AN EXPLORATION OF SOUTH AFRICA'S INNOVATION ECOSYSTEM FOR INTERNET OF THINGS DEVICES

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DECLARATION

I Didintle Mokoka declare that this Research Report is my own, unaided work. It is being submitted for the Degree of Master of Commerce in Information Systems at the University of Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

(Signature of Candidate)

28 February 2018

ABSTRACT

An innovation ecosystem is a network of individuals and organisations with the aim of delivering a holistic product. The study aimed to understand South Africa’s Internet of Things innovation ecosystem. Internet of Things is defined as network-enabled objects which could communicate with one another. This growing trend was identified as an opportunity for South Africa to partake in the manufacturing thereof, provided that there was a well-functioning ecosystem in place. Through a review of existing literature, a framework was identified. A systematic literature review was conducted and it uncovered further elements to include in the framework. The study was exploratory in nature and made use of interviews as a method of data collection. Individuals involved in the manufacture of Internet of Things devices and individuals from institutions which supported such manufacturers were interviewed. The study aimed to understand how the actors within this ecosystem experienced Internet of Things innovation. Thematic content analysis was utilised to identify codes and themes in the data. The results of the study showed that several elements such as financing, infrastructure, regulations, ideas, knowledge networks, culture, interfaces, and architecture principles were in place, but some are not functional or work against entrepreneurs. Supporting institutions felt that they provided valuable services to manufacturing companies and that some of their challenges to providing these services stemmed from the manufacturers themselves. Manufacturing companies felt as though there were a few elements within the ecosystem which could be improved upon such as financing support, marketing support, regulations, skills, knowledge, knowledge networks, and knowledge sharing. The research created a platform for further studies to take place that investigate why South Africa’s Internet of Things innovation ecosystem is not functioning as well as those that are currently flourishing.

Keywords: Internet of Things, innovation ecosystem, elements, actors, South Africa

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LIST OF ABBREVIATIONS AND ACRONYMS

CFO: Chief Financial Officer

COO: Chief Operating Officer

CSIR: Council for Scientific and Industrial Research

DST: Department of Science and Technology

DTI: Department of Trade and Industry

GDP: Gross domestic product

GTM: Grounded theory methodology

HOD: Head of Department

IC: Integrated circuit

ICT: Information and Communication Technologies

IDC: International Data Cooperation

IoT: Internet of things

IP: Internet Protocol

IT: Information technology

JIT: Just-in-time

M2M: Machine-to-machine

MIT: Massachusetts Institute of Technology

NGO: Non-governmental organisation

NIE: National Innovation Ecosystem

NRF: National Research Fund

QDA: Qualitative data analysis

R&D: Research and development

RFID: Radio-frequency identification

SEDA: Small Enterprise Development Agency

SLR: Systematic literature review

SME: Small to medium enterprise

TCP/IP: Transmission Control Protocol/Internet Protocol

THRIP: The Technology and Human Resources for Industry Programme

TQM: Total quality management

VC: Venture capital

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CHAPTER 1: INTRODUCTION

1.1 Background

The premise of the Internet of Things (IoT) is to connect every single network-enabled object in the world to the internet. This represents a vision in which the internet extends itself into the real world, embracing everyday objects (Carruthers, 2014). This means that “digital and physical entities can be linked by means of appropriate ICT in order to enable a new class of applications and services” (Gcaba & Dlodlo, 2016). Because of the nature of IoT devices, there is an opportunity for small to medium enterprises (SMEs) and developing countries to become involved in the design and manufacture of these devices (Yeo et al., 2014).

IoT technology is not without its challenges; however, the concerns and challenges do not outweigh the benefits of this set of technology. Yeo et al. (2014) predict that IoT will dominate the world of technology with an estimated 50 billion IoT devices by 2020 and over $10 trillion in generated profit over the next 20 years. IoT is considered to have a profound impact on the high-tech industry in general and the semiconductor industry in particular. It was also among “Gartner’s 2016 Top 10 Strategic Technology Trends” (2016), due to it being perceived as central to digital business products and processes.

Today, a typical IoT device requires radio-frequency identification (RFID) or similar sensors, wireless sensor networks, addressing schemes, data storage and analytics, and visualisation (Gubbi et al., 2013). Sensors are utilised to detect and monitor a variety of elements such as temperature, vibration, humidity, pressure, and altitude – all depending on the use of that particular application. The integrated circuits (ICs) for IoT devices are smaller than those for mobile devices and have a particularly low level of design. As a result, this presents new design opportunities for SMEs and developing countries (Yeo et al., 2014) to manufacture IoT devices.

The International Data Corporation (IDC) predicted that from a technology point of view, hardware will remain the largest spending category by 2020, followed by services, software, and connectivity (www.idc.com, 2017). Figure 1.1 illustrates the spending guide based on the 2016 top technology group-based market share. As IoT is a diverse developing marketplace for vendors and end-users alike (www.idc.com, 2017), it may present opportunities for South Africa to participate in manufacturing these devices.

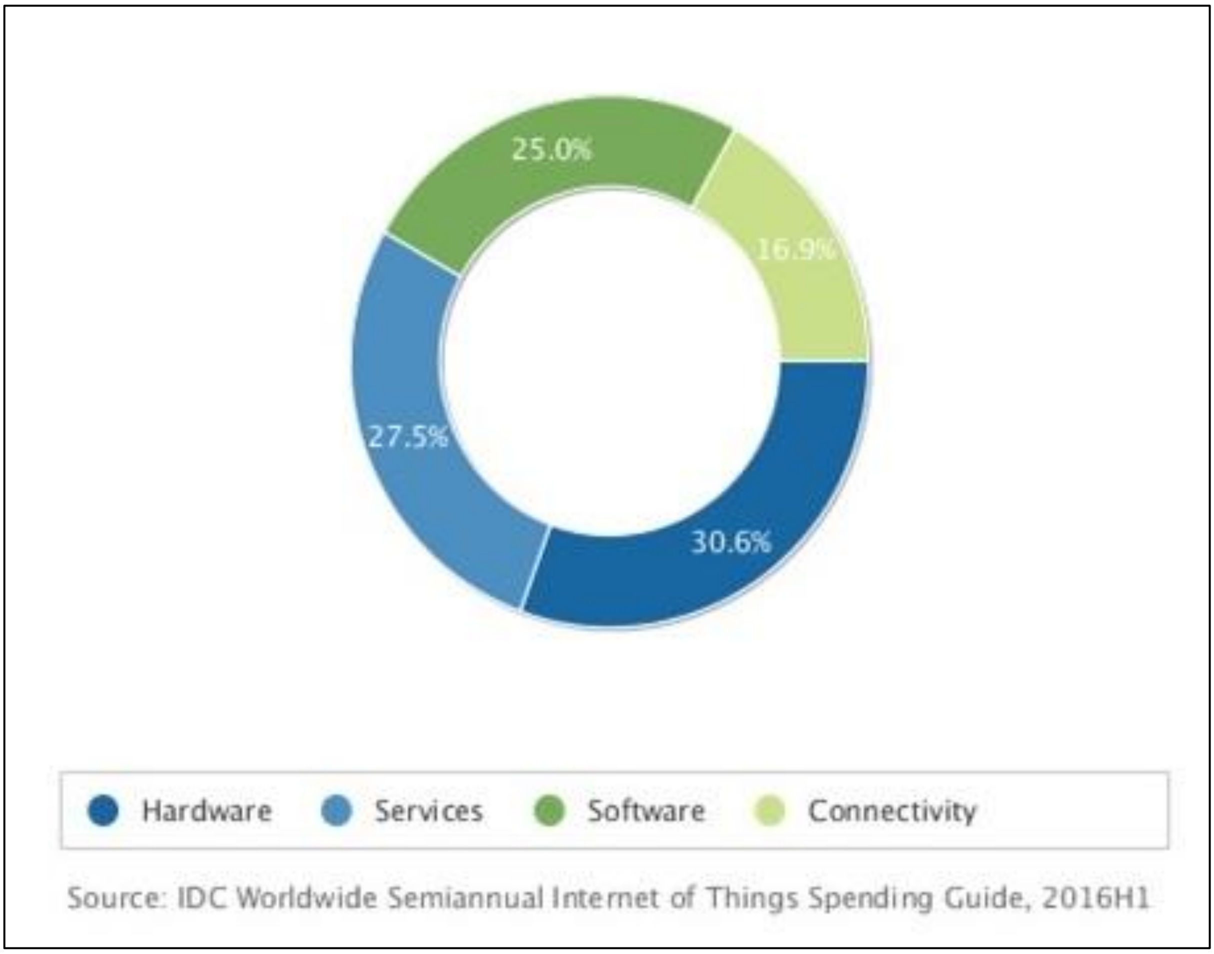

Figure 1.1: IDC's 2020 IoT Spending Guide

South Africa is a developing country and therefore needs self-sustaining development to accomplish economic growth. Self-sustaining growth is a state where a country avoids a decline in the economy and creates continuous redevelopment (Oksanen & Hautamäki, 2014). A viable manufacturing sector within a country is often seen as the key to self-sustaining growth as there is a constraint on the extent to which a country can develop through the export of primary products alone (Schneider, 2000). The manufacturing sector contributed 15.2% to South Africa's gross domestic product (GDP) in 2013, which was the third largest sector in the country's economy (Alexander, 2016).

Manufacturing is one of the ways to grow South Africa's economy. Between 1925 and 1973, the South African Government had pursued an active policy of import substitution to improve the domestic manufacturing and state investments in key sectors (Schneider, 2000). Economic growth in the 1960s soared with the manufacturing industry performing particularly well. Since the 1970s however, the entire economy including the manufacturing sector continued to deteriorate (Schneider, 2000).

South African households spent R91.6 billion on ICT products in 2012 (Africa, 2015) with ICT manufacturing contributing R6.6 billion to the ICT GDP of R94.7 billion that same year. This can be viewed as a small percentage given that South Africa's manufacturing industry is one of the strongest sectors in the country. Figure 1.2 illustrates how the various sectors in South Africa compare with one another regarding their contributions to the GDP.

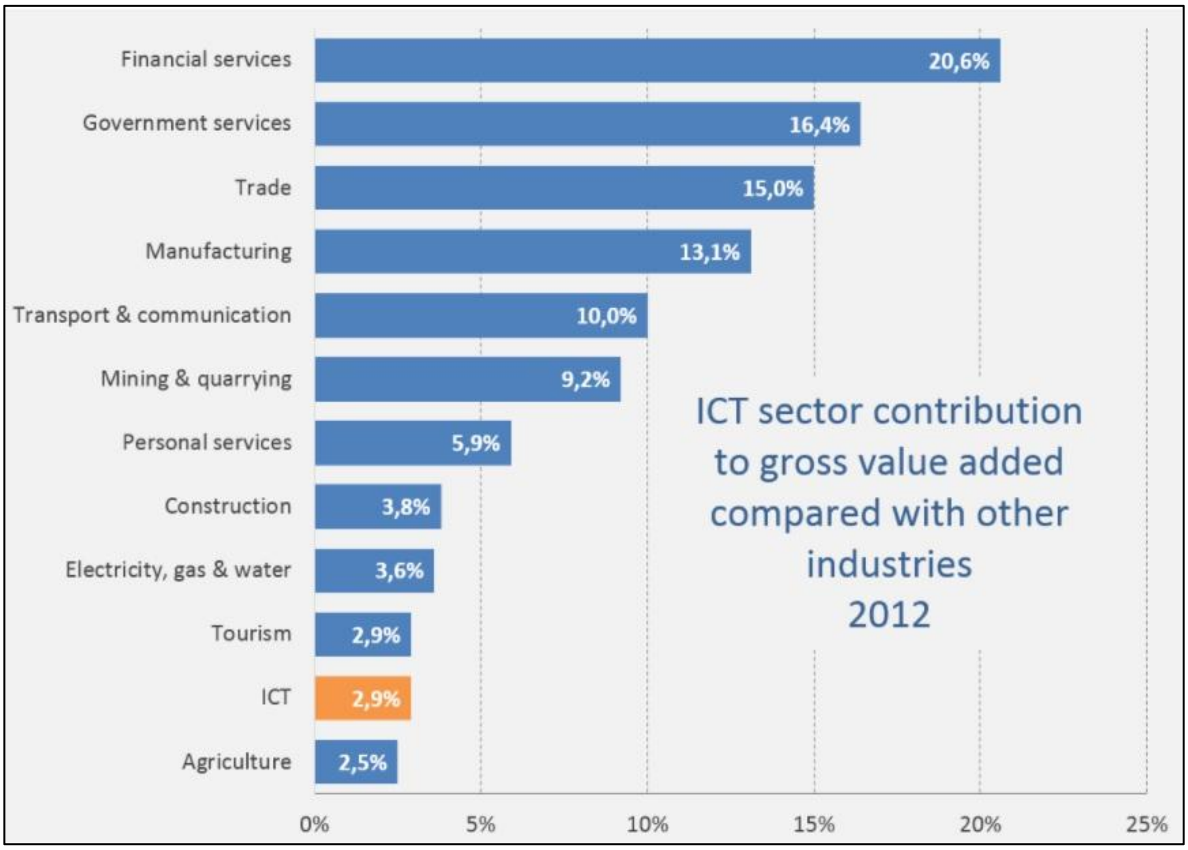

Figure 1.2: ICT sector's contribution to South Africa's GDP in 2012

The South African Government has created various policy instruments to support technology in the country (DTI, 2014). The Technology and Human Resources for Industry Programme (THRIP) is a partnership programme funded by the DTI and managed by the National Research Fund (NRF). One of the THRIP's objectives is to "stimulate industry and government to increase investment in research, technology development, diffusion and the promotion of innovation" (DTI, 2014). Such programmes enable SMEs and the various actors within the manufacturing ecosystem to take part in the economy. This could be one of the first steps in building a stronger IoT manufacturing industry within South Africa.

An IoT manufacturing industry will be more likely to develop if it is supported by an innovation ecosystem (Dedehayir & Seppänen, 2015), which requires an adequate innovation capability to determine the future of the IoT industry (Guo, 2009). An innovation ecosystem or ecology is a network of firms and support structures from different industries with the purpose of delivering product or service value to the end-user in an innovative way (Dedehayir & Seppänen, 2015).

Researchers have examined the way in which innovation takes place and there is consensus that successful innovation depends on an innovation ecosystem (Jackson, 2011; Mercier-Laurent, 2011; Sloan, 2011; Olsen et al., 2013 cited in Rabelo & Bernus, 2015). Understanding innovation ecosystems is difficult because they consist of many components with complex interactions. Rabelo and Bernus (2015) created a framework to aid in the understanding of these components and this forms the basis of this study. The framework identifies actors and elements essential to an innovation ecosystem. This study utilises Rabelo and Bernus' (2015) framework as the basis for understanding the views of actors on whether South Africa has a well-functioning ecosystem surrounding the manufacture of IoT devices.

1.2 Problem Statement

Since 2012, South Africa's economy has experienced a deceleration due to the global economic crisis (Africa, 2016). As a result, the country has an increasing level of unemployment. There are 8.4 million unemployed South Africans and "two in every three of those are young people who are left ill-equipped by an inadequate education system" (Writer & Writer, 2015). Sector interventions and support for small businesses have been named as some of the most viable ways to improve the country's economy (DTI, 2014).

Since manufacturing IoT devices has been identified as an opportunity for developing countries and SMEs (Yeo et al., 2014), it is a sector worth investigating. Such an opportunity would mean a possible improvement in the South African economy due to the high demand for IoT devices (Measuring the Information Society Report, 2015). The increasing number of interconnected devices can be seen in healthcare, manufacturing, buildings, transportation, logistics, supply chains, and telecommunications (Yeo et al., 2014).

A well-functioning ecosystem would need to be in place for South Africa to develop this sector. The research aim is therefore to examine whether there is a well-functioning innovation ecosystem in place which could support the manufacture of IoT devices in South Africa.

1.3 Purpose of the Study

The researcher investigated the nature of the innovation ecosystem surrounding the manufacture of IoT devices in South Africa with the purpose of addressing the following research question:

How do actors within the innovation ecosystem surrounding the manufacture of IoT devices in South Africa view the functioning of this ecosystem?

1.4 Research Objectives

The research objectives of the study were:

1. To identify which elements and actors of an innovation ecosystem that support the manufacture of IoT devices are currently in place in South Africa.
2. To investigate how the actors experience this innovation ecosystem.
3. To explore which elements of this innovation ecosystem could be improved (if required).

1.5 Intended Contribution of the Study

This study aimed to explore whether South Africa has a well-functioning innovation ecosystem which could facilitate the development and success of SMEs involved in the manufacture of IoT devices. The research provides insight into the existing elements of such an innovation ecosystem in South Africa as well as the actors within the ecosystem. The study also identified the gaps in the existing innovation ecosystem.

Rabelo and Bernus (2015) identified the components of an innovation ecosystem; these components will be outlined in the literature review. This research contributes knowledge regarding the extent to which these components are appropriate for and function within South Africa's IoT manufacturing sector, which contributes to the literature on innovation ecosystems within the South African context.

1.6 Delimitations of the Study

The aim of the study was not to demonstrate to what extent South Africa's economy would be improved through IoT manufacture. Nor did the study aim to analyse the data to make any generalisations towards other innovative ecosystems or the innovation ecosystems of other countries. It is assumed that the findings of this study will be regarded as unique to South Africa and within the context of this particular case study. As it was not possible to observe the functioning of the innovation ecosystem directly, this study is based on the perception of actors within the ecosystem.

1.7 Conclusion

This chapter discussed the background and problem statement of the study. The purpose of the study and the research objectives were also outlined. Lastly, the intended contribution of the study as well as the delimitations were addressed.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

A literature review is generally the first step in the research process. It is an opportunity for the researcher to "survey the current state of knowledge in the area of inquiry, identify key authors, articles, theories and findings in the area and identify gaps in knowledge in that research area" (Bhattacherjee, 2012). The need for a literature review stemmed from an abundance of information on the research topic which needed to be synthesised. The aim at this stage of the research was not to present new information but to assess what was already published (Ferrari, 2015). There are two types of standard literature reviews, namely: narrative literature reviews and systematic literature reviews (SLRs).

2.1.1 Narrative Literature Review

A narrative literature review was conducted to summarise existing literature on the IoT and innovation ecosystems and seek gaps in these knowledge areas. It is an unstructured method which entails utilising keyword searches to find information on the topic in online databases (Bhattacherjee, 2012). Keywords were added to search engines of online academic databases and combined using "and" and "or" operations in order to narrow or expand the search results. All the results rendered were browsed through to find any relevance to the topic and either discarded or included for in-depth review. Once all the articles relevant to the topics were identified and reviewed, these results were summarised and whether or not any studies had already met this study's research objectives was evident. The narrative review as an initial review was necessary as the terms "innovation ecosystem" and "Internet of Things" were at times referred to differently, therefore making some of the literature difficult to uncover using the SLR protocol alone. However, both reviews were conducted with the aim of uncovering what research had been done on the topics.

2.1.2 Systematic Literature Review

Although a narrative literature review is unstructured in nature, it should be reasonably complete. However, in order to ensure this completeness, an SLR was also conducted on innovation ecosystems. An SLR was not conducted to uncover more literature on the IoT as the aim was to understand it as a concept since it was not the unit of analysis.

An SLR provides guidelines for searching through the literature. Two protocols were defined which would render the same set of results if another researcher were to conduct such a search. These protocols included the date range, databases searched, search strings, and inclusion and exclusion criteria for conducting the SLR.

An SLR was conducted to better understand the elements and actors of an innovation ecosystem. This review included academic journals published between 2011 and 2017 in EBSCO Host and Science Direct databases. Many papers researching innovation ecosystems identified in the narrative literature review were found in these databases and therefore the databases were viewed as reliable sources. A more structured approach to conducting a literature review on the topic was taken (in the form of an SLR) to ensure that the most relevant literature was utilised.

EBSCO Host (which hosts a multidisciplinary collection of databases) and Science Direct (which also hosts a multidisciplinary database providing full-text access to journals strong in scientific and technical literature) were searched using the search strings "Internet of Things" AND "innovation ecosystem" separately, while considering the inclusion and exclusion criteria in the protocols. Two protocols were employed given that Science Direct and EBSCO Host offer different filtering mechanisms. The protocols for this review are outlined in Table 2.1: Systematic literature review protocol 1a and Systematic literature review protocol 1b

Table 2.1: Systematic literature review protocol 1a

Search strings	"innovation ecosystem"
Databases searched	Science Direct
Dates	January 2011 to December 2017
Inclusion and exclusion criteria	**Included:** • English language papers published in peer-reviewed journals or conferences. • Eighteen papers resulted. **Excluded:** • Papers from all publications other than the *Technovation* and *Technology in Society* publications; • Opinion papers; and • Papers published before January 2011.

Table 2.2: Systematic literature review protocol 1b

Search string	"innovation ecosystem"
Database searched	EBSCO Host
Dates	January 2011 to December 2017
Inclusion and exclusion criteria	**Included:** • English language papers published in scholarly (peer-reviewed) journals or conferences; • Papers published by peer-reviewed journals; • Papers limited to full text; • Sources from academic journals; • Only papers with IoT as the subject; and • Forty-five papers resulted (after exact duplicates and three false full-text availabilities were removed from a result of 64). **Excluded:** • Opinion papers; and • Papers published before January 2011.

Science Direct rendered 18 papers, while 45 papers were rendered by EBSCO Host. These papers collectively discussed the elements and actors within an innovation ecosystem. None of the articles which met the inclusion criteria discussed IoT technology. This was of no concern as the objective of the SLR was to uncover literature on innovation ecosystems.

Although 63 papers met the inclusion criteria, only 29 papers contributed to the literature on innovation ecosystems. These papers were analysed to identify the various elements and actors within an ecosystem. While some of these terms appeared to be synonyms, it was important to identify the terms as they were written.

2.2 The Internet of Things

IoT is intelligent connectivity between real-world objects, thereby making physical items interconnected with the virtual world (Mattern & Floerkemeier, 2010). The term "IoT" was not coined until 2002 when Kevin Ashton, co-founder and former Head of Auto ID Center at the Massachusetts Institute of Technology (MIT) mentioned in an interview with Forbes Magazine that an IoT was necessary as a standardised way for computers to understand the real world had become essential (Mattern & Floerkemeier, 2010). Forbes titled this interview "The Internet of Things" and this was the first documented use of the term.

Although it was only during 2002 that this term was first used, IoT technology has been evolving for quite some time. In 1969, Arpanet was the first major milestone towards IoT and the forerunner to the Internet as we know it today (Congressional Digest, 2007). In 1982, Transmission Control Protocol/Internet Protocol (TCP/IP) became a standard which enabled a world of fully integrated networks known as the Internet. Another major milestone for IoT was reached in 1990 when John Romkey and Simon Hackett created the world's first connected toaster (Rose, et al. 2015). Today, many household objects can sent data to one another through the Internet.

RFID is a major component of IoT which enables the recognition of objects through the wireless use of electromagnetic fields to transfer data. Objects can be traced by using their RFID tags which contain electronically stored data. In 1999, the first protocol to enable communication between these devices was created (Congressional Digest, 2007). This kind of communication between devices is known as machine-to-machine (M2M) communication.

2.3 Innovation Ecosystems

Understandings of innovation have stemmed from various perspectives such as sociology, economics, philosophy, and management theory (Guo, 2009). Schumpeter (1934) claimed that since firms of various sizes adopt innovations at different times, they can cause an imbalance in the economy, therefore making innovation important to economic change. Schumpeter (1934) considered innovation as a change in production (a realisation of a change in one of the elements of production means and conditions which is introduced into the production system). His study was able to detangle the concept of innovation from many other concepts which had previously formed a relation to it. He claimed that innovation is a firm characteristic that leads to growth and change, and that innovation can only be measurable on a firm basis (Schumpeter, 1934).

Further innovation philosophies include total quality management (TQM), just-in-time (JIT), and lean production (Krumwiede & Roth, 1997). These philosophies enabled an improvement in decision making and supported engineering activities. TQM is an approach to management based on three principles, namely: customer focus, continuous improvement, and teamwork. Each principle is implemented through a set of practices or activities supported by an array of techniques (Dean & Bowen, 1994). The intention behind TQM is to address quality issues that an organisation may face. JIT is “a change in workforce management, and a flexible approach to customer requirements in order to gain and maintain a competitive edge” (Maskil (1989), cited in Bernard (1996)). Lean production focuses on eliminating the waste of management and productive time and encourages the development of quality circles as well as production cells. Entire tiers of management may also be eliminated (Bernard, 1996).

Guo (2009) extended the view on innovation to be specific to that of technology and states that technological innovation is a process which stems from the generation of innovation ideas, and the marketisation and industrialisation of research results. Furthermore, innovation was considered as a comprehensive interaction between science, technology and the economy, institutional innovation, market innovation, policy, and organisational innovation.

While earlier work on innovation concentrated on defining it and establishing its various philosophies, Krumwiede and Roth (1997) concentrated on how to successfully implement information technology (IT) innovations. They postulated that organisations experienced barriers to implementing IT innovations. These so-called technical, organisational, political, and behavioural factors could prevent an organisation from realising all the innovation benefits (Krumwiede & Roth, 1997). They also addressed the barriers which organisations faced at various stages of an IT innovation's life cycle and provided possible solutions.

"The term ecosystem was early defined as the whole complex of physical factors forming the environment" (Tansley, 1935). When breaking the term "ecosystem" down, "eco" alludes to the fact that the systems are natural (Berry et al., 1998) and "system" refers to a "set or arrangement of related or connected things forming a unity or a whole" (Bormann & Likens, 1979). Moore (1996, cited in Gobble, 2014) defines a business ecosystem as "an economic community supported by a foundation of interacting organizations and individuals – the organisms of the business world". There are numerous ecosystems which exist, for example, the cellphone ecosystem (Basole, 2009), Amazon's web service ecosystem (Thierry, 2009), and Google's innovation ecosystem (Iyer & Davenport, 2008).

Dedehayir and Seppänen (2015) identify an innovation ecosystem as "a network of organizations which aim to deliver holistic product or service value to the end-user as well as firms". This network of individuals and organisations within an innovation ecosystem may include suppliers, complementors, system integrators as well as customers. This ecosystem may also include distributors, advertisers, finance providers (such as angel investors, corporate investors, venture capitalists, and investment bankers), universities and other research institutions, regulatory authorities, and judiciary (Iyer & Davenport, 2008; Pierce, 2009 cited in Dedehayir, Ortt & Seppänen). These actors create capabilities around an innovation by working together cohesively and competitively within an ecosystem (Moore, 1993).

Rabelo and Bernus (2015) define an innovation ecosystem as "an open, dynamic, sustainable and evolving networked business environment". It transforms ideas into valuable end products under various business models. Such an ecosystem is supported by capital and by diverse actors' knowledge and infrastructures. Moreover, it is controlled by policies and regulations, governance, as well as culture. This definition largely encompasses the definitions put forward by Iyer and Davenport (2008), Pierce (2009, cited in Dedehayir et al., 2017), and Whitely and Darking (2006). Rabelo and Bernus' (2015) comprehensive framework will therefore be utilised in this study.

Various elements and actors are required to create an innovation ecosystem (Rabelo & Bernus, 2015). The actors in an innovation ecosystem include government institutions, industries, supporting institutions, entrepreneurs, financial systems, customers, and civil society. The elements within an innovation ecosystem include actors, capital, infrastructure, regulations, knowledge, and ideas.

SMEs (or any business for that matter) require an effective ecosystem to be successful in any industry (Dedehayir & Seppänen, 2015). The way in which innovation takes place has been examined and there is consensus that successful innovation depends on an innovation ecosystem (Jackson, 2011; Mercier-Laurent, 2011; Olsen et al., 2013, cited in Rabelo & Bernus, 2015; Sloan, 2011).

The findings of the SLR are outlined in Table 2.3.

Table 2.3: Systematic literature review findings

No.	Title	Date	Author(s)	Innovation ecosystem elements	Innovation ecosystem actors
1	Accelerating innovation: The Nanotechnology Institute	2011	Green, A.P. Chen, E. Pourrezaei, K. Marcolongo, M. Carpick, R.W.	• Core public investment of funds carefully managed by a leadership team that integrates faculty, economic development experts, and university technology transfer officials at the same administrative level. Multi-university participation through a novel, comprehensive • IP-pooling and revenue-sharing strategy. • Strategically targeted grants to universities and loans to small businesses that promote faculty-industry collaboration and prioritise university Internet Protocol (IP) with commercial potential. • Strong emphasis on interdisciplinarity, regional strengths and high-quality research. • Recruitment of commercialisation experts in oversight and programme review, and solicitation of university technology transfer professionals in prioritising projects to fund. • Extensive outreach, networking, information sharing, and marketing efforts.	• Technology transfer offices • Innovative technology licensing companies • Financiers • Suppliers • Support services organisations • Specialised infrastructure organisations • Research institutions
2	Birth and expansion of innovation ecosystems: A case study of copper production	2015	Dedehayir, O. Seppänen, M.	• Government regulations Industry changes•	• Keystone (platform leader) or ecosystem leader or regulator • Niche players/complementors or support organisations (who perform specialised functions to help platform leader to expand the realms of its application)

No.	Title	Date	Author(s)	Innovation ecosystem elements	Innovation ecosystem actors
					• Direct customer • Inventor • Research laboratories • Universities
3	Building an innovation eco-system: A daunting challenge	2013	Kulkarni, S.K.	• Innovation culture • Entrepreneurial capability • Knowledge or ideas • Networking (for business)	• Roles models in the system • Education institutions • Government institutions
4	Campus leadership and the entrepreneurial university: A dynamic capabilities perspective	2016	Leih, S. Teece, D.		• Universities
5	Catalyzing capital for Canada's life sciences industry	2011	Tucker, J. Chakma, J. Fedak, P.W.M. Cimini, M.	• Venture capital	
6	Charting the innovation ecosystem	2014	Gobble, M.M.		• Companies • Universities • Entrepreneurs • Customers • Regulatory agencies • Municipal or regional government
7	Collaborative development planning model of supporting product in	2014	Zhang, W. Karimi, H.R. Zhang, Q. Wu, S.		• Companies • Universities • Research institutes • Upstream suppliers • Downstream distributors

No.	Title	Date	Author(s)	Innovation ecosystem elements	Innovation ecosystem actors
	platform innovation ecosystem				• Competitors
8	Design ecosystems and innovation policy in Europe	2017	Whicher, A.	• Users • Support • Promotion • Actors • Designers (specific to the study but can refer to entrepreneurs) • Education • Research • Funding • Policy	• Government • Academics • Design centre managers (specific to the study) • Policymakers
9	Disruptive change and the reconfiguration of innovation ecosystems	2017	Dedehayir, A. Ortt, R. Seppänen, M.		• Suppliers • Complementors • System integrators • Customers • Distributors • Advertisers • Finance providers (such as venture capitalists) • Corporate investors • Investment bankers • Angel investors • Universities and research institutions • Regulatory authorities • Standard-setting bodies and the judiciary

No.	Title	Date	Author(s)	Innovation ecosystem elements	Innovation ecosystem actors
10	Emerging innovation in emerging economies: Can institutional reforms help Russia break through its historical barriers?	2014	McCarthy, D.J. Puffer, S.M. Graham, L.R. Satinsky, D.R.	• Traditions • Values • Ethics • Accepted modes of behaviour	• Government • Regulatory bodies • Judicial system • Universities • Media
11	From the management of innovative projects to the innovation management of innovative projects: An analysis within the automotive industry	2016	Attias, D. Bonnardel, S.M. Donada, C.		• Niche players (who are specialised in specific skills); • Dominators (whose primary goal is to control the network); • Hub landlords (who act as liaison actors, foster extensions, and generate communication nodes); and • Keystones (leading stakeholders who orchestrate the cooperation).
12	Innovation ecosystems	2014	Adner, R. Euchner, J.		• Supply chain partners; • Software developers for hardware platforms; and • Charging infrastructure providers for electric cars.
13	Nanotechnology and innovation policy	2015	Ouellette, L.		• Government laboratories • Universities and other non-profit research institutions • Large businesses • Small start-ups
14	Saudi Arabia: From oil kingdom to knowledge-based economy	2015	Khorsheed, M.S.	• Human resources • Research and development (R&D) Knowledge networks (that • enable rapid communication and collaboration among technical professionals)	• Technical professionals • Entrepreneurs

No.	Title	Date	Author(s)	Innovation ecosystem elements	Innovation ecosystem actors
				• An environment for entrepreneurship • Policy environment • Market and financial conditions • Infrastructure	
15	The emerging innovation ecosystems and “valley of death”: Towards the combination of entrepreneurial and institutional approaches	2016	Jucevicius, G. Juceviciene, R. Gaidelys, V. Kalman, A.	• Specialised skills • Technological infrastructure • Specific industrial traditions • Educational programmes • Regulatory practices • Tax incentives • Innovation funding schemes	• Universities • Research institutes • Industry • Investors • Specialised suppliers • Service providers • Firms in related industries • Associated institutions (for universities, standards agencies, and trade associations) in a particular field
16	Innovation in real-life settings	2012	Hawk, N. Bartle, G. Romine, M.		• End-users • Secure mobile environments • Corporations • Public sector • Academia
17	The management of research and innovation systems: Comparative study of the East and the West practices	2017	Lau, T.C Choe, K.L. Cheng, M.Y.		• Government • Universities and schools • Infrastructure providers • Standard-setting agencies • Technology creation organisations • Administrating agencies
18	The new model innovation agencies: An overview	2014	Bonvillian, W.B.	(Too specific to the context of the case study.)	• Industry • Government • University research
19	The role of a local industry association as a	2015	Schwartz, D. Bar-El, R.	• Technology • Institutions • Sociological interactions	• People • Enterprises • Institutions

No.	Title	Date	Author(s)	Innovation ecosystem elements	Innovation ecosystem actors
	catalyst for building an innovation ecosystem: An experiment in the state of Ceara in Brazil			• Culture • Economic relations	• Economic agents
20	The role of university in eco-entrepreneurship: Evidence from the Eurobarometer survey on attitudes of European entrepreneurs towards eco-innovation	2014	Sáez-Martínez, F.J. González-Moreno, Á. Hogan, T.	• Technology push • Regulatory push • Market pull	• Policymakers • Businesses • Researchers • Citizens • Government
21	Transforming regions into innovation ecosystems: A model for renewing local industrial structures	2014	Oksanen, K. Hautamäki, A.	• Sufficient financing for new companies and research plans; • A symbiotic combination of large established companies and news; • Specialisation of and cooperation among companies; • A sufficient local market for new innovative products; and • Global networking.	• Top-level universities and research institutions; • Large established companies and new start-ups; • Technology centres; • Enterprise incubators; • Development companies whose primary tasks are to facilitate the transfer and commercialisation of technology, and the development of innovation networks; and • Service companies specialising in the needs of local companies.
22	What Europe needs is an innovation-driven entrepreneurship	2015	Groth, A.J. Esposito, M. Tse, T.	• Ideas • Government mechanisms	• Investors • Public and private supporters • Government involvement • Venture capitalists

No.	Title	Date	Author(s)	Innovation ecosystem elements	Innovation ecosystem actors
	ecosystem: Introducing EDIE				• Entrepreneurs
23	A profile of Mexico's technological agglomerations: The case of the aerospace and nanotechnology industry in Querétaro and Monterrey	2016	Luna-Ochoa, S.M.A. Robles-Belmont, E. Suaste-Gomez, E.	• Technological platforms • Investments in financial and human capital • Local public policies	• Research centres • Universities • Local governments • Businesses • Technology platforms
24	Connecting all the dots: Identifying the "actor level" challenges in establishing effective innovation system in Indonesia	2013	Lakitan, B.	• Human resource capacity • Natural resource availability • Market demands • Existing regulations • Public policies	• Technology developer • Technology user • Government as regulator
25	In defence of 'eco' in innovation ecosystem	2017	Ritala, P. Almpanopoulou, A.	• Actors • Organisations • Entities	
26	Innovation ecosystems: A critical examination	2016	Oh, D.S. Phillips, F. Park, S. Lee, E.	• Material resources (funds, equipment, and facilities); and • Human capital (students, faculty, staff, industry researchers, and industry representatives).	• Universities, colleges of engineering, and business schools • Business firms • Venture capitalists • Industry-university research institutes • Federal or industrial supported centres of excellence

No.	Title	Date	Author(s)	Innovation ecosystem elements	Innovation ecosystem actors
					• State and/or local economic development organisations • Business assistance organisations • Funding agencies • Policymakers
27	Market challenges facing academic research in commercializing nano-enabled implantable devices for in-vivo biomedical analysis	2011	Juanola-Feliu, E. Colomer-Farrarons, J. Miribel-Catal, P. Samitier, J. Valls-Pasola, J.	(Too specific to the paper.)	• Universities • Industry
28	Situated regional university incubation: A multi-level stakeholder perspective	2016	McAdam, M. Miller, M. McAdam, R.		• End-users • Government • Industry • Universities
29	Technology business incubation: An overview of the state of knowledge	2016	Mian, S. Lamine, W. Fayolle, A.	• Positioning in the value chain • Risk-taking/time perspective • Revenue model • Governance/control • Internationalisation • Cooperation/competition	

2.4 Innovation Ecosystem Elements

This section discusses the findings of the SLR and the most significant literature that supported Rabelo and Bernus' (2015) framework. Additionally, this section discusses areas whereby other elements or those termed differently were mentioned over and above those discussed in the framework.

2.4.1 Capital

Capital refers to financial assets which could fund activities within the ecosystem and is provided by some actors in the ecosystem (Rabelo & Bernus, 2015). All businesses require capital to run and maintain their operations. Sufficient financing for new companies and research plans are the key features of an ecosystem (Oksanen & Hautamäki, 2014). Green et al. (2011) mention financiers as part of the regional clusters they identified pertaining to the barriers to advancing the commercialisation of innovation technologies. The authors identified this group of actors as one which contributed to the ecosystem as their "competitive strengths are synergistic when shared" (Green et al., 2011). They also discussed public investment in research institutions, grants to universities, and loans to small businesses, which all pertain to the capital which funds the ecosystem (Green et al., 2011).

According to Whicher (2017), funding is among the chief policy instruments that enable governments to incentivise innovation. These funding efforts can be headed by the various strategic government departments mandated to improve the private sector with programmes. Tucker et al. (2011) investigated the effectiveness of varying government policies in attracting venture capital (VC) investment. VC refers to the financing of a business venture in exchange for equity in the business (Tykvová, 2017). Since the investor has equity in the business, it is in their best interest to make efforts to ensure the success of thereof. This could often result in further non-monetary investment over and above their initial financial investment. Although VC has its benefits, it is viewed by institutional investors as a high-risk asset class with low growth prospects (Tykvová, 2017).

Similar to Whicher (2017), Khorsheed (2015) acknowledges that there are numerous factors that drive the capacity for innovation and ability to sustain growth, but also included financial conditions as an element. Jucevicius et al. (2016) identify innovation funding schemes as a strategic weakness or constraint, which could be resolved by implementing certain processes and trends. Strapping public research funds to universities damages the quality and quantity of research and erodes the foundation of the presentation of innovation ecosystems in the long run (Jucevicius et al., 2016). Green et al. (2011) mention a revenue sharing strategy as a form of capital for multi-university participation.

Luna-Ochoa, Robles-Belmont and Suaste-Gómez (2016) cited Robinson, Rip and Mangematin (2007) when mentioning other forms of capital in the creation of technological agglomerations. Technological agglomerations referred to the collocation of scientific and technological facilities in the development of technology. This concept therefore could be likened to that of a technological ecosystem. Financial capital was highlighted when mentioning human, social, and intellectual capital.

2.4.2 Infrastructure

Infrastructure comprises the physical resources that are utilised by an ecosystem (Rabelo & Bernus, 2015). Technological infrastructure is one of the key strengths or core competencies in deciding which innovation is built (Jucevicius et al., 2016). With reference to IoT technology, the infrastructure required depends on the nature or use of that device. However, cloud computing, large data warehouses, and IoT security are the typical components required. The development of infrastructure among intellectual capital, incentives, and commercialisation is seen as the basis for the model to build a National Innovation Ecosystem (NIE) in Korea (Khorsheed, 2015).

2.4.3 Technology

Several authors cited technology as an element of an innovation ecosystem (Chaudhuri, 2012; Gil-Garcia, Helbig & Ojo, 2014; Gil-Garcia, Zhang & Puron-Cid, 2016; Gretzel et al., 2015). Technology possesses both tangible and intangible components. Infrastructure is the tangible side, which encompasses the basic physical and organisational structures required for the functioning of the ecosystem. The intangible side, however, refers to software. Rabelo and Bernus' (2015) framework refers to infrastructure in a broader sense than just technology; therefore, the researcher considered this as an element.

2.4.4 Regulations

Regulations are the laws and rules within which an ecosystem operates (Rabelo & Bernus, 2015). This element is derived by the government or professional bodies for all members operating within that jurisdiction to abide by. It can be argued that regulations play a similar role to that of culture in an innovation ecosystem because they both form cultural structures within which actors operate. However, the culture of an innovation ecosystem is largely influenced by the actors within it and regulations are set by regulatory bodies. Whicher (2017) and Khorsheed (2015) discussed the duty of policies within the ecosystem. They referred to "policies" rather than "regulations" and elaborated on the role of policymakers. Jucevicius et al. (2016) mentioned regulatory practices as a strategic weakness which could be overcome by certain processes. This element was therefore seen as a way of governing or guiding activities within the ecosystem.

2.4.5 Knowledge and Ideas

Various terms were used to describe knowledge and ideas. Knowledge is important in an innovation ecosystem because the knowledge that develops in an ecosystem generates ideas which trigger innovation actions (Rabelo & Bernus, 2015). Ideas are an integral part of an innovation ecosystem (Guo, 2009). Various authors made mention of knowledge creation and dissemination, knowledge flows, dynamic information flows, and education (Chaudhuri, 2012; Gil-Garcia et al., 2016; Rubens et al., 2011; Gretzel et al., 2015). All these terms considered the various types of knowledge as well as how this knowledge was generated and used. The authors went into more detail than the framework in mentioning other forms of knowledge and ideas. The various forms of knowledge will therefore be recognised as part of the framework. Green et al. (2011) posit that knowledge can be gained through high-quality research and that applied research aims to enhance the commercial potential of IP.

2.4.6 Culture and Architectural Principles

The way in which all these elements are connected or combined represents the architectural principles as the culture element is reflected on it (Rabelo & Bernus, 2015). Gretzel et al. (2015) briefly mentioned balance which could relate to architectural principles (the way in which the elements are orchestrated and combined). The way in which these elements are combined and interact creates a culture. This culture determines the rules the actors need to adhere to when they work together. It determines the way that actors perform and develop an innovation and "refers to the mindset of people and organizations that are combined to support and facilitate innovation initiatives and to solve related problems" (Hwang et al., 2012). McCarthy et al. (2014) described cultural traditions as an informal institution, especially in emerging economies.

2.4.7 Actors and their Interfaces

In agreement with Rabelo and Bernus (2015), Tricoire (2015) states that relationships between the actors have an impact on how the ecosystem behaves. Actors were not viewed to operate in isolation but in fact had various roles which they played while interacting with one another in the ecosystem. An interface or channel would therefore be logically necessary for actors to interact with one another as highlighted in the framework.

2.4.8 Other Elements

Various other elements were uncovered in the SLR. The role of information sharing (Green et al., 2011) and networking for business (Kulkarni, 2013) could be placed in the same category. Both elements refer to opportunities for actors to interact with one another. Values, ethics, and accepted modes of behaviour could stem from the culture and regulations within that ecosystem (McCarthy et al., 2014). It could be argued that the regulations which govern the ecosystem breed accepted modes of behaviour and guide the ethics and values within that industry. Promotion is one of the nine components of a design ecosystem (Whicher, 2017). Albeit specific to that particular ecosystem, it relates to the marketing of a product or service that can be applied to most, if not all ecosystems.

Marketing can be a significant contributor to the success of an organisation and therefore accepted as an additional element to the framework. A knowledge network can “enable rapid communication among technical professionals” (Khorsheed, 2015). These are collections of individuals who come together to create and share a body of knowledge (Pugh & Prusak, 2013). Rabelo and Bernus (2015) mentioned knowledge as an element but did not elaborate on where this knowledge resided.

Knowledge networks are considered an additional element, since universities are considered an actor within the ecosystem and represent a source of knowledge within the ecosystem. Market demands or market pull are both drivers and influencers of an ecosystem (Lakitan, 2013; Sáez-Martínez, Gonzáles-Moreno & Hogan, 2014). Rabelo and Bernus (2015) acknowledged economic agents and relations as having an impact on an innovation ecosystem but did not include it as an explicit element in their framework. Market pull will be included in the framework as it was mentioned in the literature, although different terminology was used to describe this concept.

2.5 Innovation Ecosystem Actors

This section discusses the findings of the SLR and the most significant literature that supported Rabelo and Bernus’ (2015) framework. Additionally, this section discusses areas whereby other actors or those termed differently were mentioned over and above those discussed in the framework.

2.5.1 Government

As the most commonly cited actor within an innovation ecosystem (Ehrenhard, Kijl & Nieuwenhuis, 2014; Gil-Garcia et al., 2014; Gil-Garcia et al., 2016; Grimaldi & Fernandez, 2016; Kulkarni, 2013; Lawrence et al., 2016; Rosati & Conti, 2016; Rubens et al., 2011). This category of actors included those termed public actors (Chaudhuri, 2012) and city managers (Gil-Garcia et al., 2015). Government’s primary role is to create and implement policies (Ehrenhard et al., 2014). Ehrenhard et al. (2014) furthermore described government as playing a key role in the adoption of smart homes. Government efforts include joint development projects, regulations, and funding for commercialisation. McCarthy et al. (2014) opined that government’s innovation initiatives could have an impact on the economy.

2.5.2 Universities

Universities along with government, companies, professionals, and civil society are faced with the mandated task of fostering innovation (Rabelo & Bernus, 2015). Lau et al. (2017) postulate that these groups and individuals are critical components to technology creation in the ecosystem. However, universities are specifically responsible for forming qualified people who assist in breeding future companies (Rabelo & Bernus, 2015). This category of actors also includes educational and R&D companies, students, and researchers (Rabelo & Bernus, 2015). Industry relies on the research conducted by such institutions in order to form the structures of that industry.

2.5.3 Industry

Industry refers to a wide spectrum of individuals and organisations who create the supply and demand in an ecosystem through “providing requirements, evaluating solutions, developing technologies, and knowledge in their R&D departments as well as forming qualified people via technical schools” (Rabelo & Bernus, 2015). Zhang et al. (2014) referred to upstream suppliers and downstream distributors which could arguably fall under this category of actors. These actors supply and distribute components of and/or the entire end product.

2.5.4 Supporting Institutions

Supporting industries can be either publicly- or privately-owned organisations, or individuals who provide specialised services or skills to the ecosystem (Rabelo & Bernus, 2015). These could include technology transfer offices, innovative technology licensing companies, and support services organisations (Green et al., 2011). Niche players provide specialised skills to the ecosystem (Attias, Bonnardel & Donada, 2016). Adner and Euchner (2014) describe supply chain partners as “people who lie on the critical path of the innovation itself”. These individuals or companies were not directly required in the production of the product or service, but necessary for its success. Complementors are also considered to be “off the direct-path of value creation” (Dedehayir & Seppänen, 2015). Their products or services complimented those created in that particular ecosystem. Various other support institutions were mentioned, namely: dominators (aim to control the ecosystem); hub landlords (liaisons within the network and create means of communication); and keystones (ecosystem leaders who orchestrate and manage the cooperation among actors).

2.5.5 Entrepreneurs

Entrepreneurs are individuals who own ideas and aim to transform them into something commercialisable (Rabelo & Bernus, 2015). These individuals can come from a number of backgrounds (Rubens et al., 2011) and include students, researchers, professionals, or industry actors.

2.5.6 Financial System

This system comprises institutions that provide funding mechanisms for various activities that build an ecosystem and innovation (Rabelo & Bernus, 2015). Often times when entrepreneurs do not have the capital to start their businesses, they approach financial institutions such as banks, governments, investors, virtual and venture capitalists, funding agencies, and industries that could provide them with capital (Dedehayir & Seppänen, 2015; Green et al., 2011; Oh et al., 2016; Rabelo & Bernus, 2015).

2.5.7 Customers

Customers are individuals or organisations who purchase the services or products which businesses provide. These people, companies, universities, banks, and so forth influence the stages of an innovation initiative (Rabelo & Bernus, 2015). Tricoire (2015) identified them as end-users within an innovation ecosystem, while Ehrenhard et al. (2014) referred to them as clients. These are ultimately the actual consumers within the IoT industry (Gretzel et al., 2015) or potential direct customers (Dedehayir & Seppänen, 2015).

2.5.8 Civil Society

Civil society creates societal as well as environmental demands (Rabelo & Bernus, 2015). It includes actors identified as citizens (Abellá-Garcia et al., 2015) or ordinary people in society (Rubens et al., 2011). These actors create societal and "environmental demands and requirements which in turn can deeply affect businesses and impact the innovation development" (Rabelo & Bernus, 2015). Other examples of these types of actors are individuals and non-governmental organisations (NGOs) (Rabelo & Bernus, 2015).

2.5.9 Other Actors

Although ecosystem leaders can be placed in the supporting institution category, it is argued that this type of actor should be recognised in its own right, since they are the most significant members of the ecosystem (Lansiti & Levien, 2004). They possess a substantial amount of power and require a greater portion of the profits (Moore, 1993). Ecosystem leaders are also referred to as platform leaders or keystones.

2.6 Framework

Rabelo and Bernus' (2015) framework comprises the following elements as depicted in Figure 2.1.

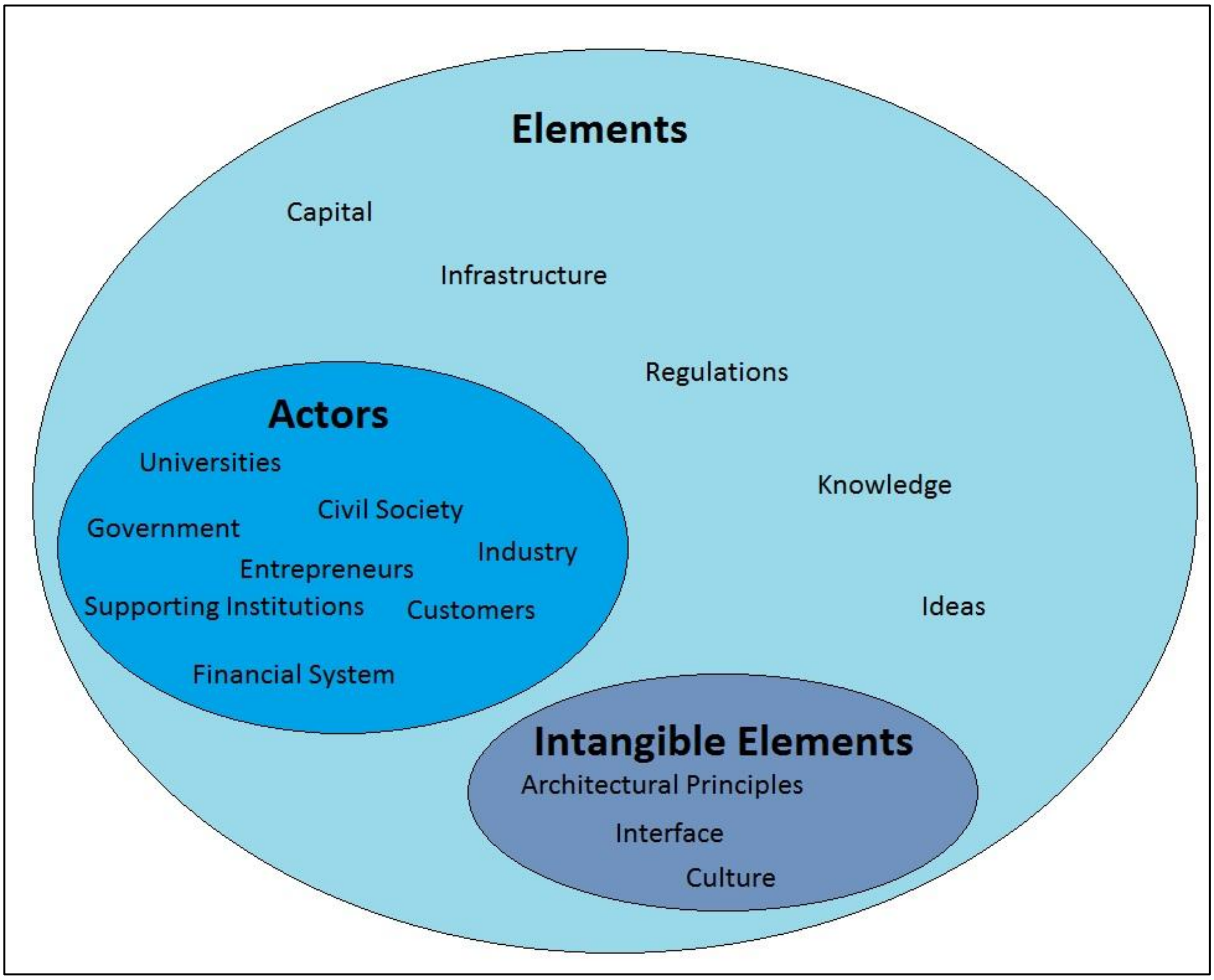

Figure 2.1: Innovation ecosystem actors and elements

The framework defines numerous actors and elements within an innovation ecosystem. According to Gobble (2014), innovation ecosystems tend to spring up around technology platforms. However, Rabelo and Bernus' (2015) framework refers to a technology agnostic innovation ecosystem.

After considering the findings from the SLR, the framework was expanded to include marketing, knowledge networks, and market pull as elements of an innovation ecosystem. Additionally, a keystone leader was included as an actor (Figure 2.2).

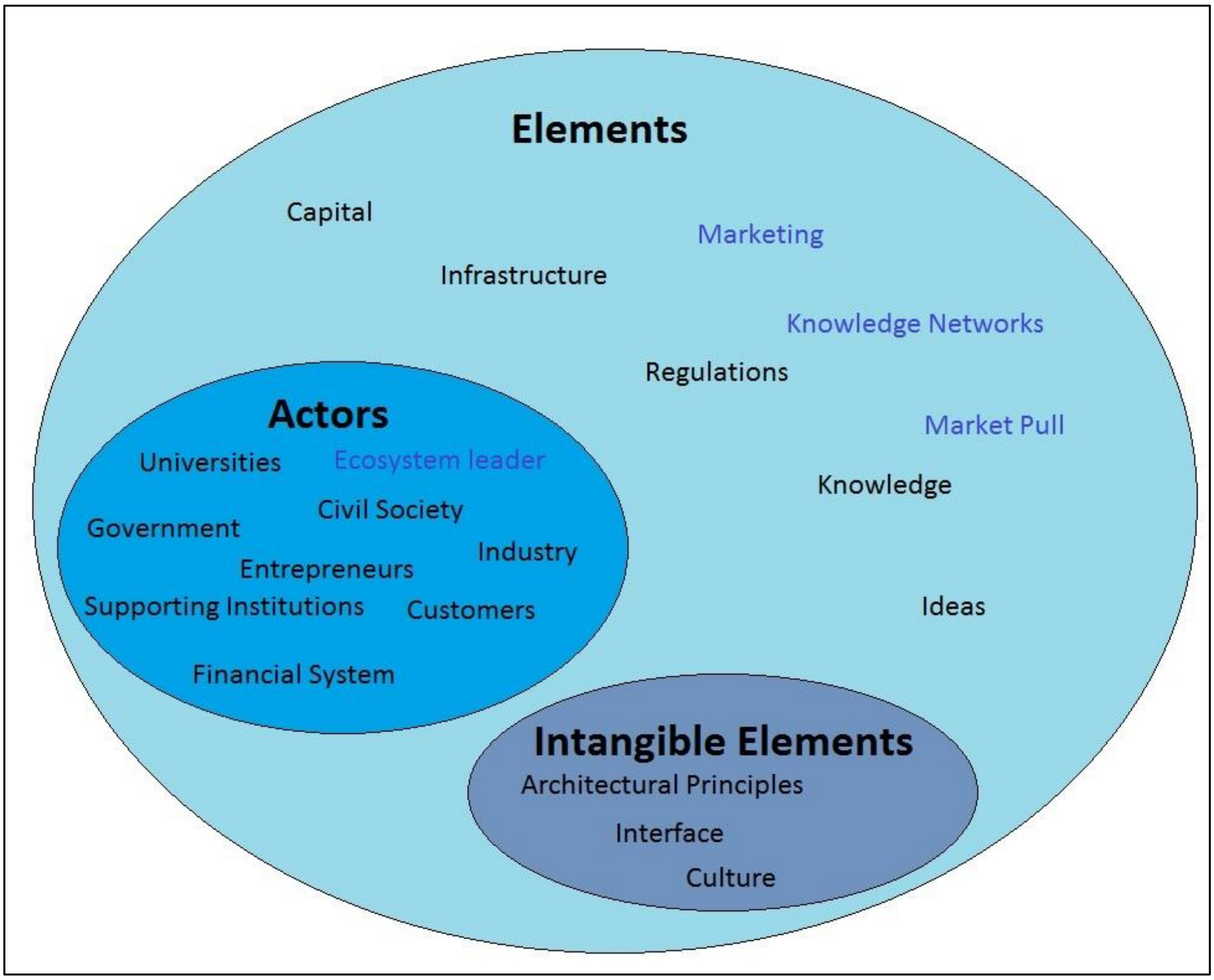

Figure 2.2: Expanded theoretical framework

2.7 Conclusion

This chapter discussed the narrative and systematic literature review as they were employed in this study. The most significant studies were discussed to create context for the current study.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

Research methodology encompasses a body of methods which describe the approach to the research process (Collis & Hussey, 2009). These methods are techniques utilised for collecting and analysing the data. Saunders, Lewis and Thornhill (2012) derived the research onion which illustrates the various stages which must be covered to develop a research strategy. Figure 3.1 will guide the discussion in this section.

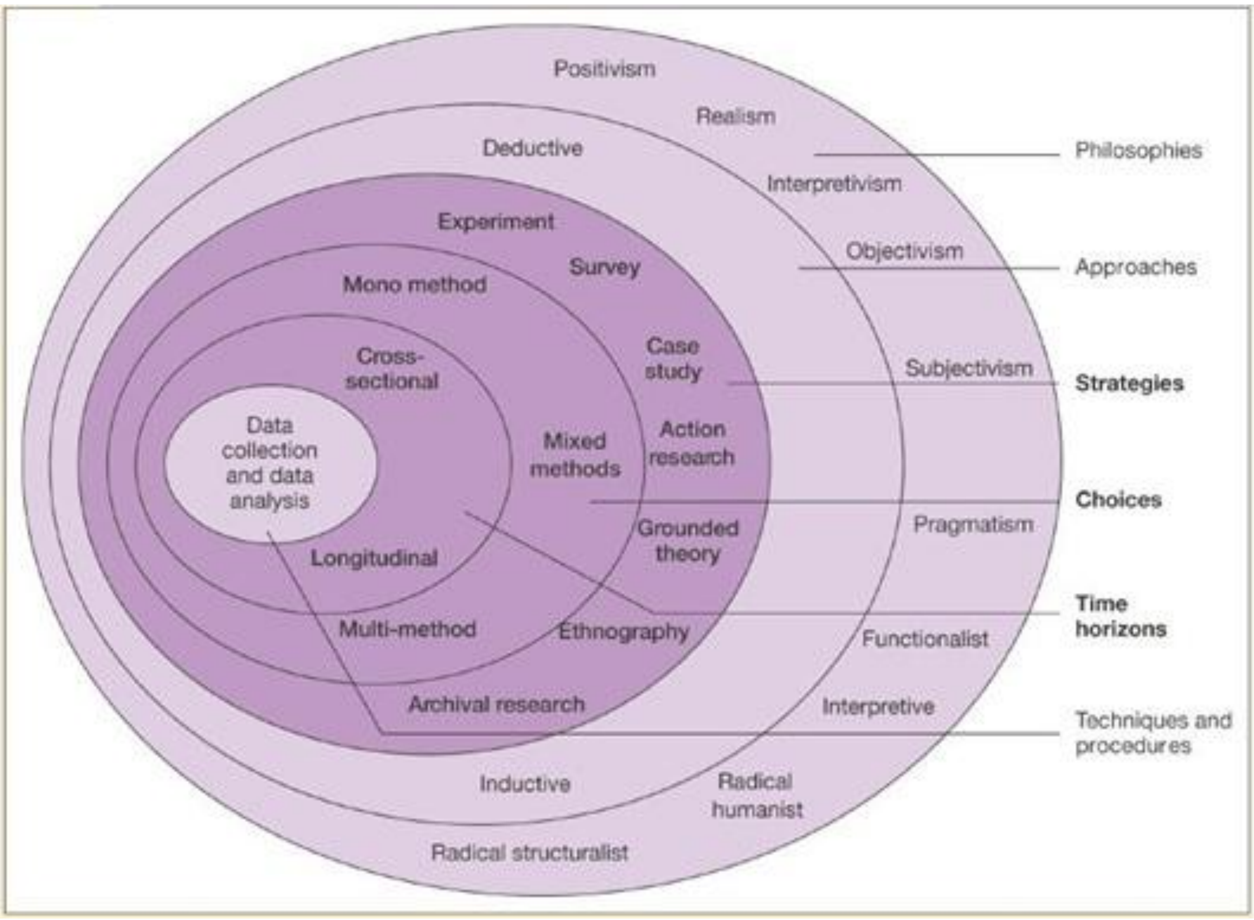

Figure 3.1: Saunders et al.'s (2012) Research onion

3.2 Underlying Philosophy

A research paradigm is a framework which describes how the research should be conducted (Collis & Hussey, 2009). It can be described as a philosophical framework because it is based on people's philosophies, their inferences of the world, and the nature of knowledge. Two main paradigms exist, namely: positivism and interpretivism.

Positivist research studies phenomena objectively without any interference from the researcher (Levin, 1988). This philosophy created the framework for research conducted within the natural sciences (Collis & Hussey, 2009). Positivists believe that observations should be replicable and objective. This type of approach therefore leans towards quantitative research. Quantitative research methods explain social phenomena in numbers. This type of research was not deemed suitable for this study as the study needed to be rich in detail and nuance. The objective was not to quantify how well South Africa's innovation ecosystem functions, but rather to understand the views of the actors within this ecosystem.

The interpretivist approach emerged from criticism of the positivist approach and it is the emergence of social sciences which led to this research paradigm (Collis & Hussey, 2009). Interpretivist research investigates causal links between constructs. Instead, this type of research concludes that people are unpredictable, and the same cause may lead to different effects (Saunders, Lewis & Thornhill, 2009). It is rooted in the belief that social reality is highly subjective (Collis & Hussey, 2009). The subjectivity of the findings is what made this study rich in detail. Interpretivist research generally utilises qualitative methods.

3.3 Research Approach

The purpose of this research is exploratory in nature since there is very little existing academic literature on the research topic (Collis & Hussey, 2009). The focus was to gain insight into the nature of the innovation ecosystem surrounding the manufacture of IoT devices in South Africa. The purpose was to address the main research question: How do actors within the innovation ecosystem surrounding the manufacture of IoT devices in South Africa view the functioning of this ecosystem? Some of the typical techniques of exploratory research include case studies, ethnography, action research, and grounded theory (Saunders et al., 2009). These techniques seek to answer how or why a phenomenon occurs. This attempt to understand meanings can be described as qualitative research. Qualitative research examines things in their organic state in order to understand or interpret phenomena in terms of the meanings people ascribe to them (Denzin & Lincoln, 1994).

A deductive approach is characteristic of a positivist philosophy. It tests theory through observation of the empirical world (Gill & Johnson, 2010), while an inductive approach starts with observations of the empirical world in order to build theory. This provides a flexible structure permitting changes of emphasis as research progresses. This study employed an inductive approach.

The study commenced by seeking to answer a set of research questions. The study moved from research questions to theory and then ultimately data collection, which led to utilising observation to answer the research question; this is the sequence for a deductive approach. While the aim of this study was not to build to theory as is typical with an inductive approach, observations of the empirical world were made whilst testing theory, which is typical of a deductive approach.

3.4 Research Strategy

A case study is a method of exploring a single phenomenon in a natural setting to obtain in-depth knowledge (Collis & Hussey, 2009). A snapshot case study was undertaken to examine a certain period of time (Starman, 2013). A group of actors within an innovation ecosystem surrounding the manufacture of IoT devices was studied. In-depth understanding of the topic rather than the breadth in a natural setting using multiple data sources (such as interviews and secondary data) was sought. This is characteristic of case study research (Yin, 2003). Since there are very few theories or a deficient body of knowledge, this study qualifies as exploratory case study research.

The following stages of case study research were conducted (Collis & Hussey, 2009):

1. *Selecting the case:* A group of individuals within an innovation ecosystem surrounding the manufacture of IoT devices was selected.

2. *Preliminary investigations:* Academic literature was initially reviewed to understand the phenomenon under study.

3. *Data collection:* The data was collected through a process of interviews. Secondary data was also utilised which consisted of documents, websites, and academic journals.

4. *Data analysis:* Thematic analysis was utilised to identify patterns across the dataset.

5. *Writing the report:* This was the final stage of the study.

George and Bennett (2005) identified several benefits of case study research. They found that case study research achieved high conceptual validity as case studies allow for conceptual refinements with a higher validity level over fewer cases than in quantitative research. Case studies allow for the recognition and quantification of the indicators that best present the theoretical concepts that a researcher wants to measure. Case studies do not require a limited number of variables but allow for the researcher to consider numerous variables and therefore serve the purpose of inductively generating new hypotheses. They also produce generalisations that are narrower and examine causal mechanisms in individual cases in detail. This makes case study research useful for close examination of the hypothesised role of causal mechanisms in the context of individual cases. Multiple variables can be examined in one case. Lastly, George and Bennett (2005) identified that case studies accommodate complex causal relationships.

3.5 Choice

A mono-method approach was employed when deciding on a qualitative approach. Qualitative research is concerned with opinions, attitudes, and behaviour (Kothari, 2004). Qualitative research utilises data gathering techniques such as focus groups, interviews, projective techniques, and in-depth interviews.

Interviews were utilised to facilitate a more informed and sophisticated understanding of this research topic. They focused on which elements in an innovation system exist, their effectiveness, as well as the actors' experience of these elements. This technique was chosen over archival research, ethnography, and grounded theory (which also lean towards an inductive approach) because they provide the researcher with the opportunity to probe and gain further information from the participants. The researcher was in a position to guide the conversation when it appeared to be going off topic. The meaning of the data collected became apparent through the process and allowed for claims and knowledge to be formed (Saunders et al., 2009).

3.6 Research Timeframe

Interviews were conducted from July to September 2017. A cross-sectional approach was therefore most appropriate as it is utilised to "investigate variables or a group of subjects in different contexts over the same period of time" (Collis & Hussey, 2009). The time constraints of the study made this approach appropriate. The data was collected over a period of three months, before it was analysed and reported. Cross-sectional research is less time-consuming and inexpensive (Greenwood & Levin, 2006).

3.7 Data Collection and Analysis

The first research objective was partially met by a review of government and industry documents and websites related to the innovation ecosystem in South Africa. These documents were analysed to determine the extent to which the identified innovation ecosystem elements were in place in South Africa. Documents sourced from the CSIR, Department of Science and Technology (DST), the Department of Trade and Industry (DTI), and other relevant government institutions published between 2011 and 2016 (based on the search criteria) were used (Table 2.3).

The second and third research objectives were met by conducting interviews with the identified actors within the innovation system. Semi-structured interviews enabled the researcher to pose predetermined questions to each participant, with an element of freedom in the sequence of the questions and some probing to elicit more information. The benefit of employing a semi-structured interview schedule is that misunderstandings can be clarified swiftly and the unstructured element allows for the interview to flow organically and provides an opportunity to probe for further information. The key would be to strike a balance between excessive passivity during the interviewing process and oversteering the interview towards one direction (Walsham, 1995).

The primary and secondary data was collected. Primary data comprises the first-hand data that was gathered through the interviews (Bryman, 2012). No historical first-hand data was used from other researchers' data collection efforts. Secondary data was derived from the work of other researchers (Newman, 1998). Both the narrative and systematic literature reviews were utilised to gather secondary data found in publications, databases, and websites.

3.8 Target Population and Sample

Snowball sampling was utilised to identify participants. The interviews started with two participants with whom a relationship was already established; an individual from a university institution and another from a supporting institution which provided services to IoT device manufacture organisations. Leads for other contacts were received while attempting to target entrepreneurs, government institutions, an industry representative, and a representative from a financial institution. The data collection came to a close once saturation was reached. Data saturation in qualitative research can be described as the point of diminishing return (Mason, 2010); therefore, data collected does not return any new information.

In order to ensure that a sufficient number of responses were spread across most actors, the following sampling matrix (Table 3.1) guided the selection of participants. No members of civil society or customers were approached as their input was not relevant at this point.

Table 3.1: Sampling matrix comparison

Ecosystem actors	Target	Actual
Universities	1	1
Government institutions	2	3
Industries	1	1
Supporting institutions	1	1
Entrepreneurs	4	4
Financial systems	1	1
Customers	0	0
Civil society	0	0
Total	**10**	**11**

The innovation ecosystem was the unit of analysis. The themes examined in this study are the necessary elements within a well-functioning innovation ecosystem.

3.9 Approach to Data Analysis

The information gathered from interviews was recorded and analysed to understand the views expressed within the various groups. ATLAS.ti was used to analyse the data. Guba (1981) suggested four criteria that should be examined for qualitative research to be considered trustworthy, namely: credibility, transferability, dependability, and confirmability.

3.9.1 Credibility

Credibility refers to ensuring that the study measures what it sought to measure (Collis & Hussey, 2009). Researchers can employ multiple strategies to promote confidence that their study is credible. These strategies include adoption of research methods which are well established; the development of an early familiarity with the participating organisation's culture; random sampling of informants; and the use of different data collection methods and ways of ensuring honesty from informants. This study adopted a qualitative research methodology based on an interpretivist philosophy. Primary and secondary data was utilised to verify the primary data collected through the interviews.

3.9.2 Transferability

Since the findings of one study cannot be inferred to apply in other situations in qualitative research, it was required that the boundaries of other research be outlined (Cole & Gardner, 1979). The boundaries of this study were that it only analysed responses from organisations in Johannesburg, Gauteng, who manufactured IoT devices or supported organisations involved in IoT device manufacture. Eleven organisations participated in this study and a snowball sampling data collection method was utilised to identify further participants to interview. The data collection period spanned three months, while the entire research timeframe spanned approximately two years. The results might apply in a scenario whereby different participants from the same organisations would be interviewed.

3.9.3 Dependability

The research should be able to be employed using the same methods and deliver the same results (Guba, 1981). This requires the processes within the study to be detailed. An SLR was conducted and detailed protocols provide the methods employed to deliver the research results. It is unlikely that the same results would be yielded using these protocols, depending on the type of organisations studied. The interviews were audio-recorded and transcribed. The transcripts did not contain any data that would be able to identify the participants and were saved on a hard drive.

3.9.4 Confirmability

In qualitative research, confirmability speaks to the objectivity of the research. Triangulation is an effective tool to promote confirmability as it reduces the effect of researcher bias. Triangulation refers to the use of multiple data sources and different research methods. It also requires that at least two researchers investigate the same phenomena under study (Collis & Hussey, 2009). A method of reproducibility was utilised during the data analysis stage whereby the same process was followed by another person. Ample literature was reviewed to locate different sources discussing the research topic and unit of analysis.

3.10 Ethical Considerations

The six key ethical principles as set out in the ESRC Framework for Research Ethics were adhered to (Key ethics principles, n.d.). The researcher sent an invitation to participate to identified participants and all they were fully informed about the purpose and intended uses of the study. All invitees had the option to decline the invitation. Naming participants in the study was unnecessary. The confidentiality and anonymity of the information received in this study were also maintained.

Any possible risks associated with participating in the study were highlighted. One of the possible risks would have been reputational damage to either the participant or the organisation that they work for. Another possible risk was for a participant to leak company information during the interviews. To mitigate these risks, all information was rendered anonymous in the research report. Places of employment and positions were not mentioned in order to protect the confidentiality and anonymity of the participants. Furthermore, the participants were identified by a number when reporting the interviews.

The participants were professionals working in government institutions, supporting institutions, or entrepreneurs and customers in either the public or private sector who would provide specialised knowledge and assistance to actors within the ecosystem (Rabelo & Bernus, 2015). None of the selected participants were in a vulnerable position (such as under the age of consent, or illiterate).

The interview questions were reviewed to ensure that they were appropriate to ask without causing any emotional harm or other harm to the participants. Participants were also interviewed in locations in which they felt safe and secure, to decrease the possibility of physical harm.

Effort was made to select participants who did not have a conflict of interest through their participation in the study. However, it was their responsibility to declare any conflict of interest which the researcher was unaware of. The researcher also had no vested in the study.

Approval from the Ethics Committee of the University of Witwatersrand was a pre-requisite to ensure that the participants' interests were safeguarded. Ethical approval was granted by the School of Economic and Business Sciences Ethics Committee on 26 April 2017 (reference: CINFO/1133).

3.11 Limitations

Researching an innovation ecosystem is complex and it was difficult to access all the actors. Therefore, only a small portion of the ecosystem was approached in Johannesburg, Gauteng. The research was cross-sectional in nature and therefore conducted in a short period of time.

The interviews captured perceived elements within the innovation ecosystem as well as their effectiveness. Participants may not have known about some components and their perceptions may have also been biased. Some of the limits of utilising interviews include hat they are time-consuming. The transcribing and coding of data was a huge task that was required after each interview. Moreover, the reliability of the interviews was another limitation as consistency and objectivity were difficult to achieve. There was, however, a standard interview protocol.

CHAPTER 4: DATA ANALYSIS

4.1 Introduction

This chapter focuses on the data analysis protocol employed in the study. Sampling of participants is discussed, and the research findings are presented according to the individual interview questions.

4.2 Data Analysis Protocol

Data analysis is conducted to test the consistency of the data with the prior assumptions, theory, or hypothesis identified (Cavanagh, 1997). After conducting the interviews, they were transcribed and resulted in a large volume of textual data. This large volume necessitated the use of computer-aided data analysis. The data analysis process involved reducing the data to sharpen, sort, focus, discard, and reorganise it (Miles & Huberman, 1994). Not all the data was useful to achieving the objectives of the study; however, all was considered while using a systematic approach to ensure that the most relevant data was highlighted in the process.

Qualitative data analysis (QDA) software was primarily utilised to import the text, storing the data, coding the data, searching and retrieving text segments, simulating interaction with the data, and building a relationship within the data (Collis & Hussey, 2009). This made it easier to perform the analysis and interpretation thereof. The use of the software benefitted the researcher as well as the research by not only speeding up the process but also "enhancing the rigor, providing more flexible data analysis from different perspectives and allowing the researcher to reflect in greater depth by reducing the operational activities" (Oliveira, Thomas & Espadanal, 2014).

The data was analysed using thematic content analysis. This type of analysis is utilized to identify, analyse, and report themes or patterns within data (Braun & Clarke, 2006). Frequently it can extend to the interpretation of various aspects of the research topic. Thematic content analysis comprises three stages (Bardin, 2011). These stages are discussed in further detail in the sections that follow.

4.1.1 Pre-analysis

The objectives of the content analysis were defined and the data was organised to meet the objectives. The objectives of the research, which formed the basis of the content analysis were:

1. To identify which elements and actors of an innovation ecosystem that support the manufacture of IoT devices are currently in place in South Africa.
2. To investigate how the actors experience this innovation ecosystem.
3. To explore which elements of this innovation ecosystem could be improved (if required).

The pre-analysis also entailed understanding the various file formats permitted by the QDA software, reading the transcripts, and organising them for analysis. There were two sets of research questions asked; one set for those individuals involved in IoT manufacture, while the other set was asked to those offering support to IoT device manufacturers. The transcripts were organised according to these two categories. The transcripts were transcribed in Microsoft Word and saved as rich text files to import into ATLAS.ti.

4.1.2 Exploration

The second stage entailed defining the unit of analysis and the codes. The unit of analysis was the innovation ecosystem. The themes examined were the elements and actors of an innovation ecosystem as identified by Rabelo and Bernus (2015). Further themes were identified after the data collection process through the analysis. A “code” refers to a word or a phrase which is representative of a portion of data (Saldaña, 2009). In this case, the data comprised interview transcripts. The coding process had two cycles. The first cycle of coding comprised long phrases and sentences, while the second cycle was used to reconfigure and refine some codes. This study made use of a combination of in-vivo codes (derived from reading the text and case transcripts) and constructed codes (based on the literature).

4.1.2.1 Open Coding

Open coding is the first stage in the creation of grounded theory and involves applying emergent codes derived from the data (Blair, 2015). According to Strauss and Corbin (1998), there are three stages to grounded theory methodology (GTM):

1. Open coding
2. Axial coding
3. Selective coding

Open coding is analytical in nature in that there was some reflection on what was expressed in the transcripts. A list of codes was produced and grouped into categories. Axial coding was also performed whereby the relationships between these codes and categories were identified. The categories were derived from the text and tested in different texts (Flick, 2013). Lastly, selective coding was conducted, and a core category was defined. Table 4.1 outlines the codes and the type of participants they were applicable to.

Table 4.1: Outline of codes and categories

Categories	Codes	Type of participant
Service/product history	Identified gap in the market	Supporting institutions and universities
	Field of study in university	Entrepreneurs
	Technology was early childhood interest	
	Need for economic growth	Government institutions
	Prior work experience	Supporting institutions
Challenges	More affordable to import products	Entrepreneurs and financial services
	High cost of labour	Entrepreneurs
	Little to no support	
	Lack of necessary laws and regulations	
	Lack of specialised skills	
	Poor business case	Financial services
	Poor economy or weak currency	Entrepreneurs and government institutions
	Need for innovations	Supporting institutions
	Bad credit	Financial services
	Poor business management skills	Entrepreneurs and supporting institutions
	Uniqueness of product results in lack of support	Entrepreneurs
	Insufficient resources	Universities and government institutions
	Difficulty in acquiring a loan	Entrepreneurs
Support available	Offer variety of support for product design and manufacture	
	Little to no support for product design and manufacture	
	Bank loan acquired	
	Funding provided	
	Marketing support available	
	No marketing support available	
	Business development support	Government institutions
	Advice	Supporting institutions
	Skills development	
	Networking	
	Hardware	
	software	
Industry importance	Important industry in South Africa	Financial services and entrepreneurs
	Skills creation	Financial services
	Large industry	

4.1.3 Treatment and Interpretation

The content was coded, and inferences were drawn from it. The reliability of the coding was checked to mitigate bias (Oliveira et al., 2014). This was done through the process of reproducibility. Stability testing was also utilised, although it may be deemed the weakest form of checking reliability; it was mainly utilised to verify the accuracy of the analysis (Krippendorff, 1980b). Stability testing occurs when a researcher performs repeated administrations and obtains the same results (Twycross & Shields, 2004). There were already identified themes from the literature and further themes were identified during the analysis (Saunders et al., 2009).

4.3 Sample Profile

Thirty people were invited to participate in an interview and eleven participants participated. The participants included the following innovation ecosystem actors:

- *Entrepreneurs:* One entrepreneur from each of the four organisations was interviewed, as interviewing all the founders of the company was unnecessary. Each entrepreneur held a specific role within the organisation.
- *Government employees:* These individuals were employed by various departments such as the DST, CSIR, and the Small Enterprise Development Agency (SEDA).
- *Financial institutions:* An individual from one of the “big four” banks was interviewed.
- *Supporting industries:* Individuals from organisations which provided non-financial support were interviewed. Some were from incubators and one was from an organisation which provided hardware and software. A staff member from one of the most prominent universities in Gauteng was also interviewed.

Table 4.3: Job descriptions of the participants presents the sampling matrix, while a sampling graph is depicted in Figure 4.1.

Table 4.2: Sampling matrix

Ecosystem actors	**No. of participants**
Universities	1
Government institutions	3
Industries	1
Supporting institutions	1
Entrepreneurs	4
Financial services	1
Total	**11**

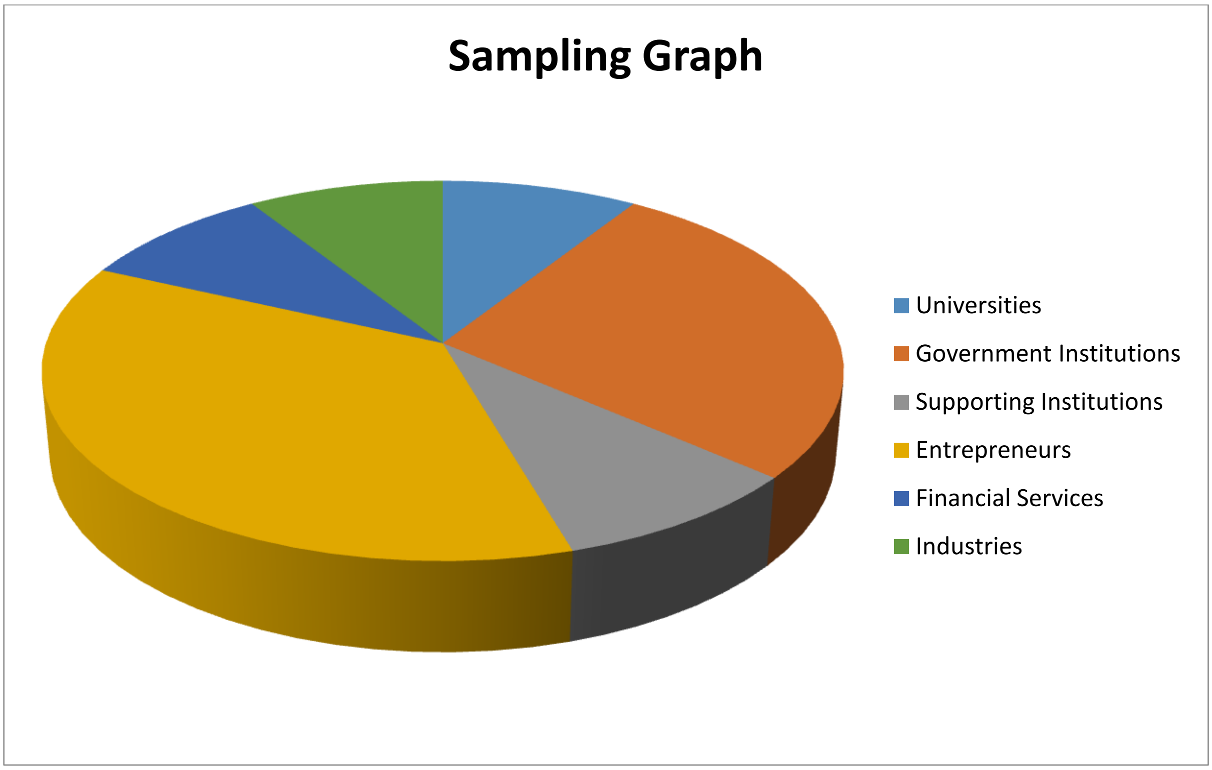

Figure 4.1: Sampling graph

Table 4.3: Job descriptions of the participants

Designation	**No. of participants**	**Ecosystem actors**
Head of Department (HOD)	2	Financial services, universities
Manager	3	Government institutions
Developer	1	Industry
Inventor	2	Entrepreneurs
Chief Financial Officer (CFO)	1	Entrepreneur
Chief Operating Officer (COO)	1	Entrepreneur
Lecturer	1	Supporting industries
Total	**11**	

All three managers were from government departments. One developer was from industry and a lecturer was from a supporting industry. As previously defined by Rabelo and Bernus (2015), supporting industries provide other actors with specialised skills or services. In this instance, the supporting institution was a technical school which produces qualified people. Two entrepreneurs were the inventors of the technology that their business sold. One individual was the CFO who only managed the financial aspects, while another was the COO who managed the business operations. Two HODs were interviewed; one from a bank and another from a university.

4.4 Missing Data

No customers or members of civil society were interviewed as it was deemed unnecessary given the focus of the research objectives. Civil society as explained by Rabelo and Bernus (2015), refers to "individuals, NGOs, associations, who create societal and environmental demands and requirements which can deeply affect businesses. They may also be customers."

The first research objective was to identify which elements and actors of an innovation ecosystem that support the manufacture of IoT devices are currently in place in South Africa. In order to meet this objective, it was necessary to approach the relevant members of the ecosystem. These were all the actors within our framework who contributed both directly and indirectly to the manufacture of these devices. Participants from universities, government institutions, financial services, and industry contributed indirectly to the production of these devices. The entrepreneurs directly contributed to the manufacture of these devices through their efforts.

The second research objective was to investigate how the actors experienced this innovation ecosystem. Civil society and customers could have insight into this from a perspective of how their demands are being satisfied by these manufacturers. This was, however, still not the objective. The intention was to understand how the actors who directly contribute to the manufacture of IoT devices viewed this ecosystem.

The third research objective was to explore which elements of this innovation ecosystem could be improved (if required). Furthermore, the objective was to identify any gaps mentioned by the ecosystem actors. The input from civil society and customers contributed to the findings to some degree as they presented a view from a demand perspective since they were not actively involved in contributing to the manufacture of these devices.

4.5 Research Findings

The following section presents the interview findings. The participants have been quoted and designated P1 to P11, indicating which one of the eleven participants is quoted. The line numbers from the transcripts are also indicated.

4.5.1 Individuals Involved in IoT Manufacture

This set of interview questions was intended for companies, NGOs, and individuals who were in involved in the manufacture of IoT devices. They were asked the set of interview questions from Research Instrument 1 (refer to Annexure A).

4.5.1.1 Interview Question 1

What technical assistance is available to companies like yours for product design and manufacture? To what extent were your needs met?

The majority of participants were unsure of the technical assistance available to them. Their narratives indicated that they felt as though their business was too specialised for there to be a sufficient amount of technical assistance from the "normal" incubators. Normal in this instance referred to incubators which provided assistance to businesses which provided a product or service which did not require specific expertise to produce. "I have not come across an incubator or government department which offers the technical assistance we need" (P6, line 8-9). The same participant cited how new the technology that they were using was the reason for the lack of technical assistance: "Internet of things manufacture is a very new business in South Africa" (P1, line 10-11). When probing where they were able to receive any guidance at all, the response was: "We rely on our international contacts to guide us in our product design" (P6, line 13).

While two participants felt that their needs were not met by the various organisations in assisting them, the common response was that "not much technical assistance is provided" (P4 and P6, line 7). One participant knew where to find the technical assistance he needed. The difficulty that they experienced in this regard was expressed as follows:

> "I have not come across an incubator or government department which offers the technical assistance we need. Our business is very specialised and quite often we find ourselves ahead of whatever assistance we have at our disposal. Internet of things manufacture is a very new business in South Africa. Not only that but a lot of Internet of Things devices are imported from China and other countries. Not many businesses offer the same product built from scratch like we do" (P6, line 8-12).

Another participant expressed the need for assistance in implementing various business processes of which they did not receive:

> "…there is no guidance on how to implement the relevant processes into your business. I found that I needed a lot of guidance on not only the business aspects of running my business but also the technical expertise I thought I had" (P4, line 7-8).

One participant who was aware of the assistance made available by various entities and individuals expressed a great deal of awareness of his ecosystem and where he could receive the necessary assistance. He attended business and IT conferences and seemed to have a network of people who could assist him.

> "I found that attending conferences sponsored by various professional associations and private companies gave me the technical assistance that I needed. A lot of those conferences are relevant to my business and … help me to stay abreast with the current technologies and ways of using them. My needs are met through these conferences" (P7, line 7-10).

4.5.1.2 Interview Question 2

How have you financed your business? Did you approach any organisations for assistance? Did they work out for you? Are there other avenues available to you?

Acquiring financial assistance from banks in the form of a loan was the most common response to this question. This method was sometimes utilised in conjunction with another funding method. "I acquired a loan from a bank and as the business grew was able to increase it to fit my needs" (P6, line 18).

> "We acquired a loan from the bank and when that ran out, I borrowed some money from my parents. I underestimated how much money it would take to get our business up and running and when it finally took off, we experienced a long slump for about a year" (P4, line 15-17).

> "…saved up a bit of capital to start my business but it was unfortunately not enough … I ended up approaching a financial institution for a loan. A loan was extremely difficult to get because of the criteria I had to meet to get it" (P7, line 15).

One participant mentioned seeking to finance their business using investors. They were unsuccessful in this regard and opined that it was due to the uniqueness of their product or the nature of their business. "…not many people were keen to invest in such a unique product" (P6, line 19-20). "Our business is very specialised" (P6, line 9).

4.5.1.3 Interview Question 3

How did you identify a market for your product? What kind of assistance is available to companies like yours in marketing your product and are they adequate?

Participants were initially drawn to the industry because they had always had a keen interest in IT. One participant in particular had experience working for a company providing similar products.

> "I previously worked at a large company which created electronics devices and they happened to also incorporate IoT technology into their products. I therefore had the opportunity to understand what competitors were in the same industry, what customers found the need for most and most importantly, what made the most sales. This opened my eyes to the opportunity I had to use this knowledge and insight and open my own business" (P7, line 24-28).

One participant stated that he always had an interest in technology and that it caused him to become more aware of the various directions it was growing in. "I had always been interested in technology and mechanics. I studied Computer Science and learnt both the hardware and software components of technology" (P4, line 22).

One participant identified a market for his product by identifying the need in his personal life. He has a deaf relative and he wanted to make her life easier. His relative did not know when someone was ringing her front doorbell and he and his business partner therefore designed a device for her to wear that notified her. "Artificial intelligence is applied to everyday objects and we identified the need for our product from my relative who is deaf" (P6, line 25-26).

An incubator and an entrepreneur considered incubators and startup competitions as a source of marketing assistance. This assistance is considered short-term or temporary and an element of the business that they felt could be improved. Entrepreneurs felt it was expensive and the view was that there is an inadequate amount of assistance in marketing their products.

> "We have had very little help in marketing our product. We have entered competitions with our inventions and won a bit of money. These competitions would get publicised and showcase our products but the marketing of our product was not the main aim" (P4, line 34-36).

Another participant valued the role of incubators in supporting their marketing efforts. "Incubators provide a lot of marketing support to us. They connect us with the right people and host a lot of events which enable us to put our product out there" (P6, line 29-30).

4.5.1.4 Interview Question 4

Do the regulations and laws in the country support your business, or do they hinder it? Can you give examples of what you mean?

The answer to this question required much thought and probing from the participants. Many were unaware of what kind of regulations and laws could impact them to the point of them posing a hindrance or assistance. “There aren’t any regulations which hamper our business at this point” (P4, line 42).

The most common response after much contemplation was in reference to import laws which could be stricter in order to promote more proudly South African products: “…there could be laws to help proudly South African businesses succeed…” (P6, line 35-36). Strict labour laws also hinder them from producing at a lower cost “…rigid labour laws in our country hinder us from competing with manufacturers from China who are able to produce similar products at a lower cost” (P7, line 39-40).

4.5.1.5 Interview Question 5

What is the one thing that would help you the most in making your business a success?

Business owners struggled with the cost of having to import components from abroad with the weak Rand. “Our weak currency makes it harder to compete because in order to make a sound enough profit, I need to price my products at a high price because making it locally is a bit expensive” (P7, line 43-44).

They explained that they had to embark on such imports due to the lack of technical skills to produce those particular components themselves: “…employees with the specialised skills are required” (P6, line 41). Participants inferred that government could possibly intervene by providing programmes that could help upskill them and their employees. “…government programs which provide an opportunity for us to gain certain skills would be of great assistance” (P4, line 60-61).

Another reason for importing components was due to the high cost associated with producing those components. Many assumed that the financial cost was too high and that importing the components was the better alternative.

> “Another thing that would make our business more successful would be the availability of raw materials at a lower price and sourced locally. At the current moment, we import a few components in our devices which cause us to have to sell them at a higher price because the cost is so high” (P6, line 42-45).

4.5.2 Supporting Institutions

Supporting institutions included individuals from banks, government departments, funders, universities, and other actors in the ecosystem who provided entrepreneurs with specialised skills or services. These individuals were asked the research questions from Research Instrument 2 (refer to Annexure B).

4.5.2.1 Interview Question 1

Tell me about what services your organisation or department offers to electronics manufacturing companies.

Supporting institutions listed numerous services that they provided to entrepreneurs. Incubators claimed to perform a supporting role through various stages within a startup and/or business.

> "We act as a support structure to entrepreneurs with ideas. We provide them with advice from the initiation stage of their startup to the point whereby they are able to secure the necessary funding from a financial institution. We help with skills development, networking, have events which bring people in the same industry together, and marketing efforts" (P3, line 10-11).

A lecturer from a technical college described their role in the ecosystem as one which provided learners with the opportunity of entering into the industry.

> "We found that there was a market to cater for those students who did not qualify to enroll in universities to study Engineering due to the educational style offered by the universities. These students required a more technical method of learning and this is exactly what we offer at our institution" (P5, line 14-17).

Representatives of government institutions stated that their organisations provided overall business development support. They concentrated their efforts on the business processes, marketing, and exposure of these enterprises.

> "Our department offers business development and support services for small enterprises. We also implement programmes for industries prioritised by the government. The various areas of support which we offer are marketing, financing, and franchising and management advice" (P10, line 8-10).

A publicly traded company provided end-to-end customer service to these enterprises. It included compiling hardware, networking, and software. However, this service was catering to large enterprises due to the cost. "Our company is a systems integrator which manages the components required to make a specific device work from networking, hardware, and software" (P1, line 8-9).

4.5.2.2 Interview Question 2

How did this service come about? How long have you been offering it? Why is this service important for electronics manufacturers?

The need to remain competitive in supplying IT hardware is what led an organisation to branch out into providing the service that they currently do. A representative explained that they "…started selling solutions to remain competitive" (P1, line 19-20). Experience with small enterprises having a lack of awareness, skills, and opportunities is how other organisations saw a gap in the market. They sought to provide services which they thought would be in high demand as they felt that they would resolve specific needs. "We identified gaps in the ecosystem for entrepreneurs and small startups which were detrimental to their success" (P3, line 16-17).

Government agencies were looking to grow the private sector in order to grow the country's economy. "Our department is a product of identifying specific industries which influence our country's economic growth and attempting to improve them" (P11, line 16-17). Another representative said:

> "Government has various initiatives which are put in place to help facilitate the country's economy. A key area in the economy post '94 was boosting the private sector. One method of this was found to be through supporting entrepreneurs by providing them with various services which could enable their businesses to grow. This service is important since manufacturing is seen as a key industry in our country. We find our services important to electronics manufacturers because some of these entrepreneurs don't have any formal education. They need some of the guidance and exposure to different ways of doing business that we provide" (P9, line 14-20).

Although government departments and learning institutions had been providing their services to entrepreneurs for many years, some had only recently focused on that specific industry. "We started developing this new information technology entrepreneurship curriculum a few years ago (perhaps five)" (P8, line 18-19).

4.5.2.3 Interview Question 3

Would you consider the manufacture of electronics to be an important industry for South Africa? If so, then why?

Most participants said that they would consider the manufacture of electronics as an important industry for South Africa because of how large an industry it is. However, a few doubted if South Africa had the required ecosystem elements in place to be successful. Lack of skills was highlighted as a concern.

> "Yes, most definitely [it is an important industry to South Africa]. It is a huge industry of which could help South Africa's economy. There are many opportunities for entry in that supply chain and if we could get the skills levels up in South Africa, we could take advantage of that opportunity" (P3, line 22-24).

> "Yes, I would consider it to be an important industry because of the amount of money that could be generated from it. We import a lot of our goods from countries like China and if we were able to manufacture them ourselves then it would be an opportunity for our economy to grow much more" (P9, line 25-27).

Others thought that manufacturing was a huge industry but not of electronics.

> "Manufacturing is big but not from a small electronics point of view. The cost of production is still a bit high so … Our [South Africa's] skills levels are not on par with the likes of China. Our currency is also not at place where we could explore that" (P1, line 28-30).

4.5.2.4 Interview Question 4

Do electronics manufacturers value your services? (Probe: How many organisations take up your services?)

Most of these participants opined that electronics manufacturers valued their services based on the continued relationship. Others used the volume of their client base as an indication of whether their services were deemed valuable.

> "Yes, they do, and we are often overwhelmed with the number of people passing through our doors. We can get anything from 300 to 380 entrepreneurs approaching us for our services. Many of them aren't necessarily in the manufacturing of electronics space but come with more software-based businesses that they need guidance with" (P3, line 29-32).

Another claimed: "Yes, we have between 6 000 and 10 000 clients a year that buy our chips" (P1, line 37).

A lecturer from a technical school opined: "Since we introduce graduates to potential employment at electronics manufacturers or the opportunity of developing into them, I would say that they definitely value our services" (P5, line 28-30). This is, however, an opinion and not based on any feedback that they have received. Others were not certain because they had not monitored electronics manufacturers specifically but had a view of how well their manufacturing client base was faring in general.

4.5.2.5 Interview Question 5

Do your services help manufacturers of electronics to succeed? (Probe: How do you know? Do you monitor their success?)

Participants from incubators, government departments, and financial services reported that they do monitor the success of the organisations that they provide services to. They were also of the opinion that these manufacturers were successful through their support services.

> "Yes, they do [help manufacturers to succeed]. We monitor their success by running a lot of exercises to see how much we are making for them. We generate these reports quite frequently and we have the analytics which can link our clients increased or decreased revenue to our efforts" (P1, line 44-46).

> "Yes, they do. I am proud to say that a number of businesses that we have interacted with in the past are now flourishing and the partnership with them is still strong. They have formed part of our

> incubator and contribute to a lot events and mentoring activities we have in place here" (P3, line 37-39).

Others were less focused on monitoring.

> "Yes, they do value our services because as a government institution, we are an important stakeholder to them. Government holds the policies which enable them to flourish from startups to large companies. We have a lot of information which enables them to not only grow but sustain that growth over a number of years" (P9, line 32-35).

A participant from a university and one from a technical school provided conflicting information. The university monitored the success of its students and was able to provide clear information on how their services helped these organisations to succeed. "Yes, I believe that these organisations value our services. Many of them continue to participate in our programmes and have employed some of our graduates after their studies" (P8, line 36-37). Conversely, the technical school kept no records of whether graduates from that institution were able to succeed. "I cannot say with certainty. We do not monitor such information" (P5, line 35).

4.5.2.6 Interview Question 6

What are the challenges your organisation faces in providing services to electronics manufacturers? What would make it possible for you to provide a better service?

A participant from a financial institution mentioned that some of their challenges were bad credit or poor business cases. This made it difficult for them to award these enterprises with any funding. "…there are credit issues or alternatively the business proposal does not make sense because the bank looks at very key elements; cost-benefit analysis and the ability for them to pay back the funding to the bank" (P2, line 186-188).

A participant from a technical school mentioned the insufficient resources to cater to the large number of students. However, it was unclear what resources were being referred to in this instance. "The maximum annual intake poses a problem to our organisation. We find that we are able to accept a large number of students but don't have the sufficient resources to provide them with an adequate service" (P5, line 40-42).

The university participant felt as though organisations were unaware of their programmes and therefore the possibility to find graduates with that particular skill. "I think that we could improve companies' awareness of our programmes" (P8, line 49-49).

An employee from an incubator mentioned the lack of information that some entrepreneurs had and their inability to run a business without assistance. He explained that some entrepreneurs had unrealistic expectations of them. He added that South Africa's education system could prepare these entrepreneurs better with a curriculum which included entrepreneurship from an earlier age.

> "The only challenge that we find is that entrepreneurs are often ill-informed about what's required to build a startup into a flourishing business. They have poor business management skills and we often find that we are starting from ground zero with them. This makes the process a bit more frustrating for them and some tend to leave the incubator. I believe that if our schooling curriculum taught entrepreneurship at an early age, it would equip learners to become better entrepreneurs and business owners" (P3, line 44-48).

A participant from a government institution made reference to their delivery model and said that it was a constant work in progress to see which would deliver the best service to these enterprises.

> "We find that our branch delivery model and implementation strategies are a constant learning curve and require continuous improvement. This effort is required to improve the capacity of our organisation's Business Advisors. Best practice needs to be adhered to and that is why we need Business Advisor seminars to review these standards" (P10, line 46-49).

Negative economic changes were also viewed as a challenge which created a domino effect between them and the businesses that they supported.

> "Economic challenges can affect these businesses quite adversely. Moreover, they affect our department too. Whereby companies are international players or import components from other countries, a recession or even a decrease in value of the rand can increase their costs and thereby decrease their revenues. As the department we also find ourselves in a position whereby some of the funding for certain projects will be scaled back" (P11, line 49-53).

Another participant from a government department mentioned funding as an essential component which was often poorly managed. The availability of resources was said to be something that entrepreneurs should educate themselves on. They were of the view that entrepreneurs did not take the time to understand their ecosystem in order to find all the resources which were available to them.

> "Funding should be prioritised better from a government perspective. There are some initiatives which require more funding than others and this is not well managed. Entrepreneurs should also take the time to educate themselves on the external resources available to them" (P9, line 46-48).

CHAPTER 5: DISCUSSION

5.1 Introduction

This chapter discusses the findings in order to answer the research questions. The elements identified in the interviews are compared with those highlighted in the expanded framework. The chapter is divided into three sections which each addresses a research question.

5.2 Research Questions

5.2.1 Research Question 1

Which elements and actors of an innovation ecosystem that support the manufacture of IoT devices are currently in place in South Africa?

The expanded theoretical framework listed actors, capital, infrastructure, marketing, market pull, regulations, knowledge networks, knowledge, and ideas as the elements of an innovation ecosystem. The intangible elements included architecture principles, interface, and culture. The actors were: universities, government, industry, civil society, entrepreneurs, supporting institutions, customers, financial systems, and an ecosystem leader.

5.2.1.1 Capital

When interviewing entrepreneurs to understand the approach that was taken to fund their businesses, a variety of approaches were mentioned. The majority of businesses had acquired a loan from a financial institution. It was mentioned by one participant that the loan application process was difficult because of the requirements that the business case had to meet. Several participants mentioned that they had underestimated the amount of funding that they needed and found that their business loan ran out before they could reach a certain stage, therefore requiring to seek some more funding. Saving up the capital was not a popular avenue for most and there was only one entrepreneur who used this option.

Another less popular avenue was funding the business through investors or venture capitalists. It was mentioned that the uniqueness of the product hindered potential investors from investing. According to these entrepreneurs, the perceived risk of them not getting their investment back or not making a profit was just too high. It is possible that investors are looking to invest in businesses which produce a more conventional product or service. It is also possible that investors consider other factors such as the strength of the business case, their own knowledge of the industry, and whether they have any contacts in that ecosystem that could assist them when needed. Conclusively, there is some capital available in the form of bank loans, but other avenues like VC are not yet well-established for these kinds of businesses. More options for raising capital would therefore improve the ecosystem.

5.2.1.2 Infrastructure

The physical resources required in the ecosystem were mentioned less often compared to other elements in the ecosystem. This is not necessarily attributed to the view that there was an insufficient amount of infrastructure in this ecosystem or that it was less important than other elements in any way. An actor who offered support to IoT manufacturers in the form of infrastructure was interviewed. It was mentioned that their organisation had to shift its business model slightly in order to remain competitive. Instead of producing microchips alone, they also started providing an end-to-end customer service involving the software, networking, and maintenance (P1, line 5). This could be an indication that there is an opportunity to provide technology infrastructure but that there is also an opportunity to provide infrastructure support to the entrepreneurs.

5.2.1.3 Marketing and Market Pull

Entrepreneurs were of the view that marketing assistance was not readily available to them. The minority of entrepreneurs mentioned incubators making these services available to businesses. The majority of entrepreneurs felt as though this element required some government intervention through specific programmes. The feeling was that currently the only opportunity to receive any marketing assistance was through competitions which would offer them some guidance and assistance to market their products and even then, this assistance was short lived.

The need to remain competitive was a reason that an IT services company revised the set of products and services that they were producing. Their customers created a demand for the services that they required, and it created a market pull in the ecosystem. In order to remain relevant in the industry, companies need to adjust to their customers' needs. Another entrepreneur used the concept of "market pull" in order to identify their product. Their own personal experience had led them to identify a need for this product. There was a significant amount of market pull for IoT products since this is what drove many entrepreneurs to produce these products. This element was evident in the ecosystem and possibly requires minimal, if no intervention at all.

5.2.1.4 Regulations

Many organisations were not fully aware of the regulations in that were in place. There was some mention of rigid labour laws hampering their ability to produce their products at a lower cost. Many participants made mention of China which was widely thought of as their biggest competitor. Their concerns were that their high production costs were making it difficult to compete with companies which manufactured their products in China at a low cost. It can be concluded that the regulations were perceived as making more difficult for these entrepreneurs to compete. In a well-functioning ecosystem, the regulations should support entrepreneurs.

5.2.1.5 Knowledge, knowledge networks, and ideas

The lack of specialised skills was introduced as an issue. Entrepreneurs were concerned with the fact that they needed to provide extensive training to their employees because they lacked the technical skills required. This could cost them time and money. In an attempt to bridge the skills gap, incubators provided networking opportunities and advice to entrepreneurs. They were among the group of actors who disseminated knowledge to them and sparking new ideas. The same two elements were brought into the ecosystem by a university and technical school. All of these actors had consequently created a knowledge network which was seemingly ineffective since so many participants mentioned skills shortages.

5.2.1.6 Interface, architecture principles, and culture

The participants did not explicitly mention evidence pertaining to the interfaces which actors communicated through, architectural principles, or culture. The way in which actors interacted seemed to require some intervention since entrepreneurs opined that there was insufficient assistance offered to them. Conversely, those offering assistance to them opined that these entrepreneurs were satisfied with their assistance. This created a culture whereby there seemed to be a minority of IoT manufacturing organisations which had all the assistance they needed and organisations providing it to them, while others struggled to have the same. The providers stated that the entrepreneurs needed to educate themselves more regarding the skills required to make their businesses flourish as well as identifying what resources were available to them. This illustrated poor communication within the ecosystem and is an area that requires some intervention. By improving the interfaces or communication between the actors, the architecture principles and culture would naturally be impacted.

5.2.1.7 Actors

The participants acknowledged the following ecosystem actors: financial systems, customers, civil society, government, supporting institutions, entrepreneurs, industry, and universities. Although no members of civil society or customers were interviewed, the other actors recognised them as part of the ecosystem. The ecosystem leader was not explicitly recognised throughout any of the interviews. However, when discussing the elements which required some intervention, government was seen as playing a significant role in any change which could have been implemented. Many participants perceived them as having the power to implement policies and programmes which could assist entrepreneurs. In the true definition of an ecosystem leader, government seemed to fulfil that role, albeit in a manner that was unsatisfactory to the entrepreneurs. The expanded model included nine actors and all of them were recognised in this study. However, the manner in which these actors interacted led to the conclusion that this is not a well-established ecosystem.

5.2.2 Research Question 2

How do the actors experience this innovation ecosystem?

5.2.2.1 Experience of entrepreneurs

Entrepreneurs had a contrasting view of the assistance offered within the ecosystem. While there was an anomaly of an entrepreneur who was well aware of the resources available to him, many seemed to be of the view that those resources were either insufficient or non-existent. They expressed that their businesses were too specialised and that the type of assistance offered to them had not considered the uniqueness of their products. This could have very well been accurate but could have also been a view shared among those entrepreneurs who had a low level of awareness of their ecosystem. The majority of the entrepreneurs who were interviewed were still in their initial years of operation and could possibly not have been established enough to be aware of certain elements of their ecosystem. This was the suggestion made by some supporting institutions.

5.2.2.2 Experience of supporting institutions

Participants who were of the view that their services were valued by electronics manufacturers, based it on their continued relationship with them and size of their customer base. It is logical to assume that electronics companies would continue a relationship with a supporting institution if they valued their services, however, it may be flawed to assume that they see value in these services based on a customer base. This is stated because one would need to find out how many organisations manufacture such devices and compare that number to those who have elected to use their services before making that assumption.

Although some actors were of the opinion that they did help manufacturers succeed, they did not have the statistics to support those claims. Their claims were either based on the fact that these businesses continued to make use of their services or because they were biased that they provided something valuable. Others monitored these organisations and maintained a relationship with them, therefore had this view of their progress, similar to the case of the university.

5.2.3 Research Question 3

Which elements of this innovation ecosystem could be improved (if required)?

A financial institution representative cited poor business cases and credit scores as creating a challenge for them providing some businesses with loans. This spoke partially to the perceived lack of business acumen they felt business owners possessed. By improving the knowledge and skills of these entrepreneurs, it could possibly make them eligible for receiving the financing that they need from financial institutions. This is because they could produce stronger business cases and possess more of the necessary skills required to run successful businesses. Perhaps if their employees' competence was also improved in this way; less time and money would be spent on training them. Programmes that identify essential competency areas for entrepreneurs and providing them with these could be of use. A government participant cited negative economic changes as a challenge since it impacted the amount of funding that they could invest in their programmes. This is a factor that is not directly controlled by members of the ecosystem.

Additional options for capital are still required for businesses that are not eligible for financing by an institution. Bank loans and saving up capital cannot be the only avenues available to them. Once this ecosystem becomes more established, other methods such as crowdfunding, getting investors, online lending, and government grants could become more widely used options.

Regulations to help with import controls on foreign goods were expressed as something that could help businesses compete with larger Chinese companies from. Government initiatives were suggested by some participants as a form of assistance in this regard.

Better knowledge networks and knowledge sharing could improve poor communication between the ecosystem actors. Investigating the different avenues or interfaces in place for the actors to communicate and collaborate could identify other interfaces, which could yield an improvement or the issues with the current ones could be identified and resolved. The architecture principles of the ecosystem could be improved to create better cohesion in the ecosystem, therefore improving the seemingly fractured culture.

CHAPTER 6: CONCLUSION

6.1 Summary of Findings

This study aimed to explore the innovation ecosystem surrounding the manufacture of IoT devices in South Africa. Rabelo and Bernus' (2015) framework was employed as a theoretical lens. A literature review was conducted to uncover the existing literature on innovation ecosystems to expand the framework. The framework was expanded to include three more elements and an additional actor. Interviews were then carried out to examine the ecosystem actors and elements according to the ecosystem actors.

The first objective of the study was to identify which elements and actors of an innovation ecosystem that support the manufacture of IoT devices are currently in place in South Africa. The actors identified the following elements as being in place to some extent: capital, infrastructure, market pull, knowledge networks, regulations, knowledge, ideas, and actors. Although these exist in some form, several did not support the entrepreneurs.

The second objective of the study was to investigate how the actors experienced the innovation ecosystem. Results showed that both IoT manufacturers and those who supported them opined that the ecosystem required intervention. IoT manufacturers felt as though there was insufficient support for marketing, capital, regulations, and knowledge sharing. Participants from IoT supporting institutions opined that knowledge and knowledge networks within the ecosystem required intervention. This was however viewed as an issue that IoT manufacturers needed assistance with.

The third objective of the study was to explore which elements of this innovation ecosystem could be improved (if required). The evidence showed that marketing, capital, knowledge, knowledge networks, regulations, interface, architectural principles, and culture could be improved. The only elements which did not require intervention were market pull and infrastructure. This led to the conclusion that the IoT innovation ecosystem in South Africa is not well-functioning enough for South Africa to be a major player in that particular industry.

Future research may wish to investigate the dynamics involved in entrepreneurs and their funding choices as this was not within the scope of the study. By understanding this, more appropriate options could be offered, and existing difficulties may be uncovered. It is worth investigating other avenues such as VC as it is widely known to promote a healthy innovation system (Tucker et al., 2011).

6.2 Implications for Academia

The study contributed to existing literature on innovation ecosystems as it expanded on Rabelo and Bernus' (2015) framework to include marketing, market pull, and knowledge networks. The ecosystem leader was included as an additional actor. By focusing on the IoT innovation ecosystem in South Africa, the study also contributed to the limited literature on IoT in South Africa and ecosystems in South Africa.

6.2.1 Implications for Practice

Elements which require some intervention were identified as: marketing, capital, knowledge, knowledge networks, regulations, interface, architectural principles, and culture. The study provided practice with the elements that they could seek to improve.

6.3 Limitations and Future Research

Although a sampling matrix was utilised to select the population target and sample in order to pursue a sufficient number of responses across most actors, this study was small in scale. It is possible that interviewing a greater number of participants who play different roles within the ecosystem would yield different findings. Furthermore, the study is only relevant to those specific actors who were identified and the findings cannot be generalised to other actors. Future research may provide an opportunity to concentrate on the actors who were not interviewed, such as civil society and customers.

All the participants resided in Johannesburg, in the Gauteng Province. Although this region hosts numerous electronics firms and may be seen as the economic hub of South Africa, the lack of dispersion of responses further limits its generalisability. Future research could provide the opportunity to expand the research to other areas.

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ANNEXURE A: RESEARCH INSTRUMENT 1

Interview questions for those involved with manufacture of IoT devices (companies, non-profits and possibly individuals)

Q1:

In getting involved in this kind of manufacture, what technical expertise did you draw on for the product design and manufacture? Did you have in-house expertise or did you have to rely on external expertise? Did you get the expertise you needed? Who provided that expertise?

Q2:

When it comes to financing your business, have you approached any organizations for assistance with financing? Who were they and how did that work out for you? (Probe: Did you try banks, government departments, or other investors? Why or why not?)

Q3:

Have you had any assistance in identifying a market for your product and in marketing? Who provided that assistance? If not, would it have been useful to you and why have you not had assistance?

Q4:

Do the regulations and laws in the country support your business, or do they hinder it? Can you give me examples of what you mean?

Q5:

What is the one thing that would help you the most in making your business a success?

ANNEXURE B: RESEARCH INSTRUMENT 2

Interview questions for those offering support to IoT device manufacturers (banks, government departments, funders, universities etc.)

Q1:

Tell me about what services your organization or department offers to electronics manufacturing companies?

Q2:

How did this service come about? How long have you been offering it? Why is this service important for electronics manufacturers?

Q3:

Would you consider the manufacture of electronic devices to be an important industry for South Africa and why?

Q4:

Do electronics manufacturers value your services? (Probe: How many organizations take up your services, say in a year? How many of these are involved in manufacturing of electronics?)

Q5:

Do your services help manufacturers of electronics to succeed? (Probe: How do you know? Do you monitor their success?)

Q6:

What are the challenges your organization faces in providing services to electronics manufacturers? What would make it possible for you to provide a better service?

ANNEXURE C: CONSISTENCY MATRIX

The below consistency matrix is to ensure that the appropriate questions are asked in order to answer specific research questions.

Research Instrument 1

Interview Question	Research Objective
Q1: In getting involved in this kind of manufacture, what technical expertise did you draw on for the product design and manufacture? Did you have in-house expertise or did you have to rely on external expertise? Did you get the expertise you needed? Who provided that expertise?	Objective 1: To identify the elements and actors of an innovation ecosystem which support the manufacture of IoT devices currently in place in South Africa Objective 2: To investigate how the actors experience this innovation ecosystem in South Africa. Objective 3: To explore which elements of this innovation ecosystem would benefit most from some intervention if required.
Q2: When it comes to financing your business, have you approached any organizations for assistance with financing? Who were they are how did that work out for you? (Probe: Did you try banks, government departments, or other investors? Why or why not?)	Objective 1: To identify the elements and actors of an innovation ecosystem which support the manufacture of IoT devices currently in place in South Africa Objective 2: To investigate how the actors experience this innovation ecosystem in South Africa. Objective 3: To explore which elements of this innovation ecosystem would benefit most from some intervention if required.
Q3: Have you had any assistance in identifying a market for your product and in marketing? Who provided that assistance? If not, would it have been useful to you and why have you not had assistance?	Objective 1: To identify the elements and actors of an innovation ecosystem which support the manufacture of IoT devices currently in place in South Africa Objective 2: To investigate how the actors experience this innovation ecosystem in South Africa. Objective 3: To explore which elements of this innovation ecosystem would benefit most from some intervention if required.
Q4: Do the regulations and laws in the country support your business, or do they hinder it? Can you give me examples of what you mean?	Objective 1: To identify the elements and actors of an innovation ecosystem which support the manufacture of IoT devices currently in place in South Africa

	Objective 2: To investigate how the actors experience this innovation ecosystem in South Africa. Objective 3: To explore which elements of this innovation ecosystem would benefit most from some intervention if required.
Q5: What is the one thing that would help you the most in making your business a success?	Objective 3: To explore which elements of this innovation ecosystem would benefit most from some intervention if required.

Research Instrument 2

Interview Question	**Research Objective**
Question 1: Tell me about what services your organization or department offers to electronics manufacturing companies?	Objective 1: To identify the elements and actors of an innovation ecosystem which support the manufacture of IoT devices currently in place in South Africa
Question 2: How did this service come about? How long have you been offering it? Why is this service important for electronics manufacturers?	Objective 2: To investigate how the actors experience this innovation ecosystem in South Africa
Question 3: Would you consider the manufacture of electronics to be an important industry for South Africa? If so then why?	Objective 2: To investigate how the actors experience this innovation ecosystem in South Africa
Question 4: Do electronics manufacturers value your services? (Probe: How many organizations take up your services, say in a year? How many of these are involved in manufacturing of electronics)	Objective 2: To investigate how the actors experience this innovation ecosystem in South Africa
Question 5: Do your services help manufacturers of electronics to succeed? (Probe: How do you know? Do you monitor their success?)	Objective 2: To investigate how the actors experience this innovation ecosystem in South Africa
Question 6: What are the challenges your organization faces in providing services to electronics manufacturers? What would make it possible for you to provide a better service?	Objective 3: To explore which elements of this innovation ecosystem would benefit most from some intervention if required

ANNEXURE D: SYSTEMATIC LITERATURE REVIEW RESULTS

The below tabulates all the findings from the systematic literature review in order to show articles which were deemed relevant to the study and those which were deemed not, along with the reason.

No.	Title	Date	Author	Paper Synopsis	Database	Relevant (Y/N)	Reason
1	21st Century R&D	2012	Mariann Jelinek, Alden S Bean, Richard Antcliff, Erik Whalen-Pedersen, and April Cantwell	How three global demographic shifts and climate change all posed as challenges that promised to transform R&D and how R&D managers are handling it.	EBSCO	No	Discusses R&D operations and managerial change.
2	Accelerating Innovation	2016	Duncan Logan	Magazine article about the CEO of a technology article.	EBSCO	No	Not academic literature
3	Accelerating Innovation: The Nanotechnology Institute	2011	Anthony P. Green, Erli Chen, Kambiz Pourrezaei, Michele Marcolongo, and Robert W. Carpick	Discusses the innovation ecosystem that The Nanotechnology Institute has created and the barriers to the commercialization of innovative technologies which touches on the actors and elements in an	EBSCO	Yes	

				innovation ecosystem.			
4	Biobanks as a Central Part of the Finnish Growth and Genomic Strategies: How to Balance Privacy in an Innovation Ecosystem?	2016	Sirpa Soini	Discusses the Finnish legislation in view of international genomic research and the governance and privacy in Finnish Biobanks.	EBSCO	No	Does not define or discuss an innovation ecosystem albeit in the title.
5	Birth and Expansion of innovation ecosystems: A case study of copper production	2015	Ozgur Dedehayir, Marko Seppänen	Discusses an innovation ecosystem's birth phase and sub-phases. Ecosystem actors are mentioned in the study in explaining the theoretical background.	EBSCO	Yes	
6	Building an innovation eco-system: A daunting challenge	2013	S. K. Kulkarni	Discusses building an innovation ecosystem surrounding the healthcare and pharmaceutical industry.	EBSCO	Yes	
7	Building an open innovation ecosystem	2014	Henry Chesbrough, Sohyeong Kim, Alice Agogino	Discusses a case study whereby a small business was able to thrive and become a business success through building a successful business ecosystem.	EBSCO	No	The ecosystem elements were too specific to the case study, e.g. wine sellers, food journalists, alumni spin-offs, customers, culinary artists, family and

							friends and local suppliers. This was the same case for the elements.
8	Building Technology Transfer Capacity in Turkish Universities: a critical analysis	2015	Marina Ranga, Serdal Temel, Ilker Murat Ar, Rustem Baris Yesilay, Fazilet Vardar Sukan	Discusses the adoption of policies created by government for universities to ensure adequate knowledge and technology transfer to new industries.	EBSCO	No	
9	Campus Leadership and The Entrepreneurial University: A Dynamic Capabilities Perspective	2016	Sohvi Leih, David Teece	Discusses the factors surrounding managing a research university. It only mentions that universities are part of an innovation system but does not mention the other actors or elements involved.	EBSCO	Yes	
10	Catalyzing capital for Canada's life sciences industry	2011	Joseph Tucker, Justin Chakma, Paul W.M. Fedak, Massimo Cimini	This is a case study about understanding the disconnect between low levels of venture capital and a healthy innovation ecosystem in terms of R&D spending, skilled workforce and enterprise support.	EBSCO	Yes	

11	Charting the Innovation Ecosystem	2014	MaryAnne M. Gobble	Discusses the terminology "ecosystem" and its popularity in various contexts.	EBSCO	Yes	
12	Collaborative Development Planning Model of Supporting Product in Platform Innovation Ecosystem	2014	Wei Zhang, Hamid Reza Karimi, Qingpu Zhang and ShaoboWu	Discusses a revenue-sharing model between the platform company and supporting company by creating a collaborative development mechanism.	EBSCO	Yes	
13	Creeping Tiger, Soaring Dragon: India, China and Competition in Information Technologies	2012	Anindya Chaudhuri	Compares China and India's information industries in a dynamic framework.	EBSCO	No	Made no reference to elements or actors of an innovation ecosystem in general but was specific to the economics of knowledge industries.
14	Design ecosystems and innovation policy in Europe	2017	Anna Whicher	Components of a design ecosystem were explored and tested.	EBSCO	Yes	
15	Digital Technology Demand is Transforming HR	2014	Jill Goldstein	Discusses how HR and service providers are affected by the digital rise.	EBSCO	No	The paper doesn't discuss innovation ecosystems.
16	Disruptive change and the reconfiguration of innovation ecosystems	2017	Ozgur Dedehayir , J. Roland Ortt , Marko Seppänen	Extends the traditional view of disruptive change and considers its impact on the innovation	EBSCO	Yes	

				ecosystem.			
17	Educational Ecosystems: A Trend in Urban educational Innovation	2015	Dr Mustafa Abdul-Jabbar and Dr Barbara Kurshan	The concept of educational innovation ecosystems is defined and discussed; however, no mention is made about the specific actors or elements.	EBSCO	No	Very specific to the impact of educational innovation systems and although mentions that there are actors within it, it doesn't describe who they are.
18	Emerging Innovation in Emerging Economies: Can Institutional Reforms Help Russia Break Through Its Historical Barriers?	2014	Daniel J. McCarthy, Sheila M. Puffer, Loren R. Graham, Daniel M. Satinsky	This article uses the triple-helix innovation model to investigate Russia's historic and current innovation initiatives	EBSCO	Yes	
19	From the management of innovative projects to the Innovation Management of Innovative projects: An Analysis within the automotive industry	2016	Sylvie Mira, Bonnardel Danielle Attias, Carole Donada	This article discusses various business ecosystems and the methods of project managing innovative projects.	EBSCO	Yes	
20	Information Technology and Product/Service Innovation: A Brief Assessment and Some Suggestions for Future Research	2013	Satish Nambisan	Develops a framework that considers IT's dual roles as operand resource and its impact on innovation process.	EBSCO	No	Does not define the actors or elements in an innovation ecosystem.
21	Innovation Ecosystems	2014	Ron Adner, Jim Euchner	This is an interview which discusses the concept of	EBSCO	Yes	

				innovation ecosystems.			
22	IP Models to orchestrate Innovation Ecosystems: IMEC, A Public Research Institute in Nano-Electronics	2013	Bart Leten, Wim Vanhaverbeke, Nadine Roijakkers, André Clerix, Johan Van Helleputte	This study illustrates the central role of the IP-model that an orchestrator develops for the innovation ecosystem partners.	EBSCO	No	Does not define the actors or elements in an innovation ecosystem.
23	Knowledge transfer in university quadruple helix ecosystems: an absorptive capacity perspective	2016	Maura McAdam, Kristel Miller, Rodney McAdam, Sandra Moffett, Allen Alexander, Pushyarag Puthusserry	The objective of this study was to improve the understanding of the Knowledge Transfer phenomena in an open innovation context where multiple diverse quadruple helix stakeholders are interacting.	EBSCO	No	Does not define the actors or elements in an innovation ecosystem.
24	Lessons from Tata's Corporate Innovation Strategy	2015	Sunil Mithas, Ravi Arora	Discusses TATA's corporate strategy	EBSCO	No	Does not define the actors or elements in an innovation ecosystem.
25	Making Innovation Happen in a Megaproject: London's Crossrail Suburban Railway System	2015	Andrew Davies, Samuel MacAulay Tim DeBarro, Mark Thurston	Presents the initial findings of an ongoing three-year action research project between Crossrail and researchers at Imperial College London and University College London.	EBSCO	No	Does not define the actors or elements in an innovation ecosystem.

26	Nanotechnology and innovation policy	2015	Lisa Larrimore Ouellette		EBSCO	Yes	
27	Open science versus commercialization: a modern research conflict?	2012	Timothy Caulfield, Shawn HE Harmon and Yann Joly	Utilizes genomics to illustrate the potential policy conflict from three countries (Canada, US and UK)	EBSCO	No	Does not define the actors or elements in an innovation ecosystem.
28	Preconditions of intercluster cooperation internationalization	2014	Omelyanenko Vitaliy Anatoliyovych	Discusses impact of internationalization on high-tech clusters functioning and determination of the impact on the international dimension of macro factors of intercluster cooperation	EBSCO	No	Does not define the actors or elements in an innovation ecosystem.
29	Quantitative VC: A New Way to Growth	2013	John Bhakdi	Discusses approaches to Venture Capital.	EBSCO	No	Does not define the actors or elements in an innovation ecosystem.
30	Saudi Arabia: From Oil Kingdom to Knowledge-Based Economy	2015	Mohammad S. Khorsheed		EBSCO	Yes	
31	Science in New Zealand’s future	2015	Professor Sir Peter Gluckman	Discusses the challenges and opportunities of New Zealand’s economy	EBSCO	No	Does not define the actors or elements in an innovation ecosystem.

32	The Emerging Innovation Ecosystems and "Valley of Death": Towards the Combination of Entrepreneurial and Institutional Approaches	2016	Giedrius Jucevicius, Rita Juceviciene, Vaidas Gaidelys, Aniko Kalman	Discusses the nature, origins and diversity of innovation ecosystems.	EBSCO	Yes	
33	The Fracking Revolution: Shale Gas as a Case Study in Innovation Policy	2015	John M. Golden, Hannah J. Wiseman	Explores questions of risk governance, federalism, and export policy regarding the US boom in natural gas production.	EBSCO	No	The ecosystem elements and actors were too specific to the study.
34	The Gathering Storm: Analyzing the Cloud Computing Ecosystem and Implications for Public Policy	2012	Kenji Kushida, Jonathan Murray, John Zysman	Discusses how cloud computing is simultaneously an innovation ecosystem, product platform and global marketplace.	EBSCO	No	The paper doesn’t mention any actors or elements but acknowledges that they exist.
35	Innovation in Real-Life Settings	2012	Nathan Hawk, Gamin Bartle, Martha Romine	Discusses how the Living Lab is an open innovation ecosystem as well as its relationships with its stakeholders and internal leadership structures.	EBSCO	Yes	
36	The Management of Research and Innovation Systems: Comparative Study of the East and the West Practices	2017	Teck-Chai Lau, Kum-Lung Choe, Ming-Yu Cheng	Reviews and analyzes innovation ecosystems in various countries to identify their uniqueness, challenges and best practices.	EBSCO	Yes	

37	The new model innovation agencies: An overview	2014	William B. Bonvillian	Discusses the lessons learnt over the past 4 major innovation organization policy moments in the US federal government.	EBSCO	Yes	
38	The Role of a Local Industry Association as a Catalyst for Building an Innovation Ecosystem: An Experiment in the State of Ceara in Brazil	2015	Dafna Schwartz, Raphael Bar-El	Shows the positive role that the local association of industries in Brazil played in acting as a catalyst for change where government intervention was not present.	EBSCO	Yes	
39	The Role of University in Eco-Entrepreneurship: Evidence from the Eurobarometer Survey on Attitudes of European Entrepreneurs Towards Eco - Innovation	2014	Francisco José Sáez-Martínez, Ángela González-Moreno, Teresa Hogan	Discusses sustainable innovations and the role that various actors can play while creating viable alternative models.	EBSCO	Yes	
40	Cui Bono? The Selective Revealing of Knowledge and its Implications for Innovative Activity	2013	Oliver Alexy, Gerard George, Ammon J. Salter	Discusses how selective revealing of information as a strategic mechanism to reshape the collaborative behaviour of other actors in a firm's innovation ecosystem is an effective alternative to collaboration mechanisms.	EBSCO	No	The paper doesn’t mention any actors or elements but acknowledges that they exist.

41	Third-mission policy goals and incentives from performance-based funding: Are they aligned?	2016	Ainurul Rosli, Federica Rossi	Investigates how a specific policy approach to encourage third mission engagement—the use of performance-based funding to reward universities' success in this domain—aligns with the broader goals of third mission policy	EBSCO	No	Only makes mention of government as an actor although acknowledging that others exist. Other literature has already covered government as an actor therefore there is no new information in this paper.
42	To become a knowledge economy	2014	R. Chidambaram	Discusses how technology-driven growth is needed to become a developed country and that a knowledge economy is essential in sustaining this development.	EBSCO	No	The components of an ecosystem in this paper are too specific to that of a research innovation ecosystem.
43	Transforming regions into innovation ecosystems: A model for renewing local industrial structures	2014	Kaisa Oksanen, Antti Hautamäki	This paper developed a model for building innovation ecosystems.	EBSCO	Yes	
44	Vision for Data and Informatics in the Future Materials Innovation Ecosystem	2016	Surya R. Kalidindi, Andrew J. Medford, David L. McDowell	Discusses emerging discipline of materials data science and informatics (MDSI) that promises to address key technology gaps.	EBSCO	No	Irrelevant to the study.

45	What Europe Needs Is an Innovation-Driven Entrepreneurship Ecosystem: Introducing EDIE	2015	Olaf J. Groth, Mark Esposito, Terence Tse	Discusses the need for a new entrepreneur- driven innovation ecosystem.	EBSCO	Yes	
46	A profile of Mexico's technological agglomerations: The case of the aerospace and nanotechnology industry in Quer_etaro and Monterrey	2016	Sergio Marco A. Luna-Ochoa, Eduardo Robles-Belmont, Ernesto Suaste-Gomez	Discusses technology clusters in Mexico and how the technological crowds get configured.	Science Direct	Yes	
47	Can breakthrough innovations serve the poor (bop) and create reputational (CSR) value? Indian case studies	2014	Shyama V.Ramani, Vivekananda Mukherjee	Tests the assumption that if an innovation serves the poor, then it will generate CSR gains.	Science Direct	No	Too specific to the ecosystem of a bottom/ base of income pyramid
48	Connecting all the dots: Identifying the "actor level" challenges in establishing effective innovation system in Indonesia	2013	Benyamin Lakitan	Discusses the three levels within an innovation ecosystem at which many diverse challenges are faced.	Science Direct	Yes	
49	In defence of 'eco' in innovation ecosystem	2017	P. Ritala, A. Almpanopoulou	Seeks to resolve a critique of the concept of innovation ecosystems.	Science Direct	Yes	
50	Innovation ecosystems: A critical examination	2016	Deog-Seong Oh, Fred Phillips, Sehee Park, Eunghyun Lee	Reviews the concept of innovation ecosystems as it is set forth in the academic and trade literature and seeks to	Science Direct		

				resolve the question of the meaning of adding ‘eco’ to our treatment of national and regional innovation systems.			
51	Innovation policy within private collectives: Evidence on 3GPP's regulation mechanisms to facilitate collective innovation	2014	David Lopez-Berzosa, Annabelle Gawer	Provides insights how to manage collective innovation in the digital economy regime.	Science Direct	No	Does not serve the purposes of the SLR.
52	Investing in advanced materials: A market-driven methodology	2016	Jin S. Kim	This study proposes a market-driven methodology for investing in materials innovation.	Science Direct	No	Does not serve the purposes of the SLR.
53	Legislative environment and others factors that inhibit transfer of Mexican publicly funded research into commercial ventures	2016	Alma Cristal Hernandez-Mondragon, Luis Herrera-Estrella, Walid Kuri-Harcuch	This study explored some factors that limit technology transfer in the process of innovation from different research institutions in Mexico.	Science Direct	No	Does not serve the purposes of the SLR.
54	Market challenges facing academic research in commercializing nano-enabled implantable devices for in-vivo biomedical analysis	2011	E. Juanola-Feliu, J.Colomer-Farrarons, P.Miribel-Catal J.Samitier, J.Valls-Pasola	The study examines the value chain and the market challenges faced by in-vivo implantable biomedical devices based on nanotechnologies	Science Direct	Yes	
55	Policy-driven ecosystems for new vaccine development	2014	Julia Fan Li, Elizabeth Garnsey	The study provides evidence on how resource-constrained firms mobilize participants in	Science Direct	No	Irrelevant to the study.

				policy-specific ecosystems to achieve their goals of new vaccine development for tuberculosis.			
56	Process-based vs. product-based innovation: Value creation by nanotech ventures	2012	Elicia Maine, Sarah Lubik, Elizabeth Garnsey	The study showcases that nanotechnology ventures benefit from prioritizing technology–market matching, alliance building and experimenting with technologies in new value networks.	Science Direct	No	Irrelevant to the study.
57	Recycling the unused ideas and technologies of a large corporation into new business by start-ups	2017	Mokter Hossain, Henri Simula	Investigates how the non-core ideas and technologies (IaTs) of a large corporation can be reused by start-ups.	Science Direct	No	Irrelevant to the study.
58	“Research is high and the market is far away”: Commercialization of nanotechnology in China	2013	Cong Cao, Richard P. Appelbaum, Rachel Parker	Showcases a study that was conducted in China that revealed that despite tangible success in publishing, patenting, and the creation of dedicated nanotechnology science parks, China’s effort to commercialize nanotechnology has been much slower than anticipated by	Science Direct	No	Irrelevant to the study.

				nanoscientists and political leadership.			
59	Service innovation structure analysis for recognizing opportunities and difficulties of M2M businesses	2015	Naoshi Uchihira, Hirokazu Ishimatsu, Shigeaki Sakurai, Yoshiteru Kageyama, Yuji Kakutani, Kazunori Mizushima, Hiroshi Naruse, Susumu Yoneda	A smart home case is used for explaining the effectiveness of the proposed M2M model.	Science Direct	No	Irrelevant to the study.
60	Situated regional university incubation: A multi-level stakeholder perspective	2016	Maura McAdam, Kristel Miller, Rodney Mc Adam	Contributes to both regional and national agendas by empirically illustrating the need for appropriate design and tailoring of university incubation models.	Science Direct	Yes	
61	Technology Business Incubation: An overview of the state of knowledge	2016	Sarfraz Mian, Wadid Lamine, Alain Fayolle	Introduces Technology Business Incubation (TBI), exploring the concept, its evolution and scholarship.	Science Direct	Yes	
62	The more the merrier? Network portfolio size and innovation performance in Nigerian firms	2015	Abiodun A. Egbetokun	Showcases the positive relationship between a firm's innovation performance and the size of its networking portfolio.	Science Direct	No	Irrelevant to the study.
63	Understanding a new generation incubation model: The accelerator	2016	Charlotte Pauwels, Bart Clarysse, Mike Wright, Jonas Van	The study contributes to the incubation literature by extending recognition	Science Direct	No	Too specific to that particular study

			Hove	of the heterogeneity of incubation models, by delineating the accelerator as a distinctive incubation model and by introducing the design lens as a useful theoretical framework.			

ANNEXURE E: PARTICIPATION INVITATION LETTER

Participation Letter

Date: 22 June 2017

Good Day

My name is Didintle Mokoka and I am a Masters student in the Information Systems Division at the University of the Witwatersrand, Johannesburg. I am conducting research on the innovation ecosystem which supports the manufacture of IoT devices in South Africa. An innovation ecosystem refers to an environment which is built or nurtured to support an industry or sector.

As a professional involved in this innovation ecosystem, you are **invited** to take part in this interview. The purpose of this interview is to find out if there is a well-functioning innovation ecosystem to support the growth of IoT manufacture in South Africa.

Your response is important and there are no right or wrong answers. Your responses to the interview will be confidential and anonymous. Anonymity and confidentiality are guaranteed by not requiring your name during the interview and the research will be reported in such a way that it will not be possible to identify you or associate you with any of your answers. Your participation is completely voluntary and involves no risk, penalty, or loss of benefits whether or not you participate. You may withdraw from the interview at any stage.

The entire interview should take up to an hour to complete. The questionnaire was approved unconditionally by the School of Economics and Business Sciences Research Ethics Committee, Protocol Number: CINFO/1133.

Thank you for considering participating. Should you have any questions, or should you wish to obtain a copy of the results of the questionnaire, please contact me on:
Email Address: ddmokoka@gmail.com – Cell number: 072 216 9748
My supervisor's name and email are: Judy Backhouse – Judy.Backhouse@wits.ac.za

Kind regards
Didintle Mokoka
Masters Student: Division of Information Systems
School of Economic and Business Sciences
University of the Witwatersrand, Johannesburg

ANNEXURE F: ETHICS CLEARANCE FORM

Faculty of Commerce, Law and Management
University of the Witwatersrand, Johannesburg

School of Economic and Business Sciences
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CLEARANCE CERTIFICATE **PROTOCOL NUMBER: CINFO/1133**

PROJECT: **AN EXPLORATION OF SOUTH AFRICA'S INNOVATION ECOSYSTEM FOR INTERNET OF THINGS DEVICES**

INVESTIGATOR: Didintle Mokoka

STUDENT NUMBER: **0704266D**

SCHOOL: SEBS

DATE CONSIDERED: 26 April 2017

DECISION OF THE ETHICS COMMITTEE: Approved

NOTE

Unless otherwise specified this ethics clearance is valid for 1 year and may be renewed upon application. Please remember to include the protocol number above to your participation letter.

DATE: 11/05/2017 **CHAIRPERSON: Jean-Marie Bancilhon**

cc: Supervisor:

Prof Judy Backhouse

SCHOOL OF ECONOMIC & BUSINESS SCIENCES