levels of assessment in the 4IR. Moreover, weightings to the significant constructs were formulated to identify what organisations can do to stimulate innovation through technology adoption. Both developing and developed world perspectives were included. Consequently, the study developed a conceptual model based on the findings to navigate the highly interconnected and integrated paradigm, where the 4IR goes beyond traditional concepts and is driving globalisation through digital transformation.

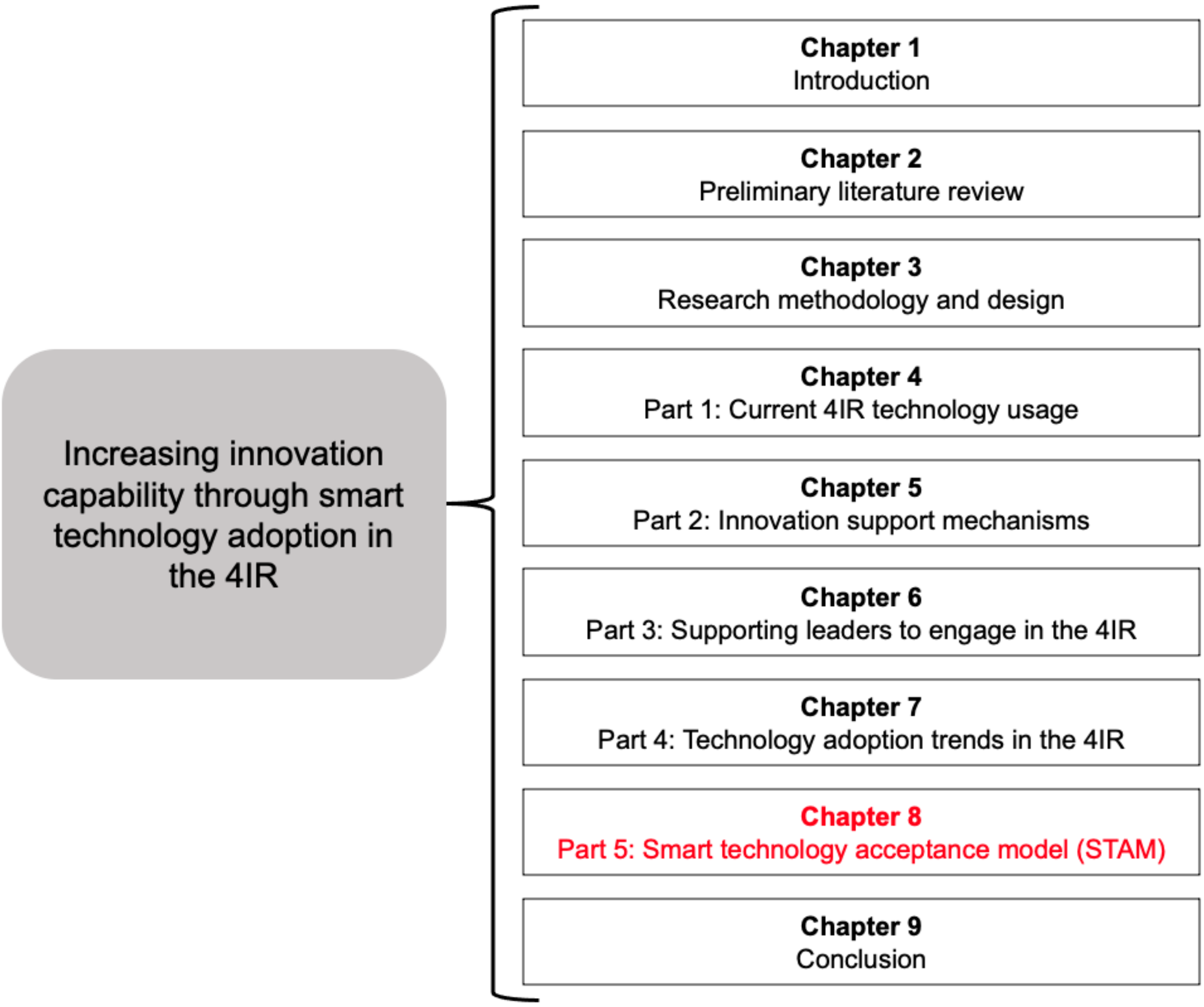
Reference article 6: Kruger, S. & Steyn, A. A. (2022). Assessing Technology Adoption Constructs That Enable Organisations to Navigate the Fourth Industrial Revolution: A

Systematic Review. Submitted for review to the Telematics and Informatics Reports journal, May 2022. The submission notice can be seen in **Appendix B**.

As with Part 1, Part 2 and Part 3, both the contributions are presented in article format. To this end, the articles presented is done to the journal's standards and styling. The references, appendices, figures and tables are all also kept with the article to support the reader to navigate the thesis and relate each articles content to the respective part presented.

Accordingly, the fourth research question is addressed, noting trends and several other facets within the 4IR paradigm.

8 PART 5: SMART TECHNOLOGY ACCEPTANCE MODEL (STAM)



8.1 INTRODUCTORY NOTES

Research question Part 5: How can we support 4IR technology adoption to enhance innovation capabilities?

From the research conducted to this point, it was found that there are many opportunities to innovate, and one way to support this is technology adoption. In this sense, the researcher provided sufficient evidence that technology adoption in the 4IR remains pivotal to supporting innovation. Thus, supporting the "why" to address the primary research question.

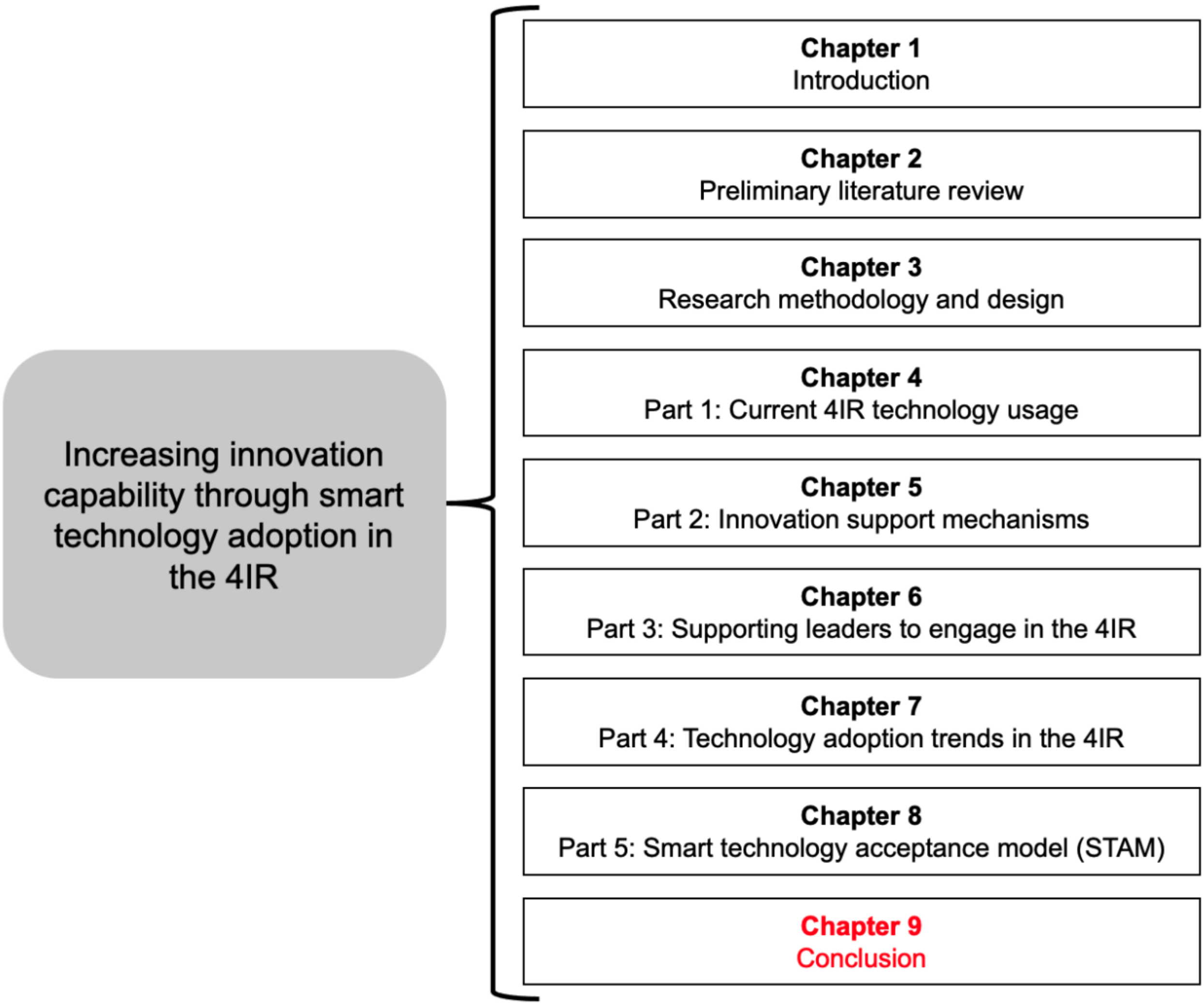
In Part 4, technology adoption trends and models at the disposal of researchers was demonstrated. This is dependent on the level of analysis. From an organisational perspective, several constructs were identified towards developing innovation. The most heavily weighted in this regard was technological capabilities and relative advantage. Furthermore, findings from Part 3 noted that leadership skills were required to support smart technology adoption. Part 2 reviewed mechanisms to support such skills. Part 1 noted that such adoption is occurring, and furthermore, is needed in developing regions. Using these insights, that was developed through iterative steps per action research, led to the final investigation.

The final article addresses the primary research question, which is a way to assess and subsequently support user adoption of smart technologies. The aim of which is to develop innovation capabilities. To do so the final study formulates a conceptual smart technology acceptance model that has potential global application. To provide insights for the developing region, the study empirically tests the model in SA. The formation of this process was based on Venkatesh *et al*. (2003, 2012), to ensure a sound theoretical basis. In this sense, the final article can be considered the primary contribution of the study.

Reference article 7: Kruger, S. & Steyn, A. A. (2022). Assessing Individual Constructs to Leverage Possibilities of the Fourth Industrial Revolution: Development of the Smart Technology Acceptance Model (STAM). Submitted for review to the Telematics and Informatics journal, August 2022. See **Appendix B**.

As with all the parts to this point, the contributions are presented in article format. To this end, the articles presentation is done to the journal's standards and styling, with all relevant information encompassed within.

9 CONCLUSION

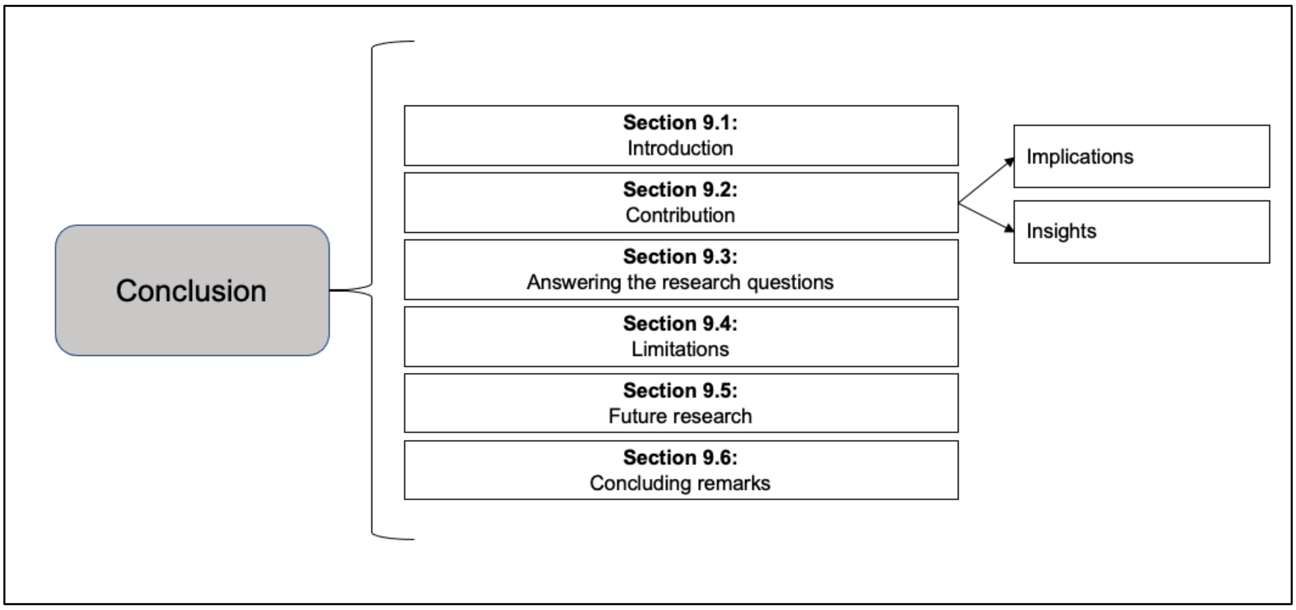


9.1 INTRODUCTION

The research efforts of this thesis have been presented, taking the reader on a journey through the introduction, literature review, research methodology and design. After which five parts containing seven articles were presented. Consequently, the research cycle is completed, returning the reader to the research questions that were asked at the onset of this thesis.

The final chapter provides a brief summary of the contributions of each part that adds to the IS body of knowledge. The researcher also notes how the iterative process led to each subsequent contribution to ensure a coherent thesis. After which the implications, both theoretical and practical are briefly reviewed, as these were extensively covered in the research articles. The contributions however go beyond only themes, which is highlighted in this chapter as insights which were gained by the researcher during the study. The research questions are then answered, followed by the limitations of the thesis. Finally, future research that can benefit from this thesis is noted with the concluding remarks. The thesis flow is shown in Figure 9-1.

Figure 9-1: Visual outline for chapter 9



9.2 CONTRIBUTION

This thesis, using the article approach, brings together several considerations and practical research on how to support innovation. The focus being smart technology adoption in the 4IR paradigm. Each part's contribution was briefly noted in Chapter 1 and in the respective article. However, they are reviewed here again for the reader's ease of reference.

Part 1 contributed by providing a practical usage case when adopting smart technologies to address disruptions being experienced due to the 4IR, also referred to as I4.0 paradigm. To add to the existing body of knowledge on IS, a conceptual model was also presented. The purpose of which was to provide insights for entrepreneurs, industry practitioners, academics and leaders to innovate through technology adoption from an IS perspective within the 4IR paradigm.

Part 2 contributed by providing a conceptual framework on how makerspaces can act as innovation mechanisms. Moreover, how such mechanisms can act as agile platforms to support innovation by streamlining critical success factors of smart technology adoption. At the basis of which is the alignment to developed regions initiatives such as DIHs. In this sense, the contribution shows how these mechanisms can create supportive facilitating conditions, develop relevant technological capabilities (skills) and create an understanding of relative advantages for smart technology usage.

Part 3 contributed by developing an artefact to improve leaders' perceptions and support their engagement in the 4IR paradigm. This adds to IS literature on enhancing technology acceptance, specifically smart technology, at a user level for the target audience of this thesis.

Part 4 contributed theoretically by providing a baseline to develop a generalisable 4IR model grounded on existing acceptance trends identified. Moreover, considering the 4IR goes beyond traditional concepts and is driving globalisation through digital transformation, the study developed a conceptual model to guide organisations towards large scale uptake and application of smart technologies to develop innovation capabilities.

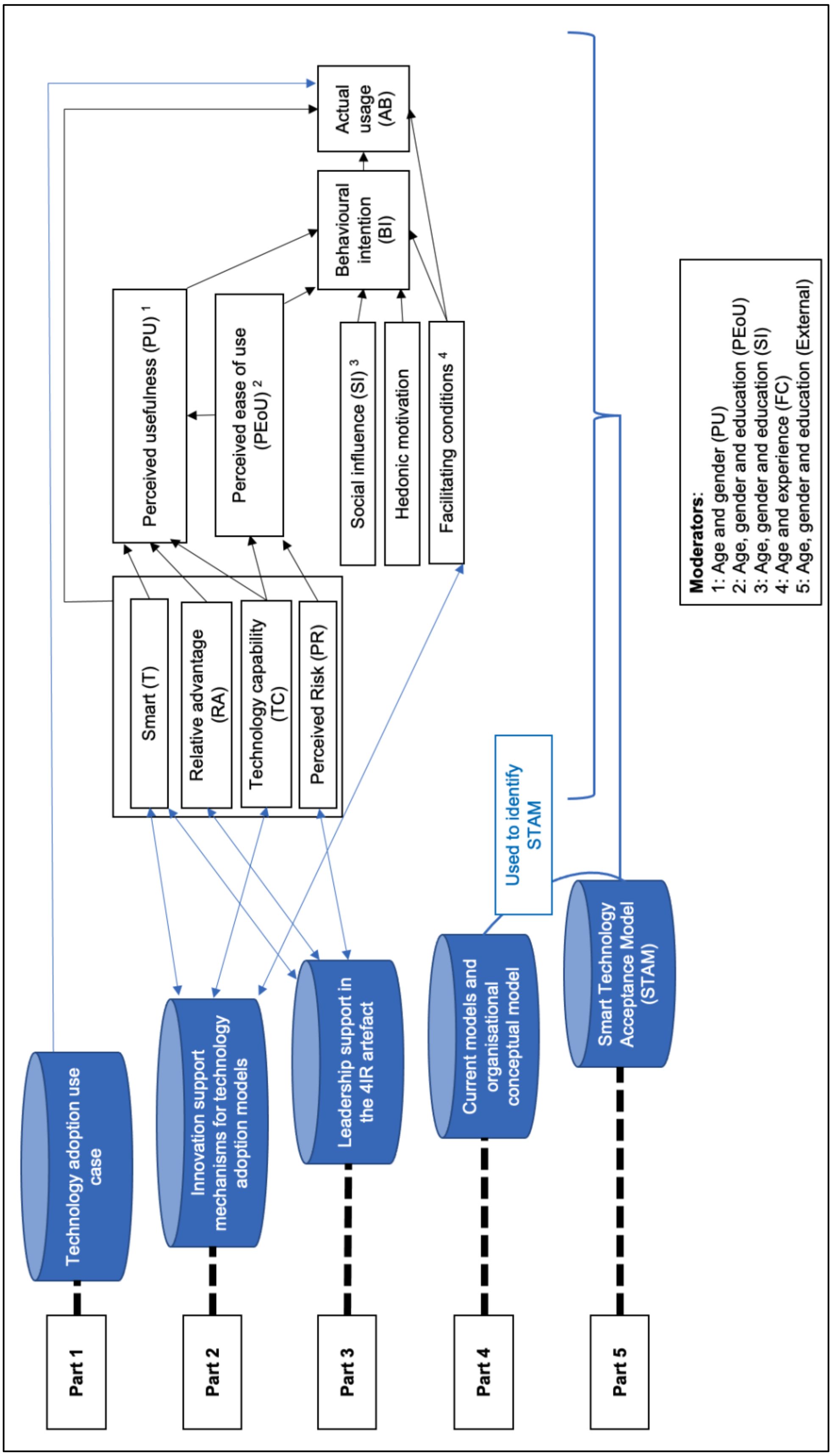
Until this point, using the iterative nature of action research, the researcher provided sufficient evidence that technology adoption in the 4IR remains pivotal to supporting innovation. Various constructs were investigated from a global perspective, where there are theoretical models being used and applied. These models also underpinned studies in Part 1, Part 2 and Part 3. Part 4 provided insights on the levels of technology adoption analysis, where organisational innovativeness had heavy weightings on their technological capabilities and ability to formulate relative advantage. These parts together furthered understanding of the 4IR paradigm and the role of technology adoption. However, in a developing world such as SA, applicable frameworks or models on how to effectively adopt and leverage technologies of the 4IR were unclear, especially when considering the regions barriers.

Part 5 contributed to literature by addressing this gap in research. The contribution was twofold. Firstly, an assessment and development of a conceptual model from a global perspective on smart technology adoption was provided on an individual level. The reason for this was that organisations need competent technological individuals and leaders who can relate smart technology to relative advantage. Secondly, the model was empirically tested to add insights into developing regions, in this instance, SA. The resulting STAM can function as a baseline tool to enable the adoption of smart technologies to develop innovation capabilities and re-invent business models. The model itself, aligns with current trends, which was found to be TAM. However, it adds certain constructs to the analysis for this paradigm, whilst ensuring a sense of simplicity to aid in its future usage.

The reason to leverage this knowledge is to strengthen innovation capabilities of individuals and organisations alike through technological advancements, such as those brought on by the 4IR. This in turn, can support decisions by leadership who can now better understand the possibilities and relate it to ROI, protecting financial performance and driving economic development. Moreover, the results can be an important guide for leaders to support skills development in academia for graduates or organisational employees, and support 4IR engagement towards a future ready workforce.

The reader may note that each contribution evolved to be more rigorous and impactful. However, as stated in previous chapters, the contributions of each could appear disjointed to the reader. For this reason, a flow of each part is shown in Figure 9-2, that link elements to the STAM model.

Figure 9-2: Visual outline of contributions



9.2.1 Implications

The researcher noted several implications from the seven articles conducted. These were reviewed in depth in each; however, the researcher would like to provide the most pertinent implications both theoretically and practically.
Theoretically, this includes the following:

- Smart technologies have furthered individual and organisation's ability to innovate by being able to integrate not only on a physical technology level, but a digital one as well.
- When navigating the 4IR and its associated smart technologies, adoption levels influence behavioural intention, and thus need to be considered when using the models developed.
- The study supports the usage of innovation mechanisms to deliver value. Moreover, R&D areas such as makerspaces are relevant, especially when they align with developed region mechanisms such as the DIH to develop innovation capability. Finally, within larger ecosystems, innovation mechanisms can be key facilitators for the future of work skills that are changing due to the 4IR.
- Usefulness perceptions can change due to accelerated needs, as with those faced with the context of the pandemic. This should be noted when adopting theory and the potential risks when pushing new technology adoptions.
- Due to the complexities and heterogeneity of 4IR, most models used have been extended to go beyond the original constructs offered.
- Business models will need to be re-invented, to define how value is proposed, but also how functional dynamics of PU and PEoU as key technology acceptance constructs can be achieved. This will require having a strong customer focus where systems alleviate frustrations and are able to offer new forms of value with their enabling features. Moreover, there needs to be a clear understanding and tracking of innovation metrics to define the ROI to ensure the right technology adoption focus areas are leveraged.
- To navigate the 4IR impacts, there needs to be an enterprise level of innovation development using these technologies. However, this depends largely on organisations and its employee's ability to adopt the smart technologies of the 4IR paradigm, where the constructs presented can act as a vital guide. This led to the final research article that contributes to existing knowledge by utilising commonly found and applied intention-based models of individual user's motivations and potential outcomes towards effective engagement and understandings of this paradigm.

Practically implications of the thesis are as follows:

- The thesis provides insights into how entrepreneurs can create value such as business intelligence using smart technologies. This in turn shows actual usage on how smart technologies can be integrated to create new forms of value.

- Innovation environments can form a key part of infrastructure towards innovation. Having the capacity to access such environments can allow users (or employees) to evaluate and test parts, capacities and technologies. They play a pivotal role in supporting technology adoption through inter-disciplinary collaboration, design thinking, consulting and access in an open environment.
- Specific efforts can be formulated to pivot on increasing usefulness through technology upskilling. One way to do so is through innovation mechanisms such as DIH or DSC.
- Developing countries can use smart technologies in various fields, making room for several opportunities for large organisations and SMEs. To achieve this, as was seen from the regional concentrations for the studies, requires digital skills and new business model development.
- Due to the rapid nature of 4IR and skills required, academic offerings may need to consider micro-credentials as a core basis for future education.
- Value creation and barriers such as ease of use can be navigated to aid individuals in organisations and SMEs to pair smart technologies to commercial value to achieve benefits.

9.2.2 Insights developed

The researcher learned through these investigations, that various skills will be needed for the future. The task however does not lie with one actor, but all, to culminate an effective way to engage and navigate this paradigm. However, the researcher noted the argument that academics are one of the primary actors tasked to ensure a future ready workforce, support entrepreneurial development and produce research outputs. In this regard academic actors need to deliver graduates who are correctly skilled and upskill the existing workforce for a future of work. Secondly, they need to continue to drive needed knowledge creation through research and facilitate innovation.

The researcher focused the thesis on participants with an existing skill set, or at the very least basic digital literacy. This however is not always the case, especially in developing regions as SA. A major challenge will be to align the efforts of the 4IR to better society as a whole, but this is a conversation for an area referred to as Society 5.0. Within the area of inquiry, the researcher noted that despite the challenges and barriers found in the region of SA, several efforts are being formulated to leverage the 4IR. This includes innovation mechanisms, policies, larger innovation ecosystems and upskilling of leadership.

The researcher also learnt the importance of entrepreneurs. With rife unemployment and a need to create businesses, they have been a focal point in strategic support by the South African government. They have also seen focus from the international community, leading to skills development and support mechanisms in this regard. From the researcher's perspective, it was noted that within this scope the effective usage of technology and varying constructs could further aid in this regard.

Finally, the researcher noted that despite the TAM model being "old", it has continued to see extensive usage. A reason for this could be its simplicity, which was found to be true in STAM as well. That which is easier to understand can hopefully be applied to the benefit of all stakeholders.

9.3 ANSWERING THE RESEARCH QUESTIONS

At the beginning of this thesis, the following primary research question was posed: **"How can we support 4IR technology adoption to enhance innovation capabilities?"**.

The reason for asking this research question was the researchers understanding (based on assumptions) that **"actors often fail to innovate in the Fourth Industrial Revolution (4IR) due to a lack of smart technology understanding".**

As the study progressed, this research question might have been worded in a different manner, as there are several facets and a global level of impact attributable to this paradigm. The reader may have noted this, as the impacts are not only on existing ICT and IS, but also business models, strategies and everyday life. Notwithstanding, the level of analysis in this regard, may have been stated from the beginning. For example, organisations require a different model. However, these organisations are run by individual leaders, and as such should focus on such individuals to guide them to leverage technologies of the 4IR.

Nonetheless, what remained consistently focused on in this thesis, guided by the action research strategy, was that innovation is one facet required to engage in this paradigm. Core to the enablement of innovation development is the usage, application and development (adoption) of smart technologies across various industries to create new forms of value.

The focus to support innovation development was addressed in five parts, each investigating a different aspect of the research questions while maintaining coherent contributions within the thesis. The questions addressed are as follows:

- **Part 1**: Have there been successful adoption cases that demonstrate innovative outcomes using 4IR technologies?

  Yes, there have been successful adoption cases with innovative outcomes, even in a developing region such as SA. The researcher answered this sub-question by presenting the reader with an actual adoption case and associated conceptual model that can be used to enable further adoption using these smart technologies. The stakeholders in this instance were entrepreneurs.

- **Part 2:** What innovation mechanisms can support the uptake of smart technologies in developing regions such as South Africa?

There are various mechanisms available within a larger innovation ecosystem. These can be used within academic or business spheres, whether it be to support innovation, develop certain skills needed for the 4IR or channel innovation activities. The study noted the trend of DIH and makerspaces in this regard. However, their evolution should align to their deliverables, such as a makerspaces progression towards a DSC. The researcher answered this sub-question by producing two articles. The first provided contextually relevant efforts during the pandemic of such a mechanism. The second was an analysis of such a mechanism in depth over six months, noting how it supports uptake of smart technologies. Both of which produced conceptual models.

- **Part 3:** How can we support leaders through technology adoption in a developing region such as South Africa?

  Artefacts and skills development is one method that can directly support leadership's engagement in the 4IR. The researcher addressed this by providing a study showing how to support usage acceptance of smart technologies that enhances the leaderships' ability to create relative advantage. In the study though, it was found that adoption of smart technologies is being limited in SA due to a lack of technical understanding and skills in terms of utility to be used towards innovating and ultimately value creation.

- **Part 4:** What are current trends in technology adoption model uptake in the 4IR paradigm?

  It was found that there are similar trends to previous IS literature in terms of models used. For organisations, the TOE. For individuals, TAM and UTAUT. However, as was explicitly noted, within the 4IR paradigm, most models were amended to understand their adoption. The researcher answered this by compiling two comprehensive literature studies. The first noting the model trends, and the second, identifying a conceptual model that had weighted constructs for organisational adoption towards innovation. From these weightings, and Part 3, individual aspects were noted as critical, leading to the constructs that can be considered pivotal for individuals to innovate using smart technology.

- **Part 5:** How can we support 4IR technology adoption to enhance innovation capabilities?

  To answer this question, it needs to be addressed on each parts merit. Part 1 notes that there are certain skills needed that enable technology adoption towards innovative outcomes. In this analysis, the researcher noted that technology adoption was the theoretical underpinning, and the skills and actual adoption was being supported by an innovation mechanism in a larger ecosystem.

Part 2 addresses these mechanisms in detail on their role to support technology adoption. In this sense supporting technological capabilities, smart technology understanding and facilitating conditions that are conducive (DIH), which is one of the constructs that align to STAM.

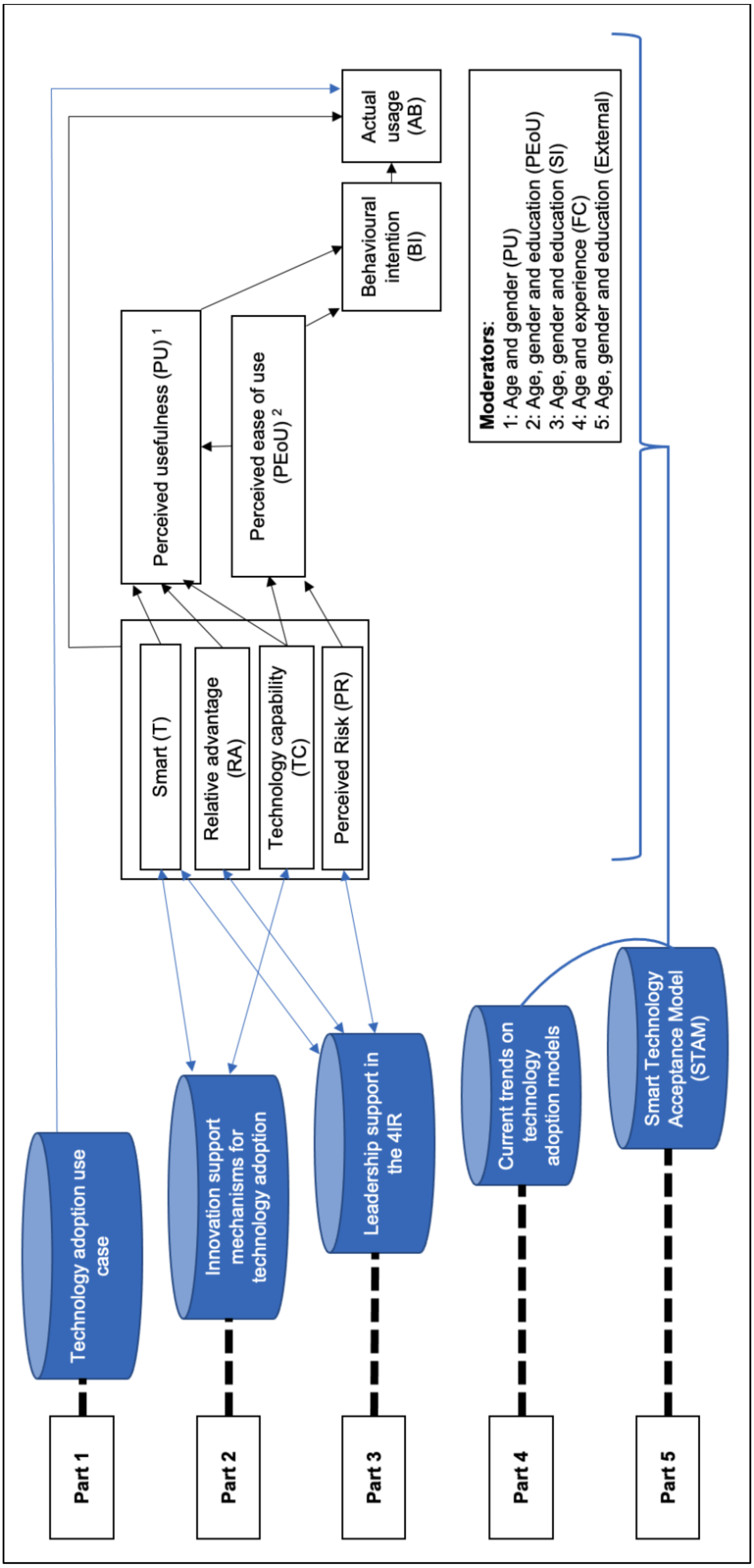
Part 3 was a specific artefact that based itself on technology adoption, where leaders were supported in the smart aspects of STAM to create relative advantage, noting a need for technological capability enhancement to achieve this.

Part 4 noted the trends and models. In this sense, there needs to a clear distinguishment for levels of analysis. Article 6 adds to this, in that weighted constructs that were identified can be focused on by organisations to enhance their innovation outputs. The most weighted was the advantage (smart understanding) and technological capabilities.

This led to the final deliverable, STAM. When investigating Part 1, Part 2, Part 3 and Part 4, it was noted that to support technology adoption in this paradigm, an individual tool was required, based on current theoretical trends. The researcher looked to support 4IR technology using STAM as a baseline, where facilitating conditions, technical skills and understanding of smart technologies would be vital in enhancing innovation capabilities.

The researcher answers the primary research question through aspects from each of the five parts. The researcher notes that innovation capabilities can be enhanced through skills development and supportive mechanisms in larger ecosystems, where technology adoption principles should underpin such efforts. Resulting from this was the conceptual STAM model and the critical constructs it encapsulates. It must be noted however, that the STAM models empirical testing led to an amendment of the model for a developing region. The resulting edits align with TAM, which is likely due to its simplistic nature, making it easier to understand. This is presented in Figure 9-3.

Figure 9-3: Visual outline to support technology adoption in a developing region



9.4 LIMITATIONS

The thesis overall limitations were noted in Chapter 1 from the onset. Furthermore, the limitations of each respective article were discussed. However, the researcher would like to further address the following. Conceptually, there is significant reliance on studies within IS on technology adoption. Although a very mature area of research, it was noted that there are various models to adopt and apply in the various contexts brought on by the 4IR paradigm. Although the critique for fundamentals of each model is beyond the scope of this thesis, it is a limitation. The study also only focused on a developing region in terms of its mechanisms. However, a global perspective was sought from reviewers to minimise narrowed insights. Finally, in conducting the literature reviews, there have been several arguments to predatory journals in such analysis.

9.5 FUTURE RESEARCH

The researcher identified future research areas in each article. However, there are several areas of future research the researcher would like to focus on. Firstly, in aligning and introducing skills to participants, populations of only literate users were considered. Moreover, in the investigations, despite a large focus to leverage the 4IR and established mechanisms and white papers, basic digital literacy remains a prevalent barrier. As such, an assessment into digital readiness not only of leaders to engage in this paradigm, but that of a larger audience could be conducted. This is because there are expectations to leverage the 4IR, but there are several laggers who need to first enable their digital literacy to begin to navigate this paradigm. Perhaps undergraduate and school programs could be a starting point in this regard. What should also be noted here, from the researcher's perspective, is also defining what is encompassed in the term, "digital literacy", as it goes beyond only accessing a computer and using basic software.

Secondly, although needed skills were identified, an overall assessment framework within the 4IR paradigm using the STAM could be developed. This could be especially useful to address each construct in turn, particularly technological capabilities, understanding smart technologies, navigating the risks and creating relative advantage. Although skills development in IS has received scholarly interest, further investigations within the 4IR could be beneficial and needed as noted by the concept of Society 5.0.

Finally, moderating variables could be tested on various levels, including organisational perspectives. Furthermore, actual technology integration and the varying smart technologies requires an in-depth review, as smart technologies do not always operate in isolation, especially in the 4IR paradigm. This could be conducted on a graduate level towards needed curriculum transformation or micro-credentialling required for an ever-changing future of work.

9.6 CONCLUDING REMARKS

The researcher’s approach used for this thesis facilitated several investigations to support innovation development using smart technologies. Each part matured through the iterative stages which was based on action research principles. In this sense, the researcher learned about the technologies, their vast impacts, the possibilities, technology adoption models and trends of this paradigm. The development outputs resulting from this thesis, by which it is measured, are dependent on an active approach to engage in this paradigm. Not just by academia which has been placed as a primary skills development agency, but by business and government leaders as well.

To this end, five critical parts were presented in article format, with each contribution and linkage to the thesis presented. The outcome addressed each research question in turn, producing a model, STAM, towards the enablement of innovation by using smart technologies of the 4IR, across various industries, to create new forms of value. The model in itself conceptually has application on a global front, which is relevant due to the digital transformation attributable to this paradigm. To add insights into understudied regions such as SA when compared to the global market, the model was empirically tested to help guide such regions. Consequently, it can function as a baseline tool in such regions to enable the adoption of smart technologies to develop innovation capabilities and re-invent business models.

Although there has been knowledge added from these investigations, the researcher notes that there needs to be a continuous assessment of this paradigm and the impact it is having on the various facets of our lives. Core to which will be digital literacy, advanced skills and a change in approach to ensure a future ready workforce due to the rapid changes brought on by this paradigm.

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APPENDIX A

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Faculty of Humanities
Fakulteit Geesteswetenskappe
Lefapha la Bomotho

Humanities 100.
Since 1919

4 June 2020

Dear Mr S Kruger

Project Title:	ARTIFICIAL INTELLIGENCE: CONSIDERATIONS AND POSSIBILITIES FOR A DEVELOPING WORLD
Researcher:	Mr S Kruger
Supervisor:	
Department:	External department
Reference number:	04359232 (HUM022/0520)
Degree:	Staff Research / Non Degree

Thank you for the application that was submitted for ethical consideration.

The Research Ethics Committee notes that this is a literature-based study and no human subjects are involved.

The application has been **approved** on 28 May 2020 with the assumption that the document(s) are in the public domain. Data collection may therefore commence, along these guidelines.

Please note that this approval is based on the assumption that the research will be carried out along the lines laid out in the proposal. However, should the actual research depart significantly from the proposed research, a new research proposal and application for ethical clearance will have to be submitted for approval.

We wish you success with the project.

Sincerely,

Prof Innocent Pikirayi
Deputy Dean: Postgraduate Studies and Research Ethics
Faculty of Humanities
UNIVERSITY OF PRETORIA
e-mail: PGHumanities@up.ac.za

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Faculty of Humanities
Fakulteit Geesteswetenskappe
Lefapha la Bomotho

Humanities 100.
Since 1919

28 July 2020

Dear Mr S Kruger

Project Title:	Academic Makerspace's Role in Developing Industry 4.0 Skills within Higher Education
Researcher:	Mr S Kruger
Supervisor(s):	
Department:	External department
Reference number:	04359232 (HUM019/0320)
Degree:	Staff Research

I have pleasure in informing you that the above application was **approved** by the Research Ethics Committee on 28 July 2020. Data collection may therefore commence.

Please note that this approval is based on the assumption that the research will be carried out along the lines laid out in the proposal. Should the actual research depart significantly from the proposed research, it will be necessary to apply for a new research approval and ethical clearance.

We wish you success with the project.

Sincerely,

Prof Innocent Pikirayi
Deputy Dean: Postgraduate Studies and Research Ethics
Faculty of Humanities
UNIVERSITY OF PRETORIA
e-mail: PGHumanities@up.ac.za

Fakulteit Geesteswetenskappe
Lefapha la Bomotho

Research Ethics Committee Members: Prof I Pikirayi (Deputy Dean); Prof KL Harris; Mr A Bizos; Dr A-M de Beer; Dr A dos Santos; Ms KT Govinder Andrew; Dr P Gutura; Dr E Johnson; Prof D Maree; Mr A Mohamed; Dr I Noomè; Dr C Puttergill; Prof D Reyburn; Prof M Soer; Prof E Taljard; Prof V Thebe; Ms B Tsebe; Ms D Mokalapa

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YUNIBESITHI YA PRETORIA

Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

22 September 2021

Reference number: EBIT/229/2021

Mr S Kruger
Department: Informatics
University of Pretoria
Pretoria
0083

Dear Mr S Kruger

FACULTY COMMITTEE FOR RESEARCH ETHICS AND INTEGRITY

Your recent application to the EBIT Research Ethics Committee refers.

Approval is granted for the application with reference number that appears above.

1. This means that the research project entitled "Which model is best? Assessing technology adoption models and theories used in the Fourth Industrial Revolution" has been approved as submitted. It is important to note what approval implies. This is expanded on in the points that follow.
2. This approval does not imply that the researcher, student or lecturer is relieved of any accountability in terms of the Code of Ethics for Scholarly Activities of the University of Pretoria, or the Policy and Procedures for Responsible Research of the University of Pretoria. These documents are available on the website of the EBIT Research Ethics Committee.
3. If action is taken beyond the approved application, approval is withdrawn automatically.
4. According to the regulations, any relevant problem arising from the study or research methodology as well as any amendments or changes, must be brought to the attention of the EBIT Research Ethics Office.
5. The Committee must be notified on completion of the project.

The Committee wishes you every success with the research project.

Prof K.-Y. Chan
Chair: Faculty Committee for Research Ethics and Integrity
FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

Protocol Number: EBIT/206/2021 **Version:** 1
Application Status: Cancelled
On whose desk: Applicant

Application Comments Documents

Submit for Approval

Application Date: 28/07/2021 **Committee Cut-off Date:** 10/09/2021

Comments and History

Navigate to: 1 of 1

	Application ID	Application Type	Fact	Sequence	Approved	Send Letter
1	EBIT/206/2021	EBIT	00012	Home	☐	☐

Please enter a Comment:

Comment type: Applicant's Comment

Post comment

Comment type	Date and Time	Display Name	Comment
Cancel Application	20/09/2021 08:33	Mr S Kruger	Per Prof. Chan comment, application cancelled as it is not needed for literature review study.
Referred back to Applicant	17/09/2021 15:18	Prof K Chan	Please cancel this application as it is a literature review which doesn't involve people.

Return

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Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

24 April 2022

Reference number: EBIT/22/2022

Mr S Kruger
Department: Informatics
University of Pretoria
Pretoria
0083

Dear Mr S Kruger,

FACULTY COMMITTEE FOR RESEARCH ETHICS AND INTEGRITY

Your recent application to the EBIT Research Ethics Committee refers.

Conditional approval is granted.

This means that the research project entitled "Assessing Individual Constructs to Leverage Possibilities of the Fourth Industrial Revolution: Development of the Smart Technology Acceptance Model (STAM)" is approved under the strict conditions indicated below. If these conditions are not met, approval is withdrawn automatically.

Conditions for approval:

The manner in which organisations will be approached and, subsequently the manner in which employees of participating organisations will be approached should be described. (The ethics issue is to establish that invitations to individuals are not sent from authority figures, whose involvement may be deemed to be coercive.)

Why is the name of the organisation asked, if it will not be used (There may well be a logical explanation, but it should be explicitly stated, the limit the extent to which such information is used.)

Not of impotence for ethics clearance: The questionnaire often uses "ranking" where the intention cannot be to rank all provided options. Perhaps rating or even scaling may be more appropriate. The best would have been to submit the questionnaire in the form it will be used, rather than with a placeholder, such as "ranking".

The word 'informed consent' should be changed to 'permission letter' that allow (provide the permission) the researcher to conduct research at the company. All signed permission letters will need to be submitted to the portal again.

This approval does not imply that the researcher, student or lecturer is relieved of any accountability in terms of the Code of Ethics for Scholarly Activities of the University of Pretoria, or the Policy and Procedures for Responsible Research of the University of Pretoria. These documents are available on the website of the EBIT Ethics Committee.

If action is taken beyond the approved application, approval is withdrawn automatically.

According to the regulations, any relevant problem arising from the study or research methodology as well as any amendments or changes, must be brought to the attention of the EBIT Research Ethics Office.

The Committee must be notified on completion of the project.

The Committee wishes you every success with the research project.

Prof K.-Y. Chan
Chair: Faculty Committee for Research Ethics and Integrity
FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

APPENDIX B

From: idia2022@easychair.org <idia2022@easychair.org> on behalf of IDIA 2022 <idia2022@easychair.org>
Sent: Sunday, 23 October 2022 14:34
To: Sean Kruger <sean.kruger@outlook.com>
Subject: IDIA 2022 notification for paper 5701

Dear Sean Kruger

We trust that you are well.

We are pleased to inform you that your paper has been selected for publication in Springer's Communications in Computer and Information Science (CCIS) proceedings volume. Please note that the volume will be published after the conference. It is estimated that it will take six (6) to nine (9) weeks for Springer to publish the volume after the conference date.

Please note the following terms and conditions for publishing your paper in Springer's CCIS volume:

1. The paper should be at least (minimum) 12 pages long. There is no prescribed maximum number of pages. You are welcome to make minor changes to your manuscript and even increase the number of pages. If you do so, please highlight in yellow the new content that you have added in the revised version. You are welcome to prepare your paper using Ms Word or LateX.

2. Should you consent to publish your paper in the CCIS volume, please complete and sign the "Springer's Licence to Publish Proceedings Papers" and send it to idia2022conference@gmail.com together with the Ms Word or LateX version of your paper and the PDF version of your paper. Please use this link (https://drive.google.com/drive/folders/12R_9D2Wrlsc146K0Kb0FvLwaBCgom7V2?usp=sharing) to access the "Springer's Licence to Publish Proceedings Papers" document as well as the instructions on how to prepare your manuscript for publication in the CCIS proceedings volume.

3. Please include "the paper ID_Springer proceedings" in the subject line when emailing these documents (eg: 5558_Springer proceedings). Please submit these documents by 10 November at the very latest.

4. Please note that each paper will be subjected to a plagiarism check, in line with Springer's requirements.

5. As a reminder, please ensure that the final version of your paper is thoroughly edited, preferably by a professional language editor, before emailing it if you have not done so already.

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Sean Kruger <sean.kruger@up.ac.za>

Track the status of your submission to Research Policy

1 message

Submission Tracker <no-reply@submissions.elsevier.com> 9 April 2022 at 09:03
To: sean.kruger@up.ac.za

Manuscript Number: RESPOL-D-22-00240
Manuscript Title: Improving Innovation Capabilities in Developing Countries through Enhanced 4IR Technology Adoption: The Supportive Role of a Makerspace
Journal: Research Policy

Dear Sean Kruger,

Your submitted manuscript is currently under review. The peer review process can take a while, so we are trying out a new service that allows you to track the peer review status of your submission in more detail. You can access the service here:
https://track.authorhub.elsevier.com?uuid=b5ec1aa8-2ca9-42de-b36b-5964dc1b2b30

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Sean Kruger <sean.kruger@up.ac.za>

ISFI-D-21-00736 - Submission Confirmation

1 message

Information Systems Frontiers Editorial Office <em@editorialmanager.com> 8 December 2021 at 15:34
Reply-To: Information Systems Frontiers Editorial Office <kristinekay.canaleja@springernature.com>
To: Sean Kruger <sean.kruger@up.ac.za>

Dear Mr Kruger:

Thank you for submitting your manuscript, "Supporting Leaders to Engage in the Fourth Industrial Revolution through Technology Adoption Principles: Perspectives from a Developing Country", to Information Systems Frontiers.

The submission id is: ISFI-D-21-00736
Please refer to this number in any future correspondence.

During the review process, you can keep track of the status of your manuscript by accessing the following web site:

Your username is: seankruger
If you forgot your password, you can click the 'Send Login Details' link on the EM Login page at https://www.editorialmanager.com/isfi/.

With kind regards,

The Editorial Office
Information Systems Frontiers

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Sean Kruger <sean.kruger@up.ac.za>

Submission to Technology in Society - manuscript number

1 message

Technology in Society <em@editorialmanager.com> 7 July 2022 at 18:28
Reply-To: Technology in Society <support@elsevier.com>
To: Sean Kruger <sean.kruger@up.ac.za>

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Manuscript Number: TECHIS-D-22-01510
Which Model is Best? A Systematic Review of Technology Adoption Model Trends for the Fourth Industrial Revolution

Dear Mr Kruger,

Your above referenced submission has been assigned a manuscript number: TECHIS-D-22-01510.

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Sean Kruger <sean.kruger@up.ac.za>

Confirming submission to Telematics and Informatics R

2 messages

Telematics and Informatics Reports <em@editorialmanager.com> 6 May 2022 at 14:10
Reply-To: Telematics and Informatics Reports <support@elsevier.com>
To: Sean Kruger <sean.kruger@up.ac.za>

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Assessing Technology Adoption Constructs That Enable Organisations to Navigate the Fourth Industrial Revolution: A Systematic Review

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Telematics and Informatics Reports <em@editorialmanager.com> 6 May 2022 at 15:14
Reply-To: Telematics and Informatics Reports <support@elsevier.com>
To: Sean Kruger <sean.kruger@up.ac.za>

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Which model is best? A systematic review of technology adoption models used for the Fourth Industrial Revolution
[Quoted text hidden]

Sean Kruger <sean.kruger@up.ac.za>

TELE-D-22-01100 - Confirming your submission to Telematics and Informatics

1 message

Telematics and Informatics <em@editorialmanager.com> 22 August 2022 at 14:36
Reply-To: Telematics and Informatics <support@elsevier.com>
To: Sean Kruger <sean.kruger@up.ac.za>

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Assessing Individual Constructs to Leverage Possibilities of the Fourth Industrial Revolution: Development of the Smart Technology Acceptance Model (STAM)

Dear Mr Kruger,

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