Competitive advantage during industry 4.0: The case for South African Manufacturing SMEs

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Declaration

I declare that this project report is my own, unaided work, except where otherwise acknowledged. It is being submitted for the degree of Master of Science in Engineering in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other university.

Signed this 20th day of May 2018

M.S. Futcher

Abstract

With the expected disruption of industry 4.0 and the current challenges that SMEs face in South Africa, there is an increasing threat that SMEs will lose any competitive advantage they currently have. This exploratory study investigates how South African manufacturing SMEs can remain competitive during the fourth industrial revolution. Data, in the form of current literature, was analysed using thematic content analysis. From the analysis process, 8 emergent themes were used to organise the results of the study. Notable findings towards generating competitive advantage included: The location of SMEs within clusters, collaboration with disruption leaders, the sharing of outcomes across the value chain, the shift of business models towards a service and software orientation, the use of data driven insights to find and capture high margin markets and the increased effectiveness of labour through technology use. The study also found that the use of the IoT and cloud computing can significantly reduce infrastructure requirements and promote a competitive advantage.

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Chapter 1 Introduction

1.1 Background

Manufacturing is one of the key drivers towards knowledge capital and economic prosperity in a country.[1] Kaldor [2] states that increased growth in manufacturing leads to a direct increase in overall gross domestic product (GDP) as well as manufacturing productivity and productivity outside of the manufacturing sector. Millin and Nichola [3] tested the Kaldor hypothesis in South Africa and found it to be true, with a positive correlation between manufacturing growth and GDP growth. Manufacturing is one of the few industries that exhibit this characteristic and is therefore one of a South Africa's most important sectors.

Within the manufacturing sector, small to medium size enterprises (SMEs) contribute around 40% of South Africa's GDP.[4] Their contribution towards the countries economy is important not only in terms of GDP output but also because of job creation. South Africa has a high unemployment rate and SMEs provide a significant portion of South Africa's much needed jobs.[5] SMEs in South Africa face a number of challenges such as limited access to skills and developed infrastructure, funding and crime.[4]

It is believed that the world economy may be entering its next industrial revolution. It will be the fourth industrial revolution and has been termed by the Germans as 'Industry 4.0'.[6] Industry 4.0 is characterised by technologies and terms such as cloud computing, artificial intelligence, 3D printing, big data and smart factories.[7] It is uniquely different to the third industrial revolution in the sense that operations are expected to link into internet technologies. This is to enable a level of intelligence in operations that makes way for decentralised decision making.[6] It is believed that industry 4.0 will significantly change the manufacturing process and resources allocation of SME manufacturers, giving them the opportunity to develop and provide downstream services. [7, 8]

1.2 Problem Statement

With the importance of SMEs in South Africa, it is crucial that manufacturing SMEs are able to maintain or create competitive advantage sustainably into the future. With the expected disruption of industry 4.0 and the current challenges that SMEs are facing, there exists the risk of manufacturing SMEs losing any competitive advantage they currently hold. This risk is intensified by the fact that South African SMEs are known to have low levels of research and development, which limits their adoption of innovative technologies.[4] It is therefore important that the South African SMEs are assisted in understanding the potential impacts of industry 4.0 and what can be done to retain or grow competitive advantage.

1.3 Critical Research Question

How can South African manufacturing SMEs remain competitive during the fourth industrial revolution?

1.4 Objectives

1. Investigate possible sources of competitive advantage during the fourth industrial revolution.
2. Determine the actions and means manufacturing SMEs can use to generate competitive advantage during the fourth industrial revolution.
3. Develop a framework for decision makers in SMEs that will assist in the creation of competitive advantage during the fourth industrial revolution.

1.5 Summary of Research Methodology

A qualitative research approach was used for this study. The data comprised of relevant literature that was selected using a combination of online database search and snowball sampling. The final data set was made up of 5 reports that totaled 75 404 words collectively. Thematic content analysis was used to analyse the data. The analysis involved selecting direct quotes from the literature that were then scanned for emergent themes. A total of 38 initial themes were found which were later refined and reduced to 8 using a frequency and co-occurrence analysis in Microsoft Excel. The results were presented as a combination of written text and infographics.

1.6 Outline of Chapters

Introduction - This chapter outlines the background and problem statement of the research. It also proposes the critical research question and the research objectives that were used in order to answer it. The end of the chapter presents a summary of the research methodology used.

Literature Review - This chapter gives relevant literature on the research topic which includes industry 4.0, manufacturing and SMEs in South Africa. A theoretical framework of competitive advantage is also presented.

Research Design and Methodology - The first part of this chapter (Research Design) outlines how and why the research process was designed. The second part (Methodology) shows the steps taken by the researcher in order to achieve the results.

Analysis and Results - The results are presented in 8 infographics, representative of the 8 themes used in the analysis. Alongside each theme is an explanation that is specific to each theme and forms part of the results. Towards the end of the chapter a competitive advantage framework is presented for SME decision makers that highlights the key findings within the research.

Discussion - The discussion chapter examines the reliability and validity of the research. It also examines the degree to which the research question was answered and details further considerations of the research findings.

Conclusion and Recommendations - This chapter outlines the limitations to the study and gives suggestions as to further action that should be taken as a result of the research findings.

Chapter 2 Literature Review

The purpose of the literature review is to highlight the core principals of industry 4.0 and define some of the key concepts that relate to it. The literature review also gives further context to the research and links theory with real-world application. A conceptual framework of competitive advantage is also presented in the literature review in order to explain existing subject matter knowledge and show the relationships between current theoretical views.

2.1 Industry 4.0

One of the challenges in defining industry 4.0 is that there is no generally accepted definition amongst universities and academics. [9] This is due to the subject matter being new and still very conceptual. In order to better understand the concept of industry 4.0 from a an academic point of view, Hermann, Pentek and Otto [9] conducted a comprehensive investigation into the fundamental design principals of industry 4.0. The investigation comprised of both a quantitative text analysis and a qualitative literature review. Hermann, Pentek and Otto [9] found that there are 4 fundamental design principals of industry 4.0:

1. Interconnection
2. Information transparency
3. Decentralised decision making
4. Technical assistance

Since industry 4.0 is not a specific methodology or tool, but a rather a fluid concept, the design principals of industry 4.0 are useful for understanding the subject matter. The 4 design principals are explained in this section, along with 7 key components of industry 4.0. The 7 components are the main contributing technologies and ideas within industry 4.0. Although the components of industry 4.0 have been discussed under certain design principals, they are not exclusively tied to any specific principal. The 7 components of industry 4.0 have connections to each of the design principals. They are categorised under the design principal with the strongest connection or relevance.

2.1.1 Principal 1: Interconnection

The first industry 4.0 design principal, which is arguably the most important, is interconnection. The connection of people, machines, devices and sensors provide the means for industry 4.0.[9] Without interconnection, information transparency, decentralised decision making and technical assistance would be difficult to achieve. Interconnection allows people and objects to share information in real-time, creating an environment where the real world and the cyber world interact instantaneously. Interconnection allows for collaboration in three ways, human-human, human-machine and machine-machine.[9] It is this collaboration that is central to industry 4.0 and what makes it uniquely different from the third industrial revolution. In order to understand the interconnection of industry 4.0 the idea of *Cyber physical systems* needs to be explored along with the *internet of things* (IoT).

Cyber Physical Systems

A cyber-physical system is the term given to "a new generation of systems with integrated computational and physical capabilities that can interact with humans through many new modalities."[10] A cyber-physical system takes a holistic view over both cyber and physical components that are normally seen separately and accounts for their interacting and interdependent behaviors.[11] They are envisioned to control manufacturing operations while at the same time monitoring them in cyber space, making corrective actions both on a process level and system operations level.[12] An example of a cyber-physical system is a semi-autonomous vehicle. The vehicle tracks and monitors its own position relative to other vehicles using proximity sensors and a GPS unit. It also monitors the drivers awareness by sensing different parts of the body. A person who is becoming tired may relax their grip on the steering wheel, take longer to make corrective actions and blink for longer periods of time. Sensors in the car would read this behaviour and the car would slowly begin taking over more steering control from the driver or force the driver to pull-over and rest. The car's decision making is done in cyber space, through a connection to the internet, which in turn controls the car in the physical space. There is a holistic understanding by the system of both the physical and cyber elements. Figure 2.1 illustrates some of the differences between traditional car design and a car designed to be a cyber-physical system. Figure 2.1 and has been modified from Bradley and Atkins [13].

Just like the example of the car, cyber-physical systems can be applied to manufacturing. Their application to manufacturing is broad and will lead to many of the advantages industry

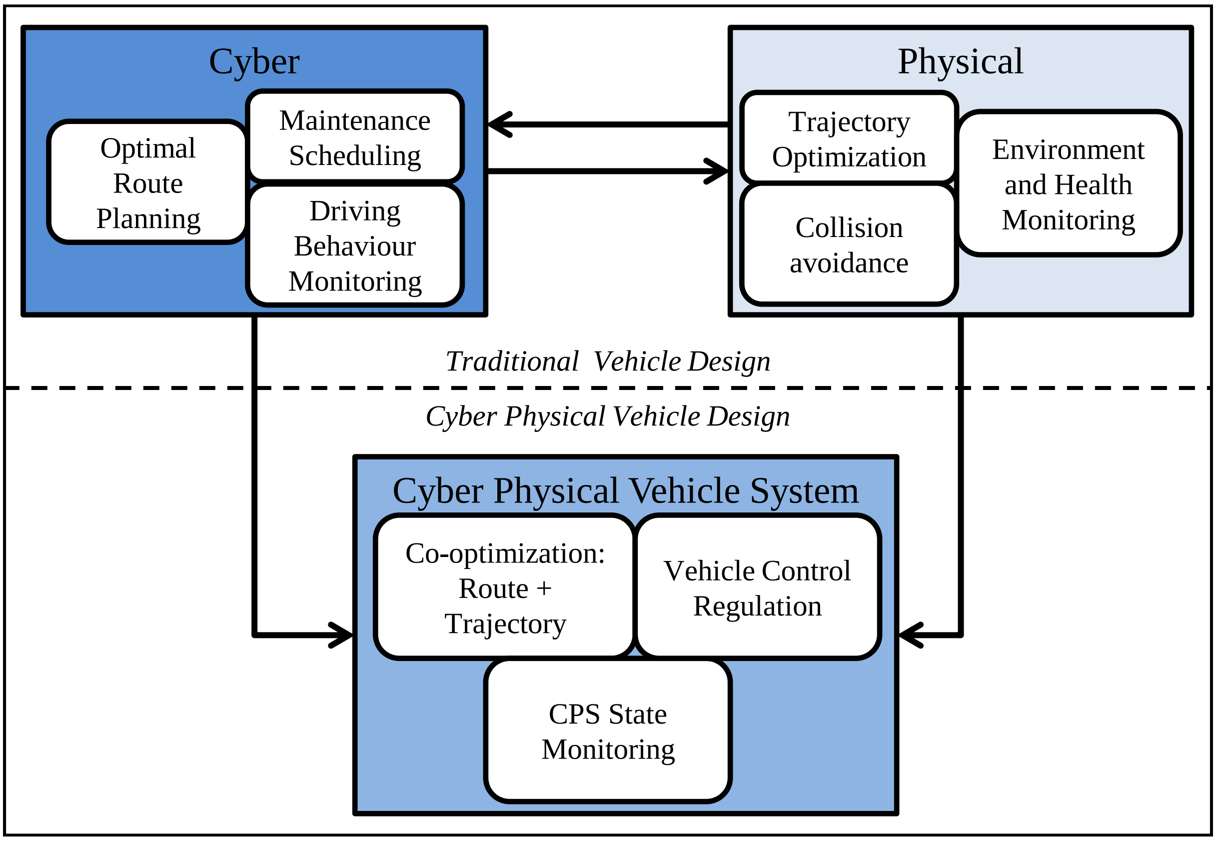

Figure 2.1: Cyberphysical vehicle design [13]

4.0 offers. Figure 2.2 shows the number of unique articles per year between 2010 and 2015 that were downloaded using the queries "cyber-physical system" and "cyber-physical system and manufacturing".[14] The significant growth trend in the output of academic papers on cyber-physical systems is evidence that they will become more significant to modern day operations and form part of the industry 4.0 ideal state. In order for cyber-physical systems to be used to their full potential they need to exist within a network. The network allows for interconnection and the first design principal of industry 4.0. In order to achieve this connection within an industry 4.0 ideal state a means for connection is required. The dominant means emerging is known by the term "internet of things".

Internet of things

The internet of things (IoT) is simply "a network of internet-connected objects able to collect and exchange data using embedded sensors."[15] Minerva, Biru and Rotondi [16] conducted an in depth study into the IoT with the aim of developing a baseline definition. They found that the a number of features are essential for the IoT to exist. The first feature is the interconnection of things. For a network to exist connection is necessary. As the name suggests this connection happens through the internet not an intranet or extranet.[16] The "things" themselves must also be uniquely identifiable and have a sensing/actuation capability. Sensors and actuators must be attached to the "things" allowing them to transmit

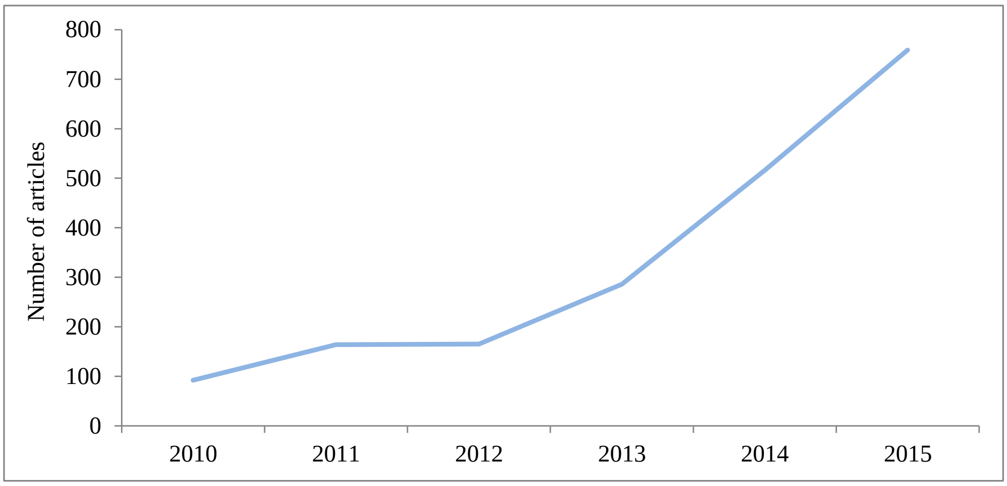

Figure 2.2: Number of unique articles produced using the key words "cyber-physical system and manufacturing".[14]

or relay information into the network as well as act or perform a task on the information they receive. This capability of sensing/actuating enables a "smartness" on the part of the objects connected to the network. The term smart devices is often used to describe these objects. [16]

Another feature of the IoT is its "ubiquity", which implies that the network is available anywhere or anytime (or at least at the times and places it is needed). There is a continual link to the internet and the network. Objects can link and communicate through the network without restriction. Linked to ubiquity is interoperability communications capability, which means that the network is standardised allowing anyone access to the network. This feature also ensures that communications can take place along the network because of a standardised communications protocol. All the objects in the network are able to communicate and understand each other through a common language.[16]

The last three features of the IoT are embedded intelligence, self-configurability and programmability. Embedded intelligence links to the design principal of technical assistance. Through the use of dynamic smart devices, which exhibit their own emergent behavior, knowledge is gathered, analysed internally and then presented back to the network. Embedded intelligence is a feature that allows the IoT to become an external extension of human intelligence.[16] Self-configurability is necessary for the IoT to operate on such a large scale. The IoT connects an almost unlimited number of devices making central management too tedious. Each object linked into the network handles its own configuration and software requirements along with its own energy and resource consumption. The final feature outlined by Minerva, Biru and Rotondi [16] is the programmability of the IoT. A programmable device is one which can execute different tasks without having to change physical form. An example of a programmable device is a computer numerical control (CNC) machine. A CNC machine can perform a number of different manufacturing tasks by getting a set of programmed instructions. These tasks include drilling, milling, turning etc. A traditional hand drill is non-programmable. It has been set to perform a single function. If a person required a drill to perform a welding operation, the physical form of the drill would need to be changed into something that resemble a welding machine. The IoT makes use of programmable devices that can perform a number of tasks from user instruction without requiring a physical change.[16]

2.1.2 Principal 2: Information transparency

The design principal of information transparency is driven by the increasing number of interconnected objects and people.[17] The merger between a physical world and a virtual world enables information to be shared in new ways and at an almost instantaneous speed.[18] It is this ability to freely share information without delay that unlocks the real-time capabilities of industry 4.0 and makes information transparency a core design principal.

In an ideal industry 4.0 state, data is captured by hundreds of sensors and linked to digital plant models resulting in a virtual copy of the physical world. This virtual copy is filled with "context-aware information", which allows other participants in the network to make correct decisions through data analytics.[9] Two key components that are closely related to information transparency are Big Data and Cyber Security.

Big Data

Big Data refers to datasets that are "not only big, but also high in variety and velocity, which makes them difficult to handle using traditional tools and techniques."[19] The 3 V's that characterise Big Data are volume, variety and velocity. Volume refers to the quantity of data, variety refers to the different formats the data exists in and lastly, velocity refers to how quickly the data is generated (or changing). Big Data sets are generated by any source of information but are prominent with industry 4.0 due to the large number of sensors in a digital environment.[20] Figure 2.3 shows the conceptual model of Big Data outlined by Sagiroglu and Sinanc [21].

As much as measuring, capturing and storing data is important to a digitised environment, the main challenges arise from sorting and interpreting the data in way that is useful for decision makers.[19] The sorting and interpretation of Big Data is known as Big Data Analytics and involves a number of advanced processing techniques that have been specifically designed to cope with the volume and variety of Big Data.[19]

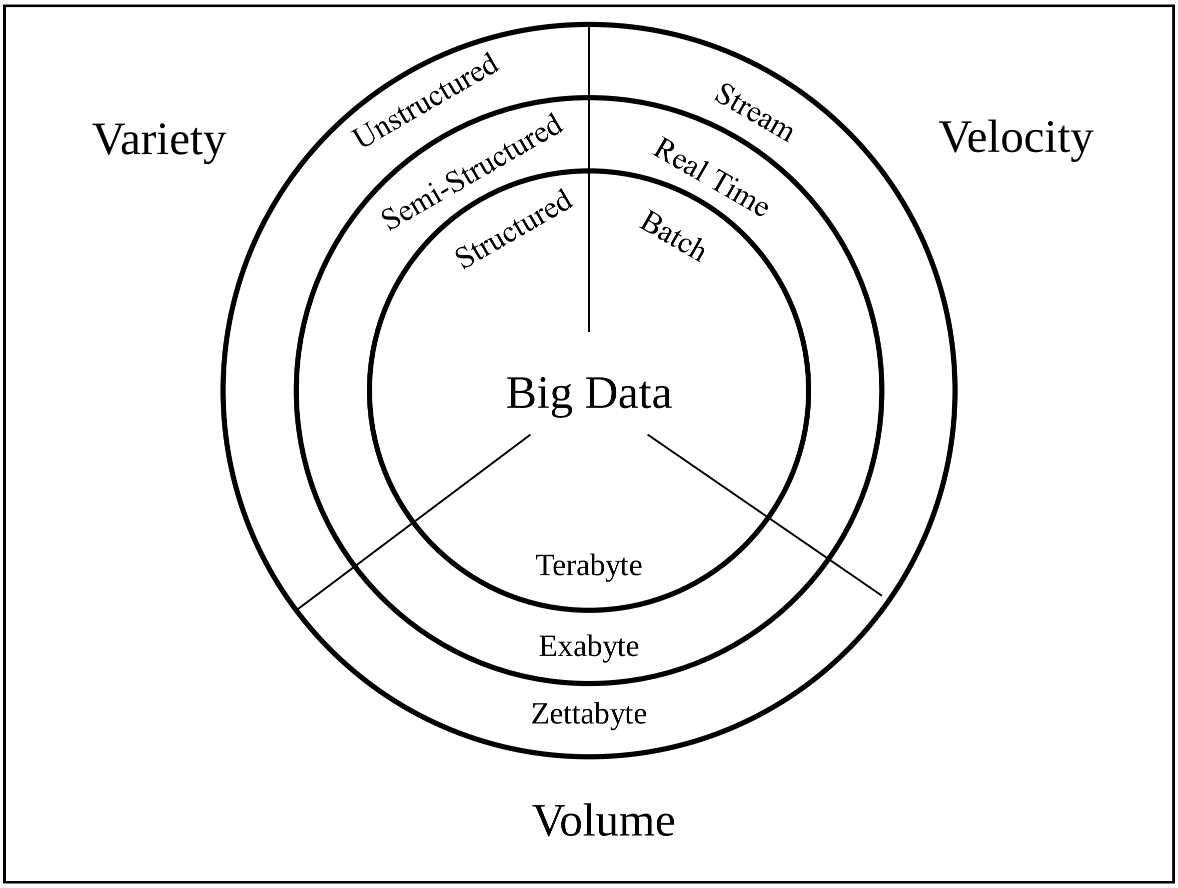

Figure 2.3: Conceptual Model of Big Data [21]

Big Data offers a number of benefits such as better aimed marketing, new business insights, recognition of sales and market chances, quantification of risk, better planning and forecasting and production yield extension.[22] It is a fundamental component to industry 4.0 and should therefore be considered extremely important by businesses who wish to succeed during the next industrial revolution.

Cyber Security

While industry 4.0 will unlock a number of benefits for businesses of the future but one of its greatest threats is cyber crime.[23] In 2016, the manufacturing industry was in the top 3 industries targeted by cyber attacks.[24] Cyber attacks were aimed at a range of objectives that included stealing confidential data, IP on new products and the sabotage of industrial processes.[23] Due to the IoT, a company will have significantly more connection points to the internet and open itself up to cyber attacks. Cyber security is a crucial component to industry 4.0 and companies will need to strengthen their cyber security management.[23]

2.1.3 Principal 3: Decentralised decision making

The third design principal of industry 4.0 builds on the first and the second. Once there is interconnection between objects and people as well as information transparency, decision making can be automated to a higher degree and executed independently.[9] Decentralised decision making systems make use of both local and global information for improved decision making which leads to an increase in over-all productivity.[25] It is through the use of Cyber-physical systems, with their array of sensors, actuators and computers that enable remote monitoring and controlling of physical objects.[26] Artificial Intelligence and The Cloud are two industry 4.0 components that are core to decentralised decision making.

Artificial Intelligence
Artificial Intelligence (AI) can be broadly thought of as machines exhibiting human-like cognition and dates back to Alan Turing in 1950.[27] The term 'Artificial Intelligence' cannot be specifically defined because AI covers a broad range of technologies and techniques that are continually changing. As people become accustomed to new technologies they generally are no longer considered as 'intelligent'.[28] There is also no agreed upon definition for "intelligence", which makes defining machine intelligence difficult.[27]

AI can be categorised into two main groups, general or narrow. Artificial General Intelligence (AGI) aims to perform any, if not all, intellectual tasks that a human is capable of doing.[27] AGI is considered extremely difficult and has not reached a point where it can be used in business applications.[29] "Narrow" AI performs specific tasks that are focused and normally aimed at a single application such as image recognition or speech and text translation.[27]

The following list outlines 4 types of narrow AI that have specific relevance to industry 4.0 and are likely to be prominent in an industry 4.0 ideal state.

- *Robotics* - Robotics is generally concerned with the automation of a physical task. Automation was the key stone of the third industrial revolution but the fourth aims to take that a step further giving this automation a degree of intelligence. The result is smart robots that operate independently with built in flexibility.[30] BMW, Tesla and Toyota are three automotive manufactures making a significant investment into robotics for production.[27] Currently some level of robotics, even in its most basic form is being applied to almost every sector.[31] An industry 4.0 company will be one in which humans and robots work collaboratively with robots adjusting completely to the human work cycle.[32]

- *Computer Vision* - Computer vision, also referred to as machine vision, aims to execute visual information tasks such as object detection and classification.[33] It uses cameras and other visual sensors to gather data which is then analysed and the result is used for controlling of a physical environment. Computer Vision is able to capture a lot more data than most other sensory systems and is best suited to examining products and detecting defects, as well as gathering data to direct and optimise robots.[34]

- *Virtual Agents* - Virtual Agents are robots that exist primarily online and usually have an anthropomorphic (human) appearance.[35] One of the major hindrances to productivity in the work place is the locating of information. People tend to spend a large portion of their time searching or sorting information.[36] This is where a Virtual Agent can offer significant benefits by executing these tasks. An example of an information finding virtual agent is "Siri", Apples dedicated chat-bot. Other applications exist that allow customers and employees to know the status of a business process without leaving their work station. [36] Other benefits of virtual agents include the automation of online processes, translation and language generation as well as customer recognition and management. [35]

- *Machine Learning* - Machine Learning arguably applies to most subsets of Artificial Intelligence and is concerned with translating experience into knowledge.[37] It has two main purposes, the first is being able to perform human/animal tasks that cannot be simply coded through programming. Examples include image understanding, driving and speaking. A learning system is able to execute these task with sufficient accuracy after being exposed to significant data (experience).[37] The second purpose of machine learning is to execute tasks that are humanly impossible due to their sheer size. This involves analysing Big Data for insights and knowledge that would otherwise be too memory intensive for a human brain.[37]

An example that highlights the impact artificial intelligence will have for the next industrial revolution is the engine block shown in Figure 2.4. The engine block is designed by Autodesk's generative design package called 'Autodesk Within'.[38] It is an example of how machine learning can be used in design applications. Engineers feed in the design objectives and constraints such as material properties, size and shape limits, forces and even the manufacturing process. The machine block in Figure 2.4 has been optimised to be lightweight, load bearing and manufactured through 3D printing.[38]

The Cloud

The Cloud refers to the access and "sharing of web infrastructure for resources, software and information over a network."[39] It can be thought of as the pooling of computing power, storage and IT infrastructure. Its main advantages are the fact that it can be accessed from almost any geographical location, it is scalable, always available and can be paid for per use.[39] The Cloud has caused a fundamental shift in the way a business can generate and

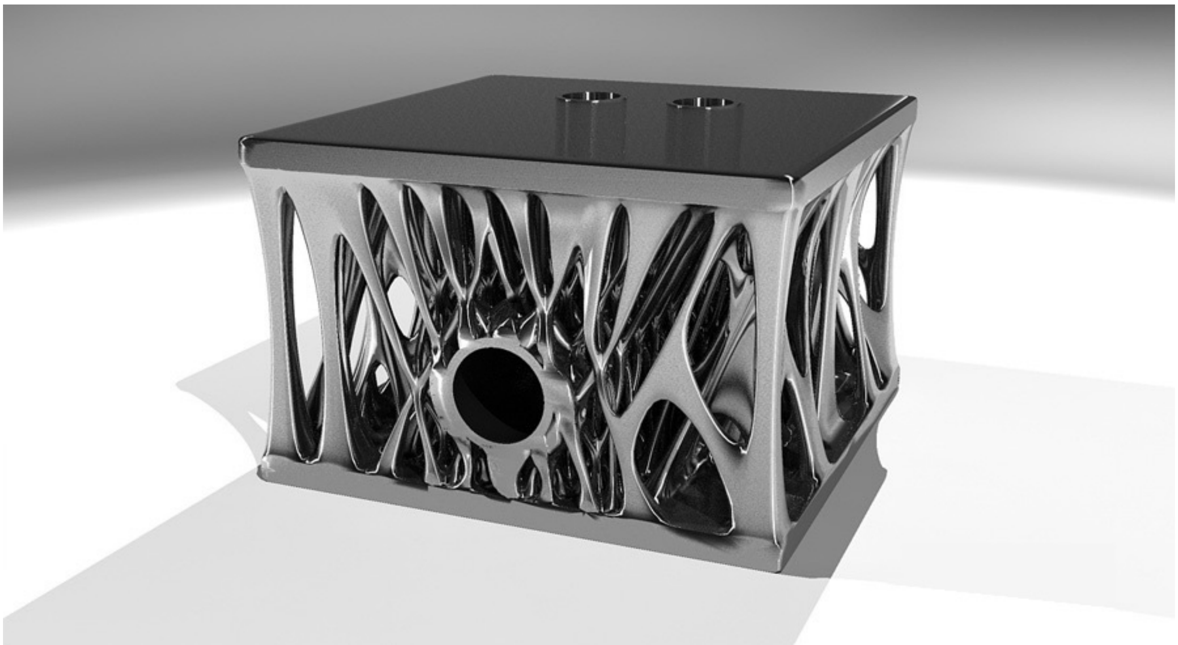

Figure 2.4: Machine Block Designed by Artificial Intelligence [38]

consume computing power.[40] The Cloud offers all businesses the opportunity to outsource a lot of their resource requirements by tapping into the 'as a service' (aaS) business model structure of the cloud. The As a Service model enabled through the cloud is spurring on digital transformation and will be a key component of industry 4.0 for the following reasons:

- *Mobility* - Employees of all level of the organisation are able to stay up-to-date and work from any location 24/7. As business roles change and become more fluid, employees will need to be able to access company information on the move. The cloud enables this by not being fixed to a single location or time.[41]
- *Open Market* - The Cloud breaks down traditional market barriers. Anyone who offers infrastructure, storage or software services can be used by any customer. The barriers to market penetration are greatly reduced and opportunities are created for all business sizes.[41]
- *Agility* - With the constant state of change, businesses struggle to keep up to date with the latest softwares and IT infrastructure. Updating physical systems is both time consuming and expensive. By using cloud services, businesses can maintain access to the latest developments in software and business service without having to overhaul infrastructure. Scalability is also essential for change and is ensured through the cloud. A start-up can easily grow it systems as and when needed, without having to face traditional challenges related to growth. Business are also given the freedom to change easily between services. Long term commitments to service providers are no longer

essential and companies don't need to worry as much about making bad decisions. If a service is not suited to their needs, they can easily switch to another one.[41]

- *Value* - The Cloud services are extremely cost effective, as mentioned already, service is paid for by use. This reduces large upfront investment that has been traditionally required in new businesses or projects. A company can focus on strategy rather than infrastructure and freely exit strategic positions that have not resulted in growth.[41]

2.1.4 Principal 4: Technical assistance

The fourth design principal of industry 4.0 focuses on the interaction between humans and a digital environment. During industry 4.0, people will shift from being operators to strategic decision makers who can flexibly solve problems.[9] An increase in complexity, due to the numerous links between cyber-physical systems and other networks, human will require support by technical systems. Assistance systems will aid in the visualisation of information so that people are able to make correct decisions and solve the problems in front of them without excessive delay.[42] Robots will also aid humans in performing tasks, especially those that are difficult, unsafe or monotonous.[9] The integration between humans and a digital environment will be extremely important during the next industrial revolution and therefore humans make up the 7th and final component of industry 4.0.

Humans

A study done by Lorenz et al. [43] found that industry 4.0 will likely increase the number of jobs available for people, however there will be a drastic shift in the nature and the skills required for these jobs. People who thrive in an industry 4.0 environment will need to be able to work alongside machines and robots, collaborating and interacting with them. Employees who struggle to adapt and change will likely find a digital environment more challenging than those who embrace it.[43] Jobs that require repetitive non-skilled tasks are at greatest threat of being automated by robotics or completed by artificial intelligence bots. While unskilled labour jobs will be lost, new job opportunities will open up in the areas of IT and data analytics.[43] People with skills in these two areas will find the most job security. This introduces a challenge for both business and government to find ways of re-skilling labour forces. Countries who have an aging work force will find themselves with the opportunity of being able to easily replace jobs as required through automation.[43]

Lorenz et al. [43] recommends that for a company to thrive in industry 4.0, it needs to be able to retain and re-skill its current workers while at the same time acquiring necessary skill-sets that will help the company change towards a digital future.

2.2 Competitive Advantage

2.2.1 Defining competitive advantage

"Competitive advantage is obtained when an organisation develops or acquires a set of attributes (or executes actions) that allow it to outperform its competitors."[44] It can also be thought of as "the degree to which a firm has reduced costs, exploited opportunities, and neutralised threats." [45]

Researchers have found a number of different working definitions for competitive advantage within literature. The vast array of definitions led Sigalas et al. [46] to conduct research into developing a single comprehensive definition. Sigalas et al. [46] concluded that competitive advantage can be defined as "the above industry average manifested exploitation of market opportunities and neutralisation of competitive threats."

The above definition explains competitive advantage in a single sentence, but to further understand what it means to 'exploit market opportunities' and 'neutralise competitive threats', some of the existing frameworks and theoretical views must be examined.

2.2.2 Theoretical views for competitive advantage

There exists a number of different views of competitive advantage within current literature, with no clear consensus on which view is the best.[44] Two of the older and more dominant theories that exist within literature are the *Resource-Based View* (RBV) and the *Market-Based View* (MBV).[44] The Market-Based view holds to the position that it is the external factors and a firm's positioning in the market that predominantly affect its performance. [47, 48] A Resource-Based View proposes that a firm's internal processes and management of resources in an environment are what govern performance. [49, 50]

Market-Based View (MBV)
Arguably one of the most famous MBV theories is the 5 forces framework by Porter [51]. The framework is based off the Structure, Conduct, Performance framework developed by Bain [52] and is outlined in Figure 2.5. The purpose of the framework is to evaluate the strength of a firm by its position in a particular market. The 5 forces framework is also useful in evaluating a new position that a firm may want to move into to achieve sustainable competitive advantage.

Figure 2.5 shows the 5 forces that determine attractiveness and degree of competition within a market. The 5 forces can be explained as:[51]

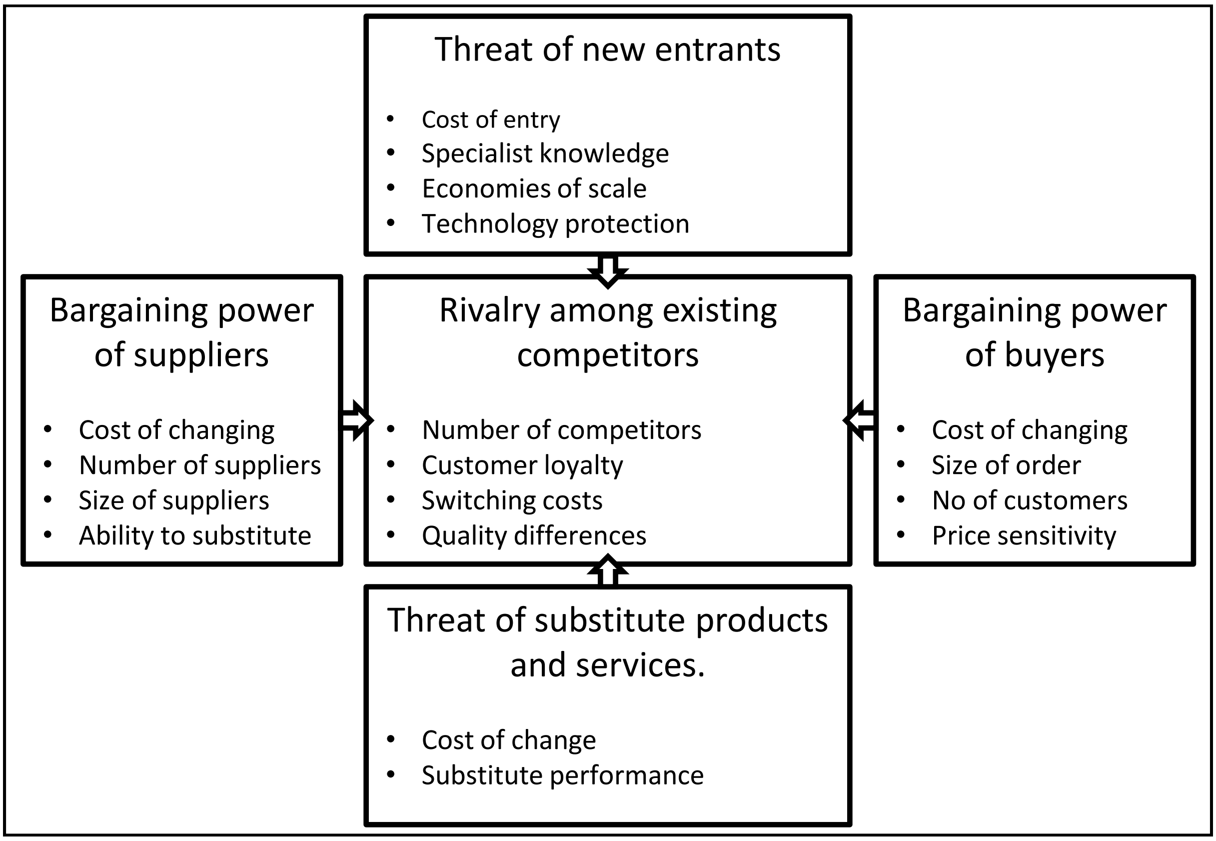

Figure 2.5: Porter's 5 forces [51]

1. *Competitor rivalry* - Competition due to existing firms in the market. The two significant drivers of competitive rivalry are the number of existing firms as well as their capabilities.

2. *Threat of entry* - As profits within an industry increase, it is expected that new entrants will try to enter the market to gain a share of the profits. What stops these new entrants is termed 'barriers to entry' and includes things such as the cost of entry, specialist knowledge and specific assets or technology that are difficult to obtain.

3. *Supplier power* - Suppliers have influence over firms within an industry. Factors such as the number of suppliers, the ease in which a firm can substitute a raw material and the cost of changing supplier, effect the degree or level of influence. Suppliers with significant influence are often in a position to increase prices and gain a larger share of the profits within an industry.[51]

4. *Buyer power* - Closely related to 'Supplier power', buyer power is influence a firm's customers have over it. The level of influence is related to factors such as the number of customers, the batch size (volume) and price sensitivity.

5. *Threat of substitute* - Industries that offer products or services that can be easily substituted by a product or service from another industry face a competitive threat. The

more available substitutes there are in the market, the more choice customers have. The degree or level to which substitution effects a firm is predominantly related to the cost a customer will incur for changing as well as the difference in quality of the substitute offering.[51]

Porter [51] published a book titled 'Competitive Advantage' (Porter [48]) in which he outlines a definition that is based off the 5 forces framework. According to Porter, the way to achieve competitive advantage is through creating either a cost advantage or a differentiation advantage. A cost advantage is achieved when a firm produces the same product or services as its rivals but at a lower cost. A differentiation advantage occurs when a firm produces a product or service that is perceived to be more valuable by customers.[48]

Resource-Based View (RBV)

From the early 1980's a paradigm shift took place from a focus on the external environment of a firm (MBV), to the internal environment (RBV). [53] The RBV became more popular as the development of capabilities and resources were investigated as primary sources of competitive advantage. Ramos-Rodriguez and Ruiz-Navarro [54] determined that research by Barney [55] as well as Wernerfelt [56] were the most influential in the development of the resource based theory.

Wernerfelt [56] highlights a balance that must be achieved under a RBV, between developing new resources and exploiting existing resources. Barney [55] argued that if all competing firms had exactly the same resources and capabilities, then there would be no difference in profit between the firms, because any of the firms could implement any strategy. It is only once the cost of resources and capabilities for implementing a certain strategy is taken into account, will one firm gain competitive advantage over another. In this way it is the firms internal environment that gives it an advantage over its competitors. One of they key underlying assumptions with the RBV is resources are distributed heterogeneously amongst competing firms.[55] Barney [55] also developed the VRIN framework, which looks at whether a resource is valuable (V), rare (R), costly to imitate (I) and non-substitutable (N). Resources that meet these criteria create sustained competitive advantage, as apposed to a short term competitive advantage.[55]. The VRIN framework was revised by Barney [57] and became the VRIO framework which posed the question, 'is the firm organised (O) to exploit these resources?'. VRIO resources can be explained by the following questions:[58]

- Valuable (V) - Does the resource aid the firm in exploiting a market opportunity or neutralising a competitive threat?
- Rare (R) - Is the resource scarce and only obtainable by a small number of firms?

- Costly to Imitate (I) - Will a firm incur significant cost to develop or obtain this resource?
- Organised (O) - Are the firm's internal processes setup to take advantage of this valuable, rare and costly to imitate resource?

Table 2.1 outlines the VRIO framework and was taken from Barney and Hesterly [58].

Table 2.1: VRIO Framework

Valuable?	Rare?	Costly to Imitate?	Organised Properly?	Competitive Implications
No			No	Disadvantage
Yes	No			Parity
Yes	Yes	No		Temporary Advantage
Yes	Yes	Yes	Yes	Sustained Advantage

Two special cases of the RBV are the *Knowledge-Based View* and a *Capability-Based View*. The following sections examine these two views in further detail. Although they are distinctly different, the views must be understood as sub-views of the RBV.

Knowledge-Based View

The Knowledge-Based View sees knowledge as the most important resource and separate to other resources.[59] Hamel and Prahalad [60] proposes that knowledge, know-how, intellectual assets and competencies are the main driver of performance in the information age. Zack [59] proposed three knowledge levels:

1. *Core Knowledge* - Allows a firm to operate in the market on a day-to-day basis and 'play the game'. All members within an industry have this knowledge but it does not allow a firm to differentiate itself from its competitors or ensure long term sustainability. The only advantage that core knowledge offers, is a barrier to new market entrants.
2. *Advanced Knowledge* - Allows a firm to remain viable and actually compete in the market place. Firms within an industry may have different scopes of advanced knowledge depending on their specific strategy or positioning within the market. Advanced knowledge allows a firm to differentiate itself to some degree, but rival firms with the same advanced knowledge may be able to position themselves similarly.
3. *Innovative Knowledge* - Allows a firm to lead its industry and all its competitors. It allows a firm to change the rules of the game and create longer terms of sustainability.

Zack [59] does highlight that knowledge is not static but rather dynamic. What starts off as innovative knowledge eventually becomes advanced and core knowledge. Figure 2.6 is replicated from Zack [59] and provides a 'snapshot' perspective of knowledge with a firm.

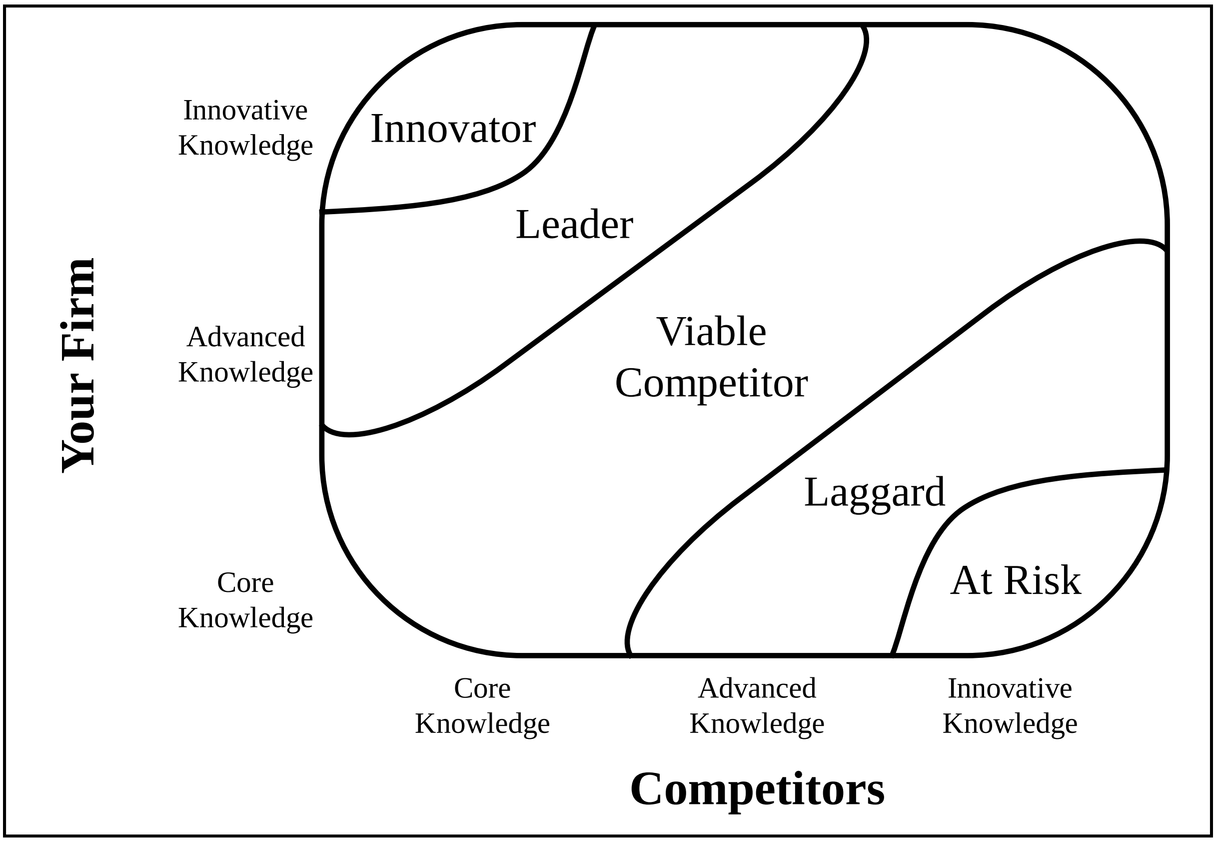

Figure 2.6: Strategic Knowledge Framework [59]

Capability-Based View

The Capability-Based View suggests that when a firm uses it's resources through distinct capabilities it is able to generate competitive advantage.[61] Resources themselves are not the source of sustained competitive advantage but rather the capabilities that govern the management of resources that lead to competitive advantage.[62] These capabilities can be a set of ordinary operational capabilities that help a firm create value.[63] Beyond a set of ordinary capabilities exits dynamic capabilities, which are defined by Teece, Pisano and Shuen [64] as "the firms ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments." Foss et al. [65] conducted empirical research on dynamic capabilities (DCs) and competitive advantage within South African SMEs. Foss et al. [65] found that "dynamic capabilities have significant impacts on competitive advantage, and that SMEs need to go beyond the level of acquiring resources and move to the level of transforming the resources to capabilities, in order to remain competitive in a changing environment." Foss et al. [65] used the 6 major DCs which can be understood as the following:

- *Sensing* - The capability a firm has to learn about its customers, market environment and competitors.[66] This capability allows a firm to sense and anticipate change in order to take action ahead of its competitors and thus create competitive advantage. [66, 67]

- *Absorptive* - The capability a firm has to use information it has gained, especially through the sensing capability, and use it to create value.[68] Absorptive capability is about recognising the value of, and using, external knowledge for the improvement of core business processes and strategies.[69]

- *Adaptive* - The capability "of a firm to respond to external changes ahead of competitors through reconfiguration of its internal resources and processes."[68]

- *Innovative* - Innovative capability is arguably one of the most important capabilities in a changing dynamic environment because innovation often leads to above normal profitability and returns.[70] Innovative capability refers to a firm's ability to adopt a new way. The new way can be focused around an internal or external process, a product, a service or even a strategy.[71]

- *Networking* - The capability that a firm has to use both internal and external networks to acquire resources. Networking capability is linked to the leveraging of relationships to create competitive advantage. [72]

- *Integrative* - The capability a firm has for bringing together resources and harmonising many other DCs towards value creation. Integrative capability is about using both internal and external resources in a way that creates sustained competitive advantage and is directly related to firm performance.[73]

MBV and RBV 'fit'

Maier and Remus [74] uses the term 'fit' to argue for the necessity between both internal (RBV) and external (MBV) perspectives. Central to this fit between internal and external is a knowledge management (KM). "Therefore, an organisation should organise its internal resources according to a resource-based strategy by managing knowledge based resources with the help of KM activities. Simultaneously, it should choose competitive business fields, customer groups, products and services according to a market-based strategy."[74] In order to achieve this, strategic knowledge assets are developed, which guide the design of business processes. A strategic knowledge asset is something that 'views core competencies in light of their application for products and services, that make a difference visible for the customers (external perspective) and helps to orient the development and management of core competencies (internal perspective)".[74]

Relational View

A relational view is founded as a critique to the RBV.[44] A RBV assumes that a firm's resources, that lead to its competitive advantage, are owned by it alone. The relational view argues that firms often share valuable resources through a network and thus it is a firm's relation within the network that leads to competitive advantage.[75] Dyer and Singh [75] talk about a 'subnormal profit' that is 'jointly generated in an exchange relationship that cannot be generated by either firm in isolation and can only be created through the joint idiosyncratic contributions of the specific alliance partners'. These 'subnormal' profits are achieved through the following four sources of competitive advantage according to Dyer and Singh [75]:

- Relation-specific assets
- Knowledge sharing routines
- Complementary resources and capabilities
- Effective governance

Transient View

A transient perspective of competitive advantage is concerned with the strategic life-cycle of a firm and was first proposed by Gunther McGrath [76]. All of the existing perspectives of competitive advantage were traditionally used for long-term strategic planning, where a firm would assume a degree of consistency within its internal and external environment, for making decisions. The transient perspective argues that opportunities for competitive advantage are now transient in light of the current business environment. Firms can no longer take such long-term perspectives if they are to achieve sustainable competitive advantage. Their strategy for gaining an advantage needs to be reviewed more frequently. A firm's ability to react in a timely manner towards opportunity is becoming an increasingly important factor in competitive advantage, regardless of whether and internal (RBV) or external (MBV) view is taken.[76]

As Wang [44] points out, all the strategic views around competitive advantage are concerned with the "actions" that a firm should be taking. For the purpose of this research, a single view of competitive advantage will not be held, rather any actions, under any view, that could potentially lead to a competitive advantage will be considered.

Figure 2.7 is a conceptual framework and shows the relationships between each of the competitive advantage views.

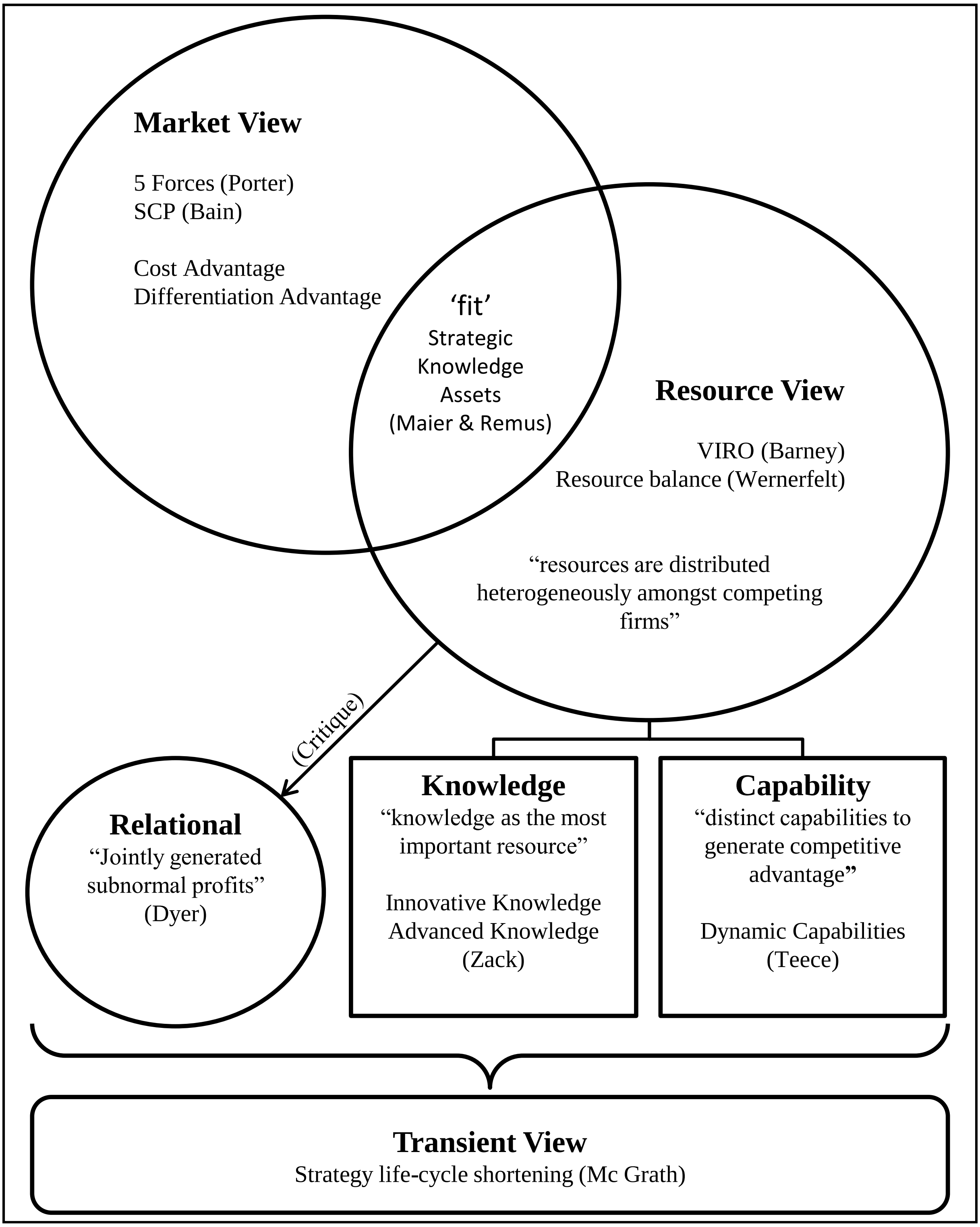

Figure 2.7: Conceptual framework for competitive advantage literature

2.3 Manufacturing in South Africa

The manufacturing sector in South Africa can be split into 10 sub-sectors. Figure 2.8 shows each sub-sector's monthly revenue contribution. It can be seen in Figure 2.8 that the four largest sub-sectors (Food and beverage, Steel and metal, Chemicals, and Transportation) account for 80% of total manufacturing revenue.

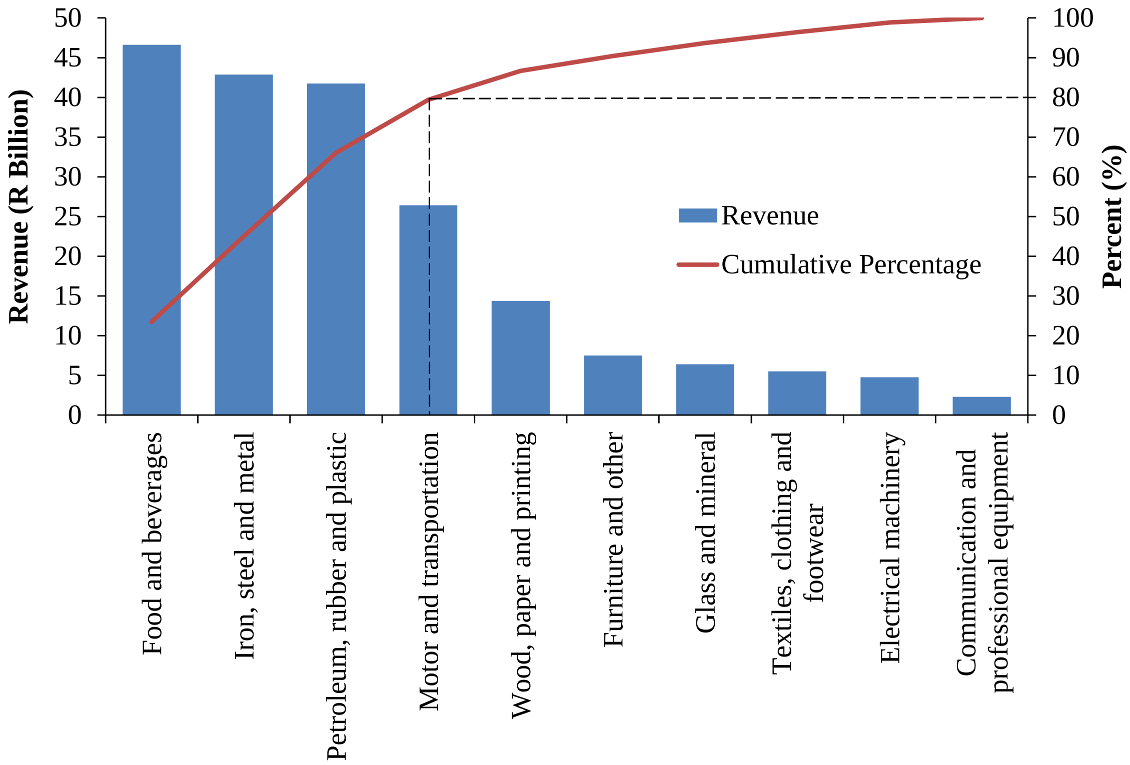

Figure 2.8: Monthly revenue contribution by sub-sector [77]

South Africa was historically an attractive manufacturing location due to its cheap electricity, relatively low labour costs, abundance of natural resources and sufficient transport and logistics capabilities. [78] In recent years the manufacturing sector has seen a decline in growth with the performance of the sector being described as 'lackluster'.[78] The following factors have contributed towards the decline in growth of the South African manufacturing sector:

- *Labour* - Pilay et al. [78] determined that manufacturing CEO's believe it is increased labour costs that are the main determinate of poor performance in the manufacturing sector with average wages increasing 5.8% year on year between 1998 and 2013. In conjunction to this increase, unit labour costs decreased in Europe over the same time period due to productivity gains making South Africa less attractive from a labour point of view.[78]

- *Remoteness* - South Africa is situated in a geographically remote location relative to major markets which means it loses out on the competitive advantage gained by location proximity. International customers are less likely to source products and services from South Africa due to the shipping distance which increases both cost and lead time. South Africa is however in a strong position to service the emerging African markets as they develop and grow. [78]

- *Energy* - Prior to 2008, South Africa's electricity was one of the cheapest in the world. Under investment in capacity during the early 2000's lead to a massive 78% increase in electricity tariffs between 2008 and 2011 as Eskom, South Africa's energy supplier, needed increased revenues to improve infrastructure and capacity. [79] As a result of the electricity price increase, manufactures found it increasingly difficult to operate. [78]

2.3.1 Industry 4.0 adoption in South Africa

In general, South Africa has very low levels of industry 4.0 adoption. Many of the smart technologies that accelerate industry 4.0 adoption are only being used at a foundation level. [80] The automotive and automation sub-sectors are leading in adoption by making use of advanced analytics, whereas other sectors who stand to benefit even more from advanced analytics are lagging.[80]

Two foundational technologies within industry 4.0 are robotics and 3D printing. Robotics is being used by manufacturers but predominantly only for automation (industry 3.0) with no usage at the smart or advanced stage yet (industry 4.0). [80] 3D printing has not been widely adopted even though manufacturers are aware of the high potential it offers. It is likely that their reluctance to adopt 3D printing is closely related to the 'The Innovators Dilemma'. The innovators dilemma is credited to Christenson [81] who showed how firms struggle to be both innovative and service a large customer base who are often not characterised as 'early adopters'. A product's perceived value over time follows an 'S'-curve, with the maximum increase in value per product iteration being achieved at the middle of the curve. To get to this stage however a significant investment is required. A firm with fast moving technology is constantly faced with the decision to either choose to design a whole new product (a new S-curve) or incrementally improve their existing product. Getting this decision wrong can lead to extreme failure. A famous case of the innovators dilemma is the failure of Kodak.[82] Disruptive technology (the digital camera) completely out performed Kodak's existing product (the film camera). By the time Kodak tried to switch over to the new technology it was too late and other companies were further along the S-curve and captured the market.[82] The innovators dilemma does not only apply to products but also to production processes. 3D printing may currently be too expensive in certain markets but as the technology improves and becomes cheaper, a point of infliction is reached where 3D printing out performs traditional manufacturing methods. Getting around the innovators dilemma is linked to competitive advantage and it is currently believed that building dynamic capabilities are the best way for a firm to ensure survival through periods of disruption.[83]

Other reasons for the low adoption in South Africa include the economic state of the country. With the economy struggling to achieve growth, manufacturers are focused on reducing costs and this leads them to spend less on innovation. Poor connectivity and cyber security are also contributors to the low level of adoption.[80]

2.4 Small and Medium Enterprises

2.4.1 Definition

SMEs in South Africa are classified by The Republic of South Africa [84], into 4 different size categories. These classifications are determined by the number of employees, annual turnover and gross asset value as seen in Table 2.2.

Table 2.2: Classification of SME size [84]

Size or class	**Number of employees [People]**	**Annual turnover [Million R]**	**Gross asset value * [Million R]**
Medium	200	40.00	15
Small	50	10.00	3.75
Very Small	20	4.00	1.50
Micro	5	0.15	0.10

*Excluding property assets

2.4.2 Challenges

It is generally believed that SMEs in South Africa operate in a challenging environment. This subsection outlines the challenges faced by SMEs. Caution must be taken in to assume that all these challenges apply to all SMEs, some of these challenges are location specific. [85]

- *Access to Finance* - New SMEs are less likely to obtain finance and SMEs in locations outside economic hubs, such as those found in Johannesburg and Cape Town, are even less likely to obtain finance.[86]

- *Labour Laws* - South African labour laws are designed to provide a high degree of protection for employees. This makes scaling a business smaller during times of downturn in revenue very difficult. With many manufacturing businesses in South Africa being extremely labour intensive, wages form a high proportion of operating costs.[87] Without being able to reduce these costs inline with demand, small businesses struggle to remain profitable during tough economic times.[88] Labour laws are a significant challenge for SMEs in South Africa. [89] SMEs report struggling to afford both skilled and unskilled workers. [4]

- *Crime* - In order to protect themselves from the risks of crime, small businesses are having to spend significant amounts of capital on security measures. [89] This impacts their profitability and negatively effects investor sentiment towards South African businesses. [88]

- *Resources* - Many SMEs struggle to get access to the necessary infrastructure and services required for their businesses at affordable prices. [88] Infrastructure includes land, buildings, communications, transport and utilities.[4] Access to professional services such as commerce, banking, accounting and legal is also a challenge for some SMEs.[4] Resource challenges are specific to location, for example, SMEs in Gauteng struggle to find affordable physical space but have easier access to commercial services such as those offered by accountants and lawyers. SMEs in a rural setting access land much easier but then struggle to obtain essential services.

- *Penetration into markets* - Many SMEs struggle to gain access to markets due to their location. Rural businesses are more prone to facing this challenge. [90] Naudé et al. [91] suggests that the forming of clusters is a way of overcoming this challenge, but that new business may be negatively affected by a cluster due to their tendency to increase competition.

- *Development* - SMEs struggle to take ideas and develop them into viable growth opportunities. Research and development is lacking in many South African SMEs and hinders their capability to be innovative.[4] Innovation in small businesses is also hindered by their ability to collaborate with larger businesses. By collaborating with larger businesses, technology diffuses into their own operations much quicker.[92] Singer, Amorós and Moska [88] suggests that innovation should be prompted in small business through government initiatives and involvement with the aim of attracting knowledge and skills from other developed countries.

- *Policy* - Both Singer, Amorós and Moska [88] and Schwab [93] found that bureaucracy within government is major hindrance to SMEs and business in general. Extensive red-tape exists in starting and managing a small business, with operating requirements such as licenses and permits taking a significant amount of time to be approved and produced by government systems. These requirements and the time it takes to meet them translates to significant cost and discourages small business growth.[4]

- *Unskilled Labour* - South Africa as a country struggles with education. Small business definitely notice the effects of this problem, with the challenge of finding skilled labour that is sufficiently trained for businesses requirements. [4] With challenges already faced from a financial point of view, new small business do not have the resources to provide extensive internal training.

2.4.3 Growth and Competitive Advantage

Wiklund et al. [94] propose an integrative growth model for SMEs that accounts for both external and internal factors. The model is outlined in Figure 2.9 which suggests that the way the 4 factors of entrepreneurial activity, resources, environment and owner attitude are combined together in a strategic manner result in sustained competitive advantage. There is evidence that the first factor, entrepreneurial activity, is strongly linked to sustained growth. Companies who have a culture of entrepreneurship are more likely to achieve sustained growth.[95] The factors of 'Resources' and 'Environment', refer to the internal and external factors of a business, much like the RBV and MBV theories of competitive advantage. There must be a correct match between external and internal for growth to occur. [96] Owners Attitude refers to the motives for the starting of the business which often changes over time.[94] These four factors must be strategically combined for a business to maintain a competitive advantage.

2.4.4 Potential impact of Industry 4.0

It is currently difficult to be certain about the effects industry 4.0 will have for SMEs in South Africa. There are the very real threats such as increased competition from the global market, loss of unskilled jobs and the increase in financial commitment to remain competitive. The outlook is not entirely negative however, Kholopane [97] found that technology has made a tremendously positive impact for SMEs. It enabled personal utilisation efficiency to increase through the elimination of repetitive tasks and opened up a number of job opportunities that required specialist skills. It also reduced costs and energy consumption, increased output and economies of scale and increased product favour amongst customers.[97]

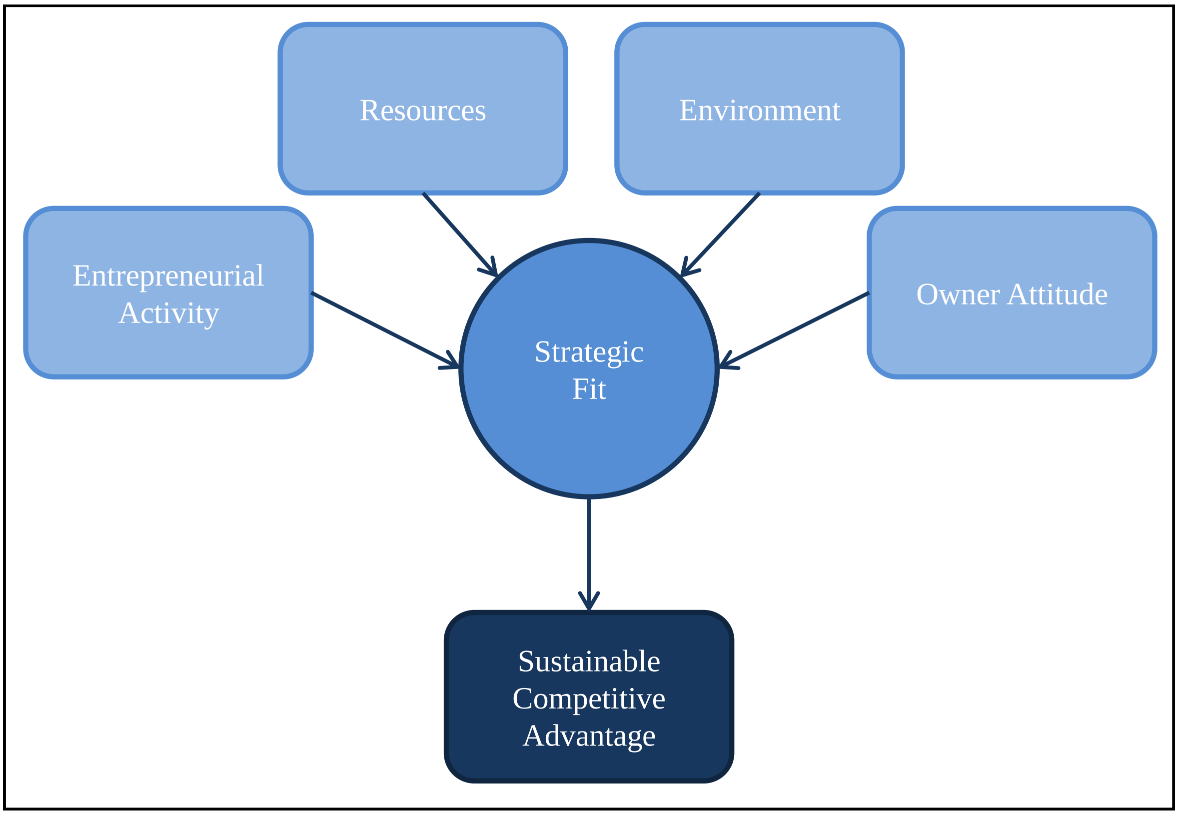

Figure 2.9: SME Growth Model [94]

Kumalo and Poll [98] looked at the potential cloud computing has to alleviate many challenges that SMEs currently face. Their study found that cloud computing could help SMEs with 6 major challenges in their current contexts and is good evidence that industry 4.0 will bring opportunities for small business. Their results are outlined in Table 2.3

2.4.5 Adoption of Industry 4.0 by SMEs

The International Trade Centre [99] released a competitiveness outlook for SMEs in 50 different countries. The SMEs were examined from both an internal and external point of view. Internally, SMEs were scored on their ability to connect, compete and change. An SMEs ability to 'connect' was determined by examining its website and the degree to which the company uses e-mails for communication. An SMEs ability to 'compete' was determined by the presence of an international quality certificate, capacity utilisation, managerial experience and the use of banking. Lastly an SMEs ability to 'change' was determined by the the presence of audited financial statements, the degree of investment financed by banks, the presence of a formal training program and whether or not the SME makes use of foreign technology licenses. The competitiveness profile for South African SMEs appears in Figure 2.10

Table 2.3: Cloud computing solutions for SMEs [98]

SME Challenge	**Cloud Solution**
Red Tape	**SaaS** Tax compliance VAT, PAYE, UIF etc
Labour Legisltaion	**SaaS** Acts: Labour Relations Employment Equity, Skills Development,etc
Lack of Skills	**PaaS** Management skill development BPM automation
Lack of Innovation	**PaaS** No hardware on sight Pay-per-use computing
Impact of Crime	**IaaS** Improved data security Mobile technology Site visible for owner
Lack of Funds	**SaaS** Access to accounting software Online funding opportunities

*SaaS - Software as a service, PaaS - Platform as a service and shows that there is a strong positive correlation between SME size and competitive performance. Figure 2.10 also shows that it is only large SMEs that score above 70% in their ability to connect. Both small and medium size SMEs score below 50%.

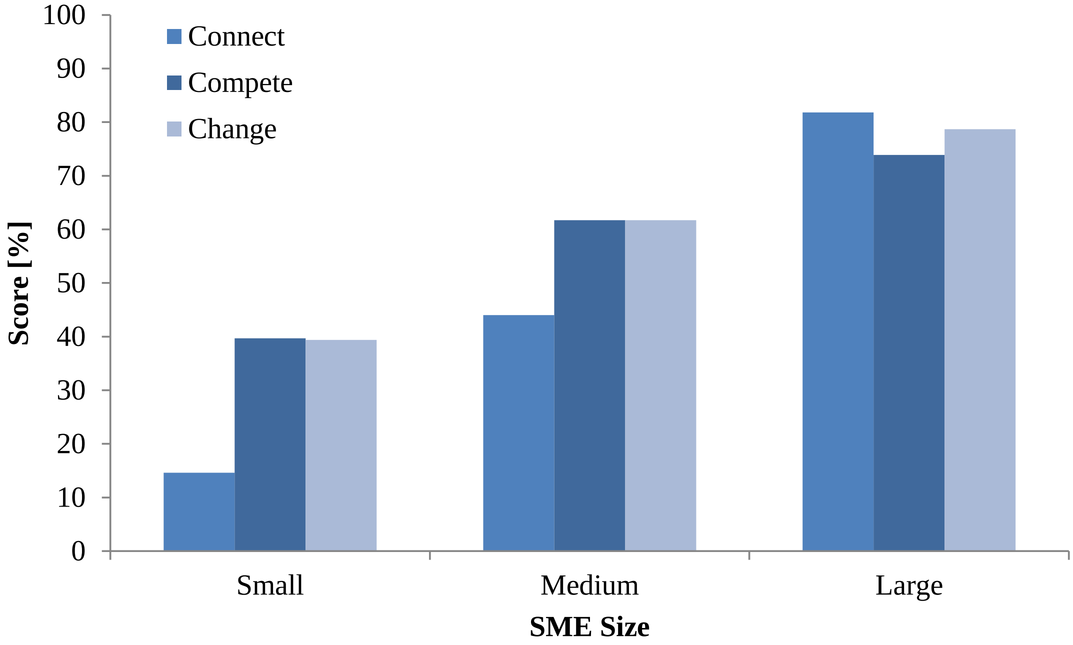

Figure 2.10: SME competitiveness outlook profile for South Africa [99]

Although South African SMEs are presented with a number of barriers to adoption, many international SMEs face similar challenges, even SMEs in countries that are considered industry 4.0 leaders such as Germany. A study done by Andulkar et al. [100] examined the challenges facing 20 SMEs in Germany in relation to the adoption of industry 4.0. Their challenges related to enterprise resource planning, automation and factory planning.[100] The study also used 5 SMEs as case studies, examining readiness and feasibility of adopting industry 4.0 concepts. Most of the SMEs were still struggling with planning, organisation and automation, making the implementation of industry 4.0 with their current operations, infeasible. Adoption of industry 4.0 would have required a considerable amount of investment which was not viable at the time of the study.[100]

A similar situation is found with SMEs within the BRICS association. The focus of industry 4.0 adoption in these countries is on skills development and the preparation of the work force for industry 4.0.[101] There is little evidence of fully integrated SMEs within the BRICS association. South Africa has begun to investigate the adoption of industry 4.0 with the BRICS Skills Development Working Group of South Africa investigating initiatives that can be under taken to promote an enabling environment. An enabling environment would be one in which there is funding to access technology, where new technology is adopted and where relevant skills are developed.[102]

2.5 Summary

The following summary presents the key information from the literature review on industry 4.0, manufacturing and SMEs.

- The concept of Industry 4.0 can be understood by its 4 main design principals
  - Interconnection - the connection of people, machines and sensors providing the means for Industry 4.0
  - Information Transparency - Mainly driven by the increased number of interconnected objects and people, information transparency relates to the sharing of information in new ways at instantaneous speeds enabled by the merge between the physical and virtual world.
  - Decentralised decision making - Once principals 1 and 2 are in place, the decision making process can be automated to a higher degree and executed independently.
  - Technical assistance - the interaction between humans and the digital environment. The complexity of work will increase and people will need to adapt to becoming flexible problem solvers who are able to make strategic decisions.
- Manufacturing in South Africa has recently shown a decline in growth due to the following contributing factors:
  - Increase in labour costs.
  - South Africa is located in a geographically remote location resulting in the loss of competitive advantage through location proximity.
  - An increasing electricity price making it difficult for manufacturers to operate profitably.
- SMEs in South Africa operate within a range of 5 - 200 employees, 0.15 - 40 Million Rand turnover and 0.10 - 15 Million Rands Gross asset value. These enterprises operate in extremely challenging environments. The challenges include:
- Access to finance - New SMEs are less likely to obtain finance.
- Labour laws - South African labour laws restrict businesses from scaling smaller in financially challenging times.

- Crime - Significant amounts of capital needs to be spent on security measures affecting the profitability of the company.
- Resources - Struggle to get access to the necessary infrastructure and services required at affordable prices.
- Penetration into market - Struggle to gain access to markets due to location.
- Developments - Lack of research and development which hinders their capability to be innovative.
- Policy - Bureaucracy within government is a major hindrance to SMEs due to the time it takes to meet all the requirements and the significant costs this translates into.
- Unskilled labour - South Africa struggles with education and it makes it challenging for small businesses to find skilled labour, sufficiently trained for business requirements.

Chapter 3 Research Design and Methodology

3.1 Research Design

3.1.1 Research Classification

The critical research question for this study is relatively forward looking from a time perspective. The specific research area, SMEs in the context of Industry 4.0, is unexplored with little existing work on the topic. It is for these reasons that the research is exploratory in nature. Exploratory research is primarily used when there is little known about the topic under study. It aims to better define an area of study and provide initial findings that can be further explored in more detail.[103] Exploratory research can normally also be classified as inductive research because it moves from the general towards the specific.[104] An inductive research approach was used for this study with data being qualitative in nature. Qualitative data is suited towards an exploratory study because it is rich in information and can be used to cover a large scope of research.[103]

3.1.2 Data Collection

A semi-structured approach was used towards data collection. Since the study is exploratory in nature, a very rigid and structured approach potentially limits the degree to which the research area can be explored. Flexibility is seen as an asset for an exploratory study.[103] It was therefore decided that the data collection process would not be predetermined. Instead a few standard data collection approaches would be tested for applicability and suitability. 3 different approaches, namely case study analysis, semi-structured interviews and literature analysis were examined.

Case Study

Case study is a "useful design when exploring an area where little is known or where you want to have a holistic understanding of the situation, phenomenon, episode, site, group or community."[103] Initially it was believed that examining one or two South African SMEs as case studies would provide the best way to reach the research objective. The difficulties in this approach were that there were no SME manufacturers that exhibited an industry 4.0 operations environment. By focusing on a single company, many of the fundamentals about industry 4.0 may be misunderstood since one of the design fundamentals of industry 4.0 is connection to an ecosystem. A single company cannot be in an industry 4.0 state unless it exists as part of a network with other companies who are also digitised and share information in order to create competitive advantage.[9] Industry 4.0 developments are being led by international countries with no South African cases exhibiting a mature industry 4.0 state.[80] For these reasons, case study research was not used. Once adoption of industry 4.0 in South Africa is more significant, it may prove to be more effective.

Semi-structured Interviews

Interviews can be a good way of collecting rich data on a subject matter.[104] Interviews can range from structured to unstructured, be telephonic or face-to-face and be with individuals or in group settings.[104] Structured interviews involve predetermined questions being read to the participant word for word. This approach reduces bias and ensures that the interview is controlled. Responses can be compared in more detail because questions were posed exactly the same to each participant. The drawback to this approach in exploratory research is that the interviewer is restricted from leading the interview in any way and moving towards conversations that offer broader insight. Unstructured interviews do however allow for this. Due to their nature and increased flexibility the researcher is able to lead the discussion into areas where he/she believe useful information may be uncovered. The research normally brings up discussion points and allows the research participant to lead the interview. This type of interview covers a broad range of responses but can sometimes be at risk of not answering the actual research question. It was therefore believed that using semi-structured interviews would be the most useful due to their balance between participant freedom and interviewer control. Semi structured interviews involve a standard set of questions being posed to a participant but additional probing questions can be asked throughout the interview.[103, 104]

Through investigation into this method it became clear that there existed a very broad range of opinion on industry 4.0 with not many true subject matter experts. It was determined that companies within South Africa are in the initial stages of investigation on the potential of industry 4.0.[80] For many companies, adopting an industry 4.0 state right now would be too expensive.[101] Once some of the barriers to entry are removed such as the high cost of technology and the low levels of infrastructure, companies may begin to focus their research and knowledge on it.[101] This would lead to more subject matter experts existing in South Africa. At the moment internal knowledge of industry 4.0 is at a surface level and semi-structured interviews would be useful for understanding the general consensus on industry 4.0 but not how it can be used for competitive advantage. Through informal discussions with potential subject matter experts, it was determined that most of their knowledge was sourced through reading literature and not necessarily through experience in the research topic. It was therefore decided that collecting data directly from literature may improve the accuracy of the research and reduce potential bias by gathering information directly from the source.

Literature

It was determined that the most relevant and current information on the subject matter is being produced through academic papers and consulting reports. Knowledge on industry 4.0 is growing exponentially. Evidence of this is seen through the literature analysis done by Liao et al. [105] on industry 4.0. Figure 3.1 shows the number of academic publications, and conferences held, on industry 4.0 per year.

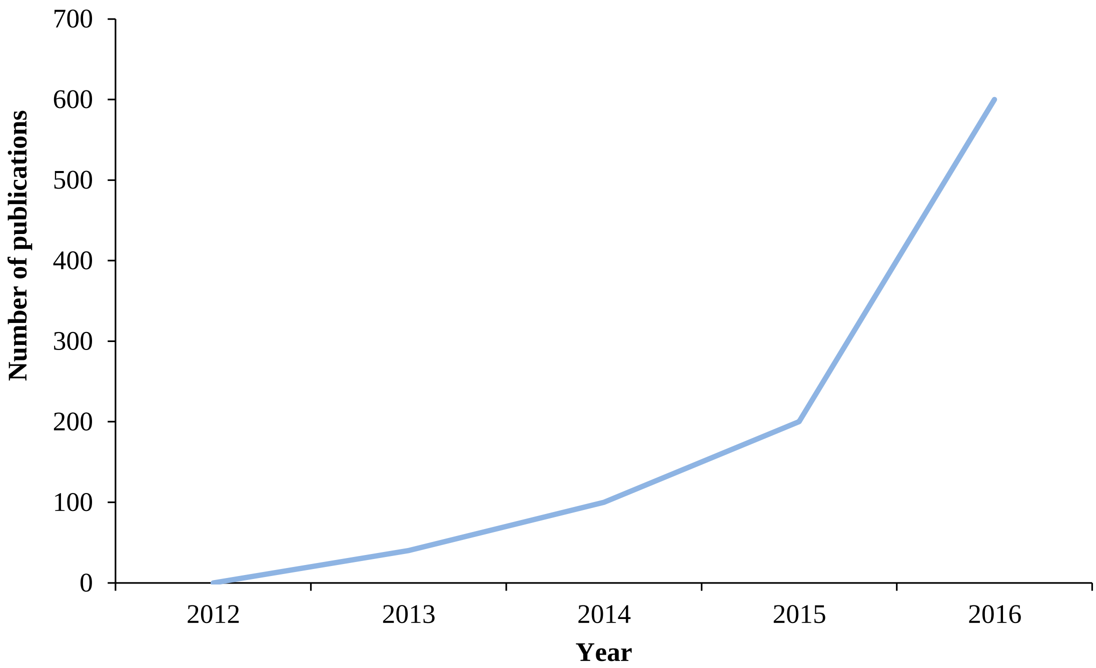

Figure 3.1: Publications and conferences on Industry 4.0 [105]

Unlike the first two data collection methods that are considered primary sources of information, literature is classified as secondary.[103] Secondary research has the potential for introducing bias. How this was minimised through research design is discussed in the proceeding methodology section.

Data Analysis

The data was analysed using a thematic content analysis. Thematic analysis is "a method for identifying, analysing, and reporting patterns (themes) within data.[106] There is no single agreed upon method on how it should be done. Rather it is used by researchers as they find necessary to their research.[106] This method of data processing has been criticised for reliability due to it being based on the understanding and interpretations of the researcher.[107] It may also leave out nuanced data and its flexibility can make it difficult to know which single aspects to focus on.[106, 107] Despite these criticisms, thematic analysis was found to be the method of data analysis due to the following reasons; it is well suited to large sets of data, the interpretation of themes is supported by data and it allows for categories to be emergent from the data set.[107, 108]

Reliability and Validity

Both reliability and validity do not hold consistent meaning across qualitative research, with meanings being attributed by the researcher/s depending on the study. [109] While reliability and validity are seen as separate terms in quantitative research, they are largely viewed as the same thing in qualitative research and are synonymous with terms such as credibility, transferability, and trustworthiness.[109]

The term 'verification' in qualitative research, refers to the mechanisms used during the research process to ensure reliability and validity.[110] These mechanisms should be included in every step of the research process to ensure that errors are identified and corrected before they are built into the research.[111] The following verification strategies were used in the research process to ensure reliability and validity during the research process.

- *Methodological Coherence* - The purpose of methodological coherence is to maintain congruence between the critical research question and the components of the research method.[110] It is the matching of the method, data and analytical procedure with the research question. It often requires that the research method proceeds in a non-linear manner so that all these components can be fit together.

- *Appropriate Sample* - The correct and appropriate sample should be used to ensure the best knowledge on the research topic is found.[110] Appropriate sampling also leads to effective and efficient data saturation. Data saturation is evidence that sufficient data has been captured and that all aspects and phenomenon have been obtained.[110] Data saturation leads to data replication in categories of knowledge. Data replication verifies and ensures comprehension and completeness has been achieved.[110]

- *Concurrent data collection and analysis* - By collecting data and analysing data at the same time, a mutual interaction is made between what the researcher knows and what the research needs to know. This creates reliability and validity because it closes the gap between known and unknown. Knowledge that has already be gained is used to collect and analyse knowledge that is not yet known. This iterative approach leads to a verified research process, contrasted against a research approach where all planning is done upfront with less knowledge and understanding of the data and knowledge space.[110]

The specific methodology followed in this research study and the reasoning behind it is outlined in the methodology section.

3.2 Methodology

The methodology section details the processes that were followed by the researcher in collecting and analysing the data. Justification for each process is discussed alongside the steps followed. An exhaustive amount of detail has been provided in this section to ensure that the reliability and validity of the research is maintained.

The research methodology made use of a systematic review process to ensure that a structured approach is taken to the research. This methodology develops its results from information within already published literature.[112] The systematic review process allows for a comprehensive evaluation of selected literature to be produced.[112] This comprehensive evaluation is focused on addressing a particular research question. The selection process for literature, based on a systematic method, reduces error and bias.[112]

The systematic literature review process addresses the topics of reliability and validity through three key features. The key features include:

- The systematic rules-driven search process requires the selection criteria being applied to be explicitly stated.[112] This assists in minimizing the bias within the selection of published material.[112] The search criteria made use of in the research study is detailed in step 1.

- Clear and transparent inclusion and exclusion criteria should also be detailed and applied to all the various selected material. This assists in replicating the review process.[112] The inclusion and exclusion criteria applied in this research study is also incorporated in step 1.

- The quality of the selected papers should be evaluated and detailed.[112] To effectively assess these reports the depth of understanding of each study is extremely important.[112] This quality check assists in reaching valid conclusions and should be done before all the available data is summarised.[112] The quality of the selected material was evaluated by making use of two criteria. The first one being the number of subject matter experts who provided input for the specific study (the larger the number of subject matter experts the better the quality of the report). The second criteria involved a comparative verification analysis of the various selected material (the content of each report was compared and assessed for similarities and extreme differences to identify the quality of the report). Each report was also read through thoroughly to ensure that there was complete understanding of the material in its entirety.

The following steps outline the research process followed.

Step 1 - Literature Selection

The first step involved finding literary texts. A distinction is made between types of texts. Braun and Clarke [106] defines 'data corpus' to refer to all data collected for a particular research study, while 'data set' refers to all the data used for analysis. For further explanation, data corpus (all data collected) will be referred to as *potential* data, since all data collected had the potential for being used in the analysis. Data that was used will be referred to as *actual* data, or in other words data that was actually analysed.

Potential data was found in one of two ways, by online search or through what some may call "snowball sampling". The online search used a number of keywords, these keywords are presented in Table 3.1. The databases searched include E.I. Compendex, Inspec, NTIS(National Technical Information Services) and Scopus. Along with these databases, Google Scholar was used to conduct literature searches for industry related reports and white papers. The abstract would first be reviewed and an initial judgment of relevance would be made, this was done to reduce the total time needed and allowed for more potential sources to be reviewed. If, by reading the abstract, the literature showed relevance, the entire study was read and then grouped as a potential text or not, depending on the content in the text. In assessing the applicability and relevance of the literature, it was evaluated against the simple question "Does the text address the critical research question either in part or full?". This method is highlighted as one of two main ways for selecting data by Braun and Clarke [106]. If the answer to this question was 'yes' then the text was deemed a potentially useful text and grouped with the other texts that were also deemed relevant.

The second method of finding text was through snowball sampling. Snowball sampling is the discovery of new data sources, using an existing data source.[113] It can be either forward

Table 3.1: Literature search keywords

Industry 4.0	SME	Industrial
Industrie 4.0	Small Business	Revolution
Digitisation	Competitive	Smart
Manufacturing	Advantage	Factory
Manufacture	South Africa	Future

or backward. Backward snowball sampling is the use of the reference list to identify new literature to use. Similarly forward snowball sampling is finding new data sources based on citations being used. In other words looking for papers that cite the existing paper.[113] Snowball sampling has a number of advantages, the main one being that it helps a researcher to find new data that is relevant and inline with the current research topic. It also allows for data to be found that may fall outside of search terms.[113] For this reason it was used in conjunction with an online search. It also requires an initial sample to be snowballed from and cannot start without a reference point.[113] The online search therefore was a good means to generating one or two potential samples that could then be snowballed from. Precaution must be taken when using snowball sampling that the data set does not become dominated by research that supports the same view, introducing a biased perspective.[113] This was done by a deliberate effort to include data samples that included a range of views. The combination of snowball and search generated data also helped to diversify the data set.

Texts found through snowball sampling would be judged for applicability in the same way the search generated texts were. Applicability would be tested once after reading the abstract and again after reading the entire text. It is important to note that the literature section process was done iteratively and not completed in full before analysis. The reason for this was to ensure a level of flexibility in the research approach ensuring that a truly exploratory view of the subject matter was achieved. This iterative approach is explained in more detail in step 4.

In order to move from a group of potential literature sources to obtaining the texts that would be used as research data two criteria were used. These criteria were used to extract the best possible sample first for analysis out of the pool of potential samples. Each criterion is outlined below:

1. *Target Audience* - The literature should be written for business leaders and managers as a primary target audience. This criterion was put in place so that the data analysed would remain relevant to the study and achieve the research objectives. Literature that was more theoretical in nature may have produced results that weren't practically relevant to an SME owner/manager.

2. *Scope* - The second criterion examined the range of topic covered by the literature. Broader literature included or consider many aspects of industry 4.0 providing a more through, holistic outlook on the subject matter. This criterion was specifically chosen due to the research being exploratory and needing a range of input. Literature that drew on a range of expert opinion from multiple countries and even across different industry sectors was favoured.

Step 2 - Familiarisation and quote extraction

Once a text was chosen it would then be read through for the second and third time. This was to ensure familiarisation with the data set, an important step in thematic analysis which ensures deeper understanding by the researcher and improves the validity of the analysis.[106] After the third reading of the text, it was read a fourth time but during this reading relevant quotes were extracted. Using verbatim quotes was a way of organising the data for further analysis and helped to separate relevant parts of literature from irrelevant parts. In order to separate relevant and irrelevant parts of data, without introducing bias by the researcher, quotations were extracted using two conditions. If either condition was true, then the quote was extracted. These conditions were employed by asking two questions that are explained below:

1. **Condition 1** - "Is change mentioned that refers or relates to competitive advantage as seen under any theoretical view of competitive advantage view?" This question was used to filter for parts of the text that spoke to competitive advantage through change. For example, literature might say "Factories of the future will be focused around human-robot collaboration, which will enable greater overall efficiency." The text speaks to a *change* in factories from classical operations to operations that see collaboration between humans and robots. The change is seen as a means to gaining better efficiency and is thus motivated by competitive advantage. The change enables a company to produce more with the same input and thus be more competitive. In this way by looking for instances of change, data relating to competitive advantage could be extracted.

2. **Condition 2** - "Is a suggestion or instruction given that relates to competitive advantage as seen under any of the theoretical views of competitive advantage?" The second question used to filter for competitive advantage used instruction and suggestion as an indicator for relevant information. For example, literature might say "Companies must focus on automating decision making processes." It can be then be questioned 'why' are companies being given this instruction. In its context, literature is suggesting that automating decisions will lead to a faster, more agile company. This relates to competitive advantage under of views such as the dynamic capabilities view and the transient

view. In this way by using suggestions or instructions as indicators, information relating to competitive advantage could be identified and extracted.

Both questions or conditions end in the phrase "as seen under any of the theoretical views of competitive advantage." This phrase is an important part of both conditions because it keeps the researcher focused on competitive advantage that has been proven or is generally accepted in academia. Without this emphasis, bias may be introduced with any thought or idea of improvement in the researchers mind being accepted as legitimate competitive advantage. Quotes selected under either condition 1 or two were placed in an excel spreadsheet, which would help with the sorting and organising of the data at a later stage. An example of the quotes that were selected from each of the five data samples appear in Table 4.1, in chapter 4.

Step 3 - Theme generation and quote classification
All the quotes extracted in step 2 were then read through twice to reinforce familiarisation and understanding as before.[106] They were then numbered in an excel spreadsheet as seen in Figure 4.1 in chapter 4. On the third reading of the quotes emergent themes were written down in the columns. If a specific theme existed in the quote an 'x' was put in the block where quote (row) and theme (column) intersected. Ryan and Bernard [114] suggests a number of ways to identify themes. The predominate methods used were *repetition* as well as *similarities and differences*. Some content analysis methods suggest that the length of data should remain the same and each piece of information categorised to a single theme. This was initially attempted but proved too restrictive. The length of each quote ranged from a partial sentence, to in some cases three. This was done in order to capture a greater range of information. Some quotes had their true meaning become clear after two or three sentences and would lose their original meaning had a shorter quote been used. Some quotes could also not be forced into a single theme but related to a number of different themes.

Step 4 - Iteration
Steps 1 to 3 were iterated until until information saturation was reached. Information saturation is a way of determining sample size and was used in this case because the research was exploratory in nature.[115] The total number of occurrences of words or themes was not as important as getting a broad range of representative data on the research area. Once the discovery of new themes stopped and data was continuously being categorised into existing themes (information saturation) the data set was deemed large enough.

Figure 3.2 summarises research methodology steps 1-4.

Step 5 - Frequency and co-occurrence analysis
The previous steps in the methodology served the purpose of selecting, extracting and categorising the data. Steps 5 and 6 are focused towards refinement and re-categorisation.

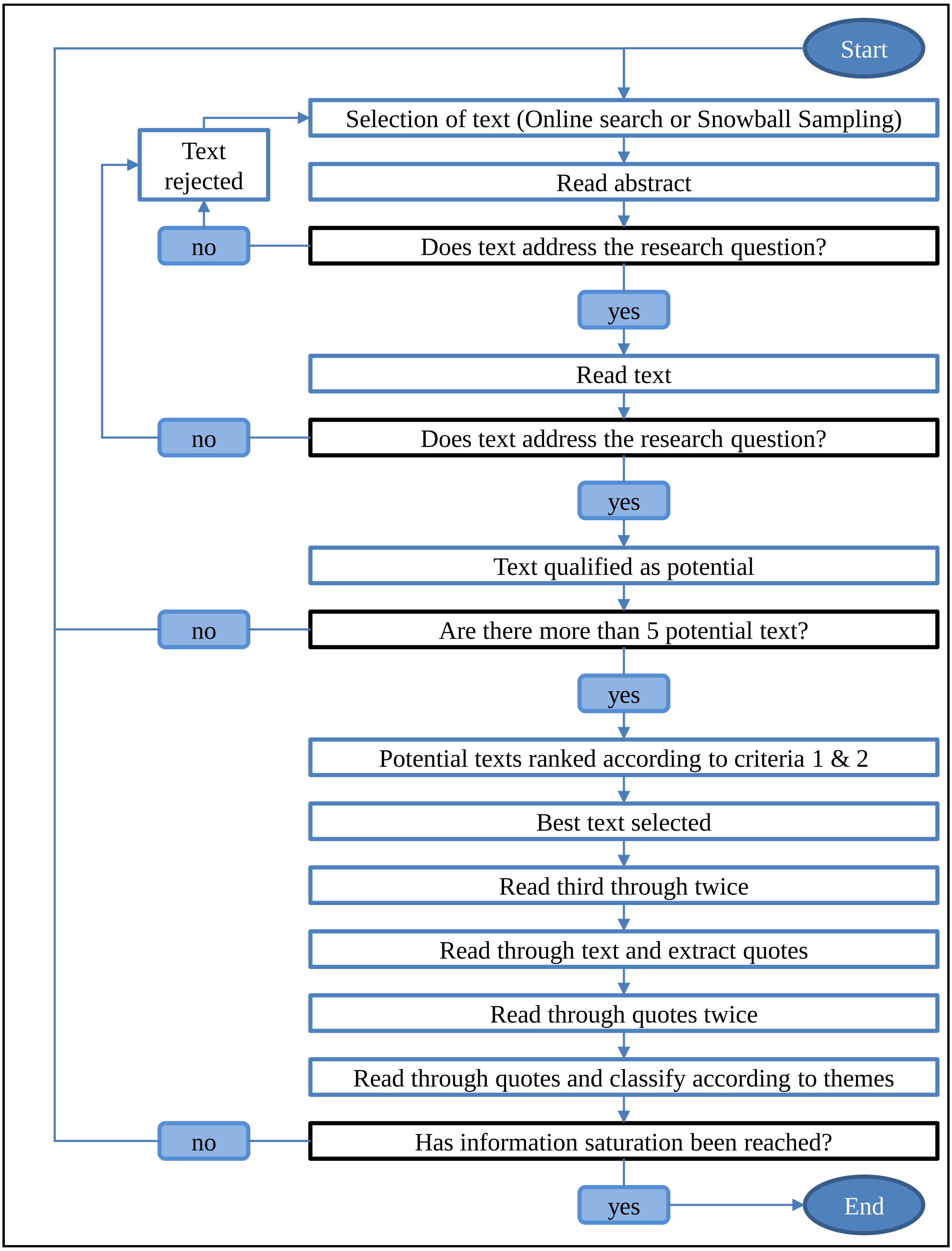

Figure 3.2: Methodology steps 1 to 4

Frequency analysis, whereby the total occurrence of each theme is counted, is useful for understanding which themes were the most popular.[108] This information along with a co-occurrence analysis made reducing and refining the number of themes easier. By using a quantitative approach it also helped remove any researcher bias.[108]

In order to count each theme's total number of occurrences the excel spread sheet from step 3 was used. Each theme was listed in its own column and the "COUNTA" function was used to count the number of 'x's' for each theme. The COUNTA function technically counts the number of non-empty cells in a range. The themes were then order by frequency as seen in Figure 4.2 in chapter 4. The result from the frequency analysis is seen in Table 4.2.

Co-occurrence analysis is a method for identifying themes. [114] By understanding which themes generally occurred together it is easier to determine if two themes may be grouped together. A VBA macro was coded in excel that would quickly count how many times one theme occurred in relation to the other and then highlighted instances where there was more than a 50% co-occurrence. The result can be seen in Figure 4.2 in chapter 4. The VBA code used appears in Figure A.4.

Step 6 - Final Theme Selection

By using the frequency analysis and co-occurrence analysis in step 5, themes were reviewed and categorised into 8 major themes. These 8 themes would serve as the final organisation of data to be used for extraction of results. Although the number of themes a thematic analysis produces may vary, each theme should have sufficient data to be considered completed.[106] Each theme was revised for completeness and in some instances the name of theme was changed to be more inclusive of sub categories. Initial themes with low frequency counts and high co-occurrences were generally considered a category of a broader theme and classified as such.

Step 7 - Interpretation

Each of the 8 major themes were analysed by putting all their relevant quotes together on a single page. They were then read through 3 to 4 times until such point as their collective latent meaning could be established. The main ideas relating to competitive advantage and manufacturing SMEs were recorded in a bulleted list. This gave the researcher a way of refining and condensing meaning in a concise manner that would then form the basis of the results. Each themes list has been reproduced in Table A.6 in Appendix A.

Step 8 - Presentation of results

The information from each theme in Table A.6 was then compiled as infographics to form the final presentation of results. The use of infographics, sometimes known as information collages, is well suited to presenting qualitative research. Their formation provides both the researcher and the research audience a tacit way of understanding information that is presented.[116] In order to keep the infographics precise, only the 'crucial' pieces of information were presented. If additional explanation or elaboration was needed, this was put into the explanation that accompanies each infographic. The final set of infographics are presented in chapter 4.

Chapter 4 Analysis & Results

4.1 Analysis

The following section presents the data analysis process outlined and explained in chapter 3. The section focuses on the results of each step and presents the final infographics that display the results of the research.

Table 4.1 shows an example of the selected quotes from the first literature report analysed. The quotes are from KPMG [117]. The selected quotes from the other reports can be found in Appendix A.

Table 4.1: Project configuration commands and arguments

Source: The Factory of the Future - KPMG [117]	
Page	**Quote on Industry 4.0 related change**
10	More permeable boundaries between sectors, technologies and companies.
10	All the relevant parameters are thus available in real-time, which means maximum transparency and an improved decision-making basis.
10	How quickly the networking proceeds depends primarily on the technological innovation cycles (Moore's Law, Glider's Law), the acceptance of technology and the willingness to invest.
15	Location advantage through technology clusters
17	The value added processes in the "factory of the future" are transparent and flexible...so that free capacity can be identified, accurately measured and consistently used.

18	Displays, user interfaces and visualisation tools ensure that operators have constant and easy access to the relevant data
18	For companies in the manufacturing sector, the transition from Industry 3.0 to Industry 4.0 represents a change of more than one digit. It is a paradigm shift that means comprehensive change.
Page	**Quote on "how" to change towards Industry 4.0**
10	Identify existing or potential points of contact between their value chain and that of others and develop these into efficient, standardised interfaces.
13	Not everyone needs all the disciplines or has to master all the abilities. Instead the task is to identify and develop or acquire the disciplines and missing abilities that are actually required.
14	Cross-system consistency and thus global applicability require uniform and general conditions for technologies, systems and processes based on international norms and standards.
18	In order to make full use of the potential of industry 4.0, companies have to be versatile.
18	Realignment of the business model must be carried out across all functions.
18	The company has to define its factors for success (Where is value created? Where are the best cost positions? Are there alternative revenue models or new sales structures?), align itself on its core processes and skills and transfer these these to new application areas and revenue models.

Figure 4.1 shows how the quotes were numbered and emergent themes were identified. If a quote related to an emergent theme an 'x' was placed in that themes column.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
Quote	Number	Colloboration	Decsion Making	Real Time	Adoption rate	Technology	Cluster	Transparency	Flexability	Paradigm shift	Organisational change	Efficiency	Digital Capabilities	People	Standardisation	Business Model	Disruption	Feedback learning	Data	Ecosystem	Organisational Culture	Customer Focus	Leadership	Speed	Prcoesses	Transient	Rsik	Physical Resources	Product	Innovation	Control points	Effectivness	Digitise	Customisatiion	Quality	Optimisation	Investment	Modular
Mo	1	x																																				
All t	2		x	x				x																														
Hov	3				x	x		x																													x	
Loc	4					x	x																															
The	5		x					x	x			x																										
Disp	6		x					x						x														x										
For	7									x	x																											
Ider	8	x	x									x			x																							
Not	9		x								x		x																									
Cro	10					x									x										x													
In o	11								x																													
Rea	12										x					x																						
The	13												x			x									x													
If m	14									x	x		x			x	x												x									
Ma	15					x				x	x		x			x	x																					
Atte	16															x	x																					
Wit	17		x		x													x								x						x						
Nev	18	x																										x										
Ove	19	x				x								x																								
The	20								x		x		x	x		x																						
Cap	21										x					x																						
All c	22															x			x																			
Con	23	x	x					x												x																		
Suc	24													x							x		x															
Do	25	x														x	x			x									x	x							x	
Sen	26	x			x											x	x											x					x					
Exp	27																x	x				x																
Unc	28												x	x		x			x										x									
Buil	29												x	x																								
Par	30	x																					x														x	
Org	31												x	x									x	x														

Figure 4.1: Theme classification

Once the quotes had been classified into emergent themes, a frequency analysis was done to determine which emergent themes were the most significant as seen in Table 4.2.

Table 4.2: Theme frequency analysis

Theme	**Count**	**Theme**	**Count**
Collaboration	36	Feedback learning	9
Digital Capabilities	29	Ecosystem	9
Business Model	28	Real Time	8
Data	28	Organisational Culture	8
Decision Making	28	Transparency	7
People	26	Digitise	7
Product	25	Optimisation	7
Organisational change	23	Standardisation	6
Processes	19	Paradigm shift	5
Technology	18	Innovation	5
Flexibility	16	Investment	5
Efficiency	15	Cluster	4
Physical Resources	15	Effectiveness	3
Speed	14	Risk	2
Adoption rate	13	Control points	2
Leadership	13	Customisation	2
Disruption	12	Quality	2
Customer Focus	12	Modular	2
Transience	12	-	

The total data set of literature that was analysed is given in Table 4.3. The amount of text analysed was 75 404 words, which were resulted in 38 initial themes as seen in Table 4.2.

An interdependency analysis was conducted on the data using Microsoft Excel. The VBA code used to generate the output in Figure 4.2 is presented in Figure A.4 in Appendix A. The green shaded blocks in Figure 4.2 highlight when a certain theme occurred more than 50% of the time with another theme. The interdependency analysis helped to determine which themes should be grouped together.

Table 4.3: Description of final data set

Title	The Digital Manufacturer:Resolving the Service Dilemma [118]
Size	8 373 words
Description	This report done by Cisco in November 2015 was compiled with input from 600 senior manufacturing decision makers across 13 different countries. Countries included were Australia, Brazil, Canada, China, France, Germany, India, Italy, Japan, Mexico, South Korea, United Kingdom and the United States. The report primarily used surveys and verbal interviews as data. Participants surveyed and interviewed were both industrial machine manufactures and "end-user" manufacturers.
Title	*World Economic Forum White Paper: Digital Transformation of Industries* [119]
Size	12 850 words
Description	A report commissioned by the World Economic Forum in conjunction with Accenture held working groups, work shops and interviews. Participants included over 200 subject matter experts from government, academia and business as well as over 100 industry partners and businesses. The report was published in January 2016.
Title	How to navigate digitisation of the manufacturing sector [120]
Size	19 459 words
Description	A 2015 report organised by McKinsey consulting which used surveys, market research and interviews. The report drew on input from over 300 participants across 3 different countries. Countries represented were Germany, Japan and the United States.
Title	*Industry 4.0: Building the digital enterprise* [121]
Size	13 097 words
Description	A report conducted by PwC and released in 2016. The report made use of data from over 2,000 senior executives, across 26 countries, representing 9 major industrial sectors.
Title	*The Factory of the Future* [117]
Size	21 625 words
Description	Research report compiled by KPMG using input subject matter experts as well as industry research from multiple countries. The report was published in 2016.

	Colloboration	Digital Capabilities	Business Model	Data	Decsion Making	People	Product	Organisational change	Prcoesses	Technology	Flexability	Efficiency	Physical Resources	Speed	Adoption rate	Leadership	Disruption	Customer Focus	Transient	Feedback learning	Ecosystem	Real Time	Organisational Culture	Transparency	Digitise	Optimisation	Standardisation	Paradigm shift	Innovation	Investment	Cluster	Effectivness	Rsik	Control points	Customisatiion	Quality	Modular
Total Occurances	**36**	**29**	**28**	**28**	**27**	**26**	**25**	**23**	**19**	**18**	**16**	**15**	**15**	**14**	**13**	**13**	**12**	**12**	**12**	**9**	**9**	**8**	**8**	**7**	**7**	**7**	**6**	**5**	**5**	**5**	**4**	**3**	**2**	**2**	**2**	**2**	**2**
Interdependencies	**1.0 = Extreme Dependency, 0 = No Dependency (Linear scale)**																																				
Colloboration	1.0	0.1	0.1	0.1	0.2	0.1	0.1	0.0	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Digital Capabilities	0.1	1.0	0.2	0.2	0.1	0.5	0.2	0.3	0.1	0.1	0.0	0.0	0.1	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Business Model	0.2	0.3	1.0	0.2	0.1	0.1	0.3	0.4	0.1	0.1	0.2	0.1	0.1	0.0	0.1	0.1	0.3	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Data	0.2	0.2	0.2	1.0	0.4	0.1	0.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Decsion Making	0.3	0.1	0.1	0.4	1.0	0.1	0.1	0.1	0.2	0.0	0.2	0.3	0.1	0.2	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
People	0.2	0.6	0.2	0.1	0.2	1.0	0.1	0.3	0.1	0.2	0.1	0.1	0.1	0.2	0.0	0.3	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Product	0.2	0.2	0.3	0.3	0.1	0.1	1.0	0.1	0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
Organisational change	0.0	0.4	0.4	0.0	0.1	0.3	0.1	1.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.2	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Prcoesses	0.3	0.2	0.2	0.2	0.3	0.2	0.1	0.0	1.0	0.2	0.2	0.2	0.3	0.2	0.1	0.1	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.2	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technology	0.2	0.2	0.1	0.0	0.0	0.2	0.1	0.1	0.2	1.0	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1
Flexability	0.3	0.1	0.3	0.0	0.4	0.1	0.2	0.3	0.2	0.1	1.0	0.1	0.1	0.3	0.0	0.1	0.1	0.2	0.2	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1
Efficiency	0.4	0.0	0.2	0.1	0.5	0.2	0.1	0.1	0.3	0.1	0.1	1.0	0.3	0.3	0.1	0.1	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.3	0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Physical Resources	0.3	0.1	0.3	0.0	0.3	0.1	0.1	0.1	0.4	0.3	0.1	0.3	1.0	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.2	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.1
Speed	0.3	0.1	0.1	0.0	0.4	0.4	0.2	0.1	0.3	0.1	0.3	0.3	0.1	1.0	0.1	0.3	0.0	0.1	0.2	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Adoption rate	0.2	0.2	0.2	0.0	0.1	0.0	0.1	0.2	0.1	0.1	0.0	0.1	0.1	0.1	1.0	0.0	0.1	0.0	0.2	0.2	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Leadership	0.3	0.5	0.2	0.1	0.2	0.5	0.1	0.2	0.2	0.1	0.1	0.1	0.0	0.3	0.0	1.0	0.1	0.0	0.2	0.1	0.0	0.2	0.3	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Disruption	0.3	0.2	0.7	0.1	0.0	0.0	0.3	0.3	0.0	0.3	0.2	0.0	0.2	0.0	0.1	0.1	1.0	0.1	0.3	0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.2	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Customer Focus	0.2	0.0	0.0	0.3	0.3	0.0	0.3	0.0	0.0	0.2	0.3	0.0	0.1	0.2	0.0	0.0	0.1	1.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Transient	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.1	0.2	0.3	0.1	0.1	0.3	0.2	0.2	0.3	0.0	1.0	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0
Feedback learning	0.2	0.0	0.0	0.2	0.3	0.1	0.3	0.3	0.0	0.0	0.2	0.0	0.0	0.1	0.2	0.1	0.2	0.1	0.4	1.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Ecosystem	0.6	0.0	0.2	0.0	0.1	0.0	0.2	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	1.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Real Time	0.4	0.1	0.0	0.5	0.4	0.1	0.3	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.3	0.0	0.0	0.1	0.3	0.0	1.0	0.0	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Organisational Culture	0.0	0.3	0.4	0.0	0.1	0.5	0.1	0.6	0.1	0.0	0.3	0.0	0.1	0.1	0.1	0.5	0.1	0.0	0.1	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Transparency	0.3	0.0	0.0	0.1	0.7	0.1	0.0	0.0	0.1	0.1	0.1	0.3	0.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Digitise	0.1	0.3	0.3	0.0	0.0	0.3	0.4	0.3	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Optimisation	0.4	0.0	0.1	0.3	0.4	0.3	0.0	0.0	0.4	0.1	0.1	0.7	0.4	0.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Standardisation	0.5	0.0	0.0	0.2	0.3	0.0	0.2	0.2	0.2	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Paradigm shift	0.2	0.4	0.6	0.0	0.0	0.0	0.2	0.6	0.0	0.4	0.2	0.0	0.2	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Innovation	0.4	0.2	0.2	0.0	0.0	0.2	0.4	0.0	0.2	0.2	0.0	0.2	0.0	0.2	0.2	0.0	0.2	0.0	0.4	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0
Investment	0.4	0.4	0.2	0.0	0.0	0.0	0.2	0.0	0.2	0.4	0.0	0.0	0.2	0.0	0.4	0.2	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.2	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cluster	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Effectivness	0.0	0.0	0.3	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.3	0.0	0.3	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Rsik	0.0	0.0	0.0	0.5	0.5	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Control points	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.5	0.0	0.0	0.5	0.0	0.5	0.0	0.0	0.0	0.5	0.0	0.5	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
Customisatiion	0.0	0.0	0.0	0.5	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Quality	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Modular	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.5	1.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0

Figure 4.2: Frequency and Co-occurrence Analysis

In Table 4.4 the themes that were grouped according to co-occurrence are shown. A strength value of 1.0 indicates that the theme appeared 100% of the time with its co-occurrence, while a strength value of 0.5 would indicate that it only occurred 50% of the time. For example, quotes that made reference to a cluster were also quotes that mentioned collaboration, 80% of the time. The co-occurrence matrix is not symmetrical due to the fact that each theme has a different number of total quotes. For example, if the themes of "collaboration" and "cluster" co-occur 3 times and there are a total of 36 collaboration quotes and 4 cluster quotes then the co-occurrence is 3 of 36 (0.1 rounded) for collaboration but 3 of 4 (0.8 rounded) for cluster.

Table 4.4: Co-occurrence analysis

Theme	**Co-occurrence**	**Strength**
Cluster	Collaboration	0.8
Ecosystem	Collaboration	0.6
Disruption	Business Model	0.7
Transparency	Decision Making	0.7
Effectiveness	Decision Making	0.7
Paradigm Shift	People	0.6
Optimisation	Efficiency	0.7
Customisation	Product	1.0
Modular	Flexibility	1.0

The final selected themes are presented in Table 4.5.

Table 4.5: Final ranking of themes

Theme	**Ranking**
Collaboration	1
Digital Capabilities	2
Business Model	3
Data	4
Decision Making	5
People	6
Organisational change	7
Operations	8

The final classification of themes is outlined in Figure 4.3.

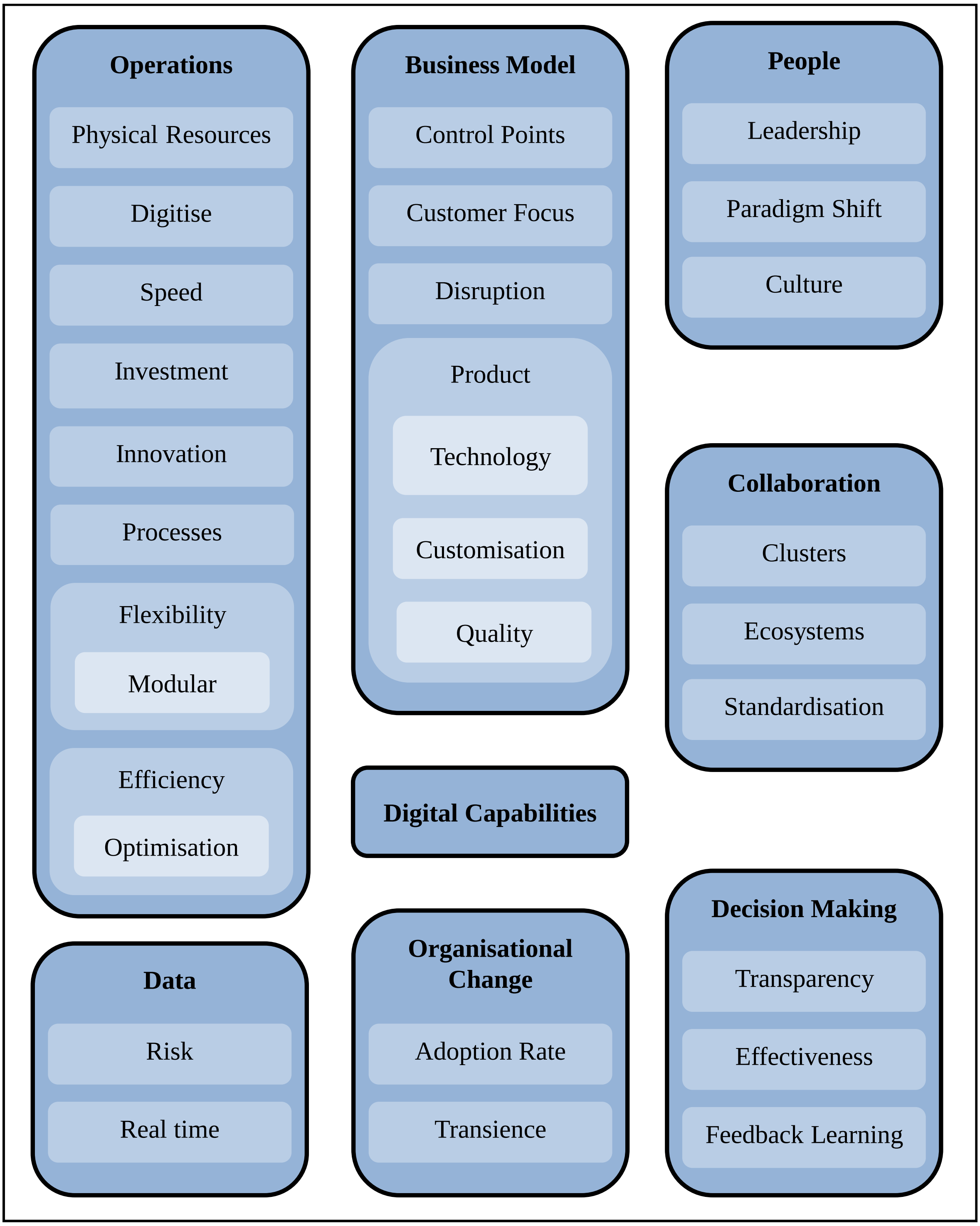

Figure 4.3: Theme Classification

4.2 Results

The infographics and their preceding explanations form the final results for the study. The infographics provide a summmarised way of understanding the results. They provide a means of assessing a large field of knowledge in a concise manner and present qualitative data in its most simplified essence. A single statement or picture in an infographic was not always sufficient to fully describe all the data collected within a theme. For this reason an explanation follows each infographic which provides necessary detail and context to the reader. The explanations are in themselves also part of the results and should be read in conjunction with the infographics. No additional literature was used in the explanations that follow the infographics and the text in the explanations is drawn from the literature research data.

The infographics are presented in order of their ranking by theme occurrence (Figure 4.2). Although the research was not specifically designed towards quantitative content analysis the higher ranking themes may be deemed more important towards competitive advantage during industry 4.0. The four highest ranking themes in order of importance are collaboration, digital capabilities, business model and data. The remaining four themes (decision making, people, organisational change and operations) are also important but scored lower on the frequency analysis.

4.2.1 Theme 1 - Collaboration

The results for theme 1 are presented in Figure 4.4.

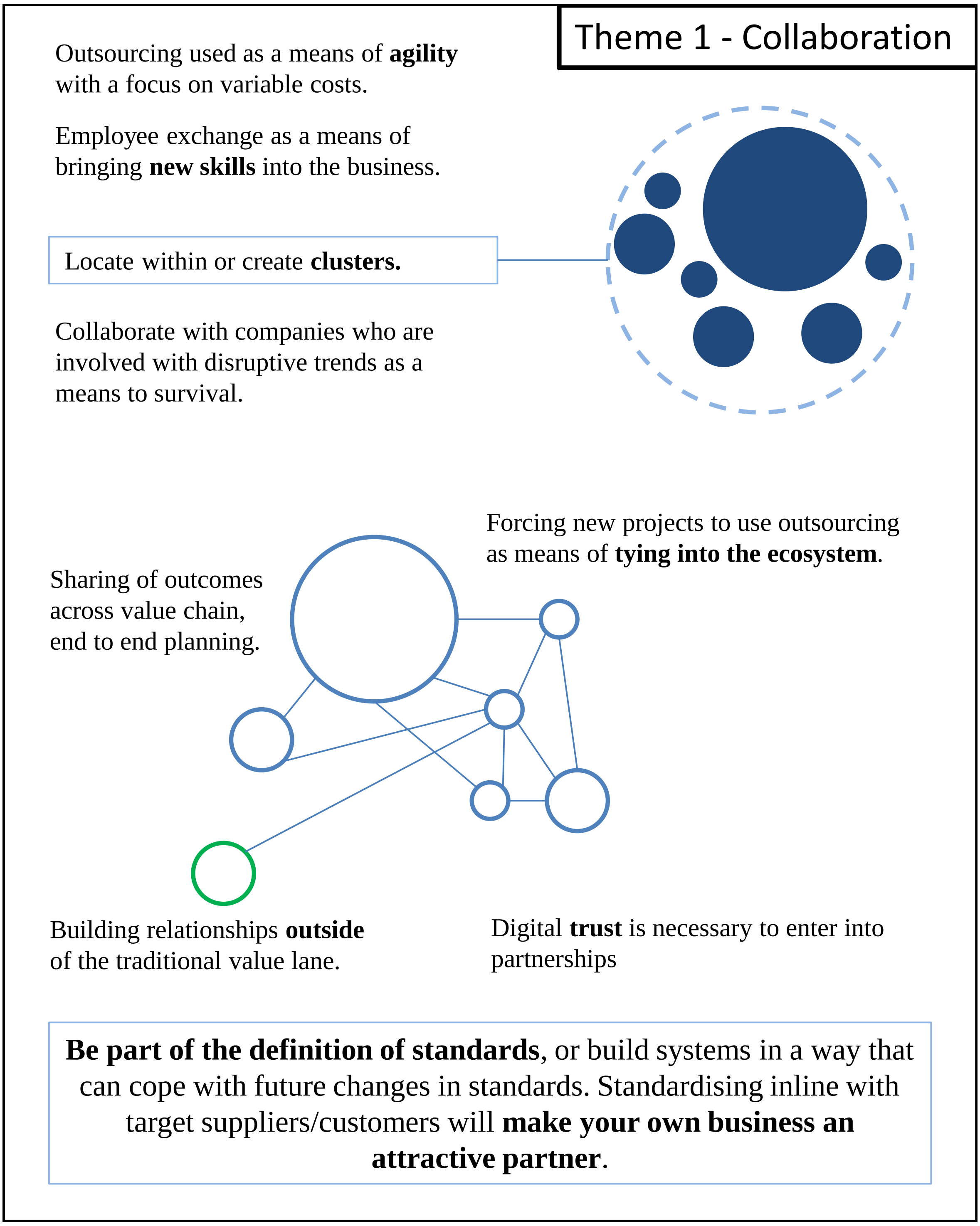

Figure 4.4: Theme 1 - Collaboration

The idea of collaboration is fundamental to competitive advantage during industry 4.0. Since industry 4.0 will be like an ecosystem , a business's ability to tie into the ecosystem is crucial.[121] Quality and quantity of relationships or connections with the ecosystem will be correlated with success and competitive advantage. SMEs should develop partnerships that go beyond a human relationship and are characterised by digital integration.[119] This should involve sharing data and outcomes with not only their neighboring supply chain partners but also those further up and down stream.[120]

SMEs should also position themselves within clusters and actively use their position for not only revenue generation but also learning, skill development and growth.[117] A cluster is the "the regional conglomeration of companies that are active along a common value chain, including the manufacturers, service providers, suppliers, primary customers, research institutes, universities and other institutions such as trade associations and chambers of commerce".[117] The members or participants within a cluster realise synergistic benefits from being in close proximity to one another. They share resources, skills, knowledge, and costs which generally leads to accelerated innovation.[117]

A major source of competitive advantage for SMEs will be their ability to outsource. Many SMEs have failed in the past due to a lack of critical resources and the cost involved in obtaining them. Through collaboration and the outsourcing of non core business functions, SMEs will have an opportunity to scale much easier and more incrementally with a focus on more variable costs instead of fixed costs.[119] Figure 4.4 highlights the importance of employee exchange programs.[119] If SMEs can find businesses who need training on skills they have already acquired and vice versa, temporary employee exchange can be a cost effective way of bringing new skills and ideas into their own business while at the same time giving employees an opportunity to develop. The potential gain is twofold, firstly the 'foreign' employee will bring a new set of skills that can be internalised within the business while he/she is present. Secondly the 'loaned' employee will return with new skills that can also then be shared within the business.[119]

4.2.2 Theme 2 - Digital Capabilities

The results for theme 2 are presented in Figure 4.5.

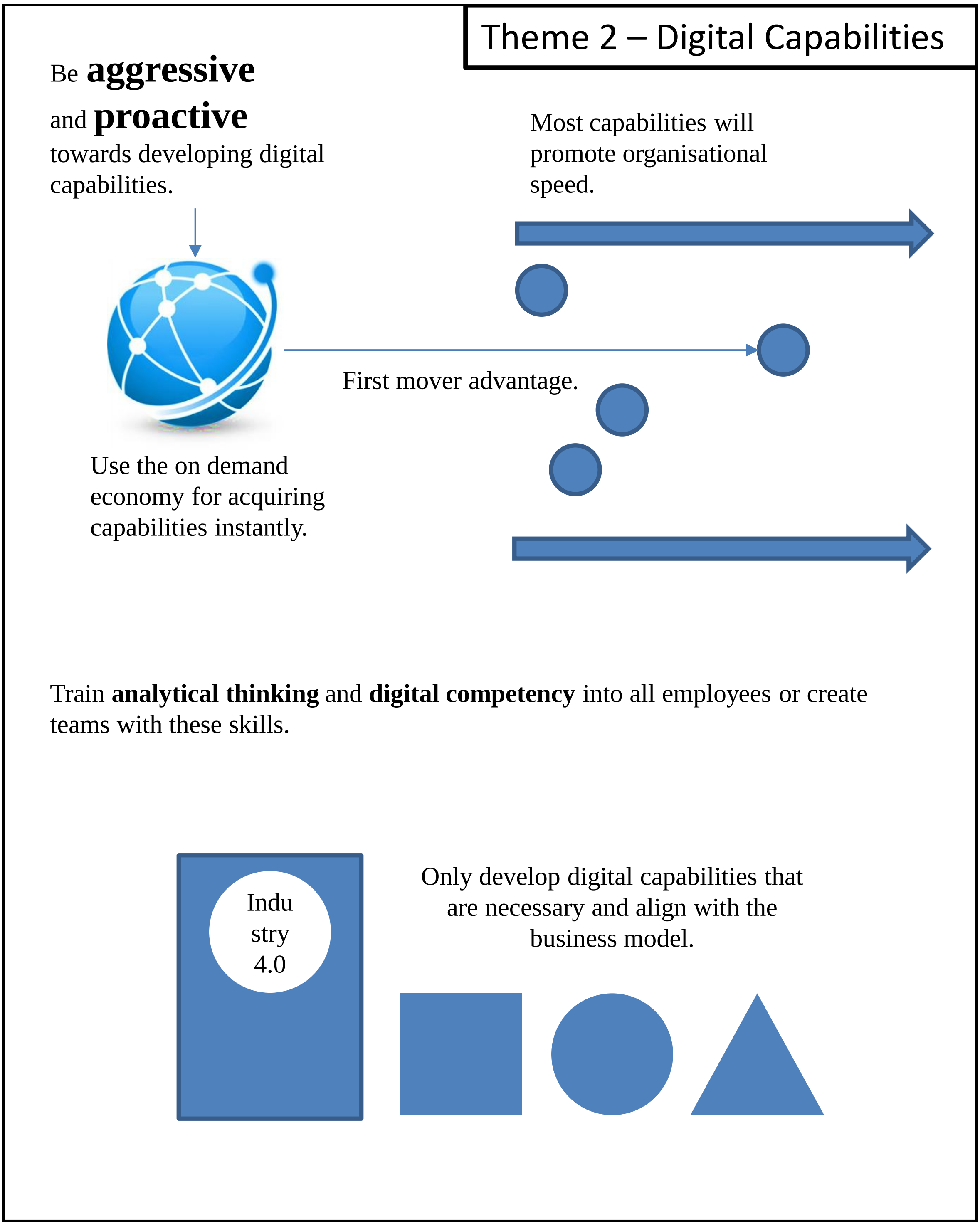

Figure 4.5: Theme 2 - Digital Capabilities

Digital capabilities should be viewed from a resources based view of competitive advantage due to their internal nature. They can be broadly thought of as capabilities, skills, competencies or resources that a business will need to specifically operate in a digital environment. There is no strict list of digital capabilities, but analytical ability is mentioned constantly and is definitely a core capability. Figure 4.5 suggests that businesses should not worry about obtaining every digital capability but only those that are necessary to their business model. SMEs can outsource most of their digital capabilities, at least initially, in order to gain first mover advantage.[121]

First mover advantage refers to the competitive edge gained by being the first business to take action in a specific area. First mover advantage often allows a business to become known for a certain ability of proficiency and sets them apart as the leader in the market's eyes. As an SME begins to try incorporate a new technology or idea, it will naturally move along the learning curve. To avoid a significant upfront commitment of costs SMEs should outsource these capabilities until they come to understand the impact they will have. If an advantage is materialised by a certain capability they are now way ahead of their competitors and if it does not they haven't lost significant time or money.[121]

The on-demand economy will be major source of digital capabilities and a potential source of competitive advantage to SMEs who take advantage of it. It will allow SMEs to acquire skill as and when they need them, without having to worry about labour laws or increasing their wage expense.[119]

Most digital capabilities will promote organisational speed in a digital environment and must be developed proactively. It is the constant learning and internalising of capabilities that will lead to sustained competitive advantage over an extended period as the environment changes. How digital capabilities are acquired, managed and used, as the market based view suggests, is what leads to the advantage.

4.2.3 Theme 3 - Business Model

The results for theme 3 are presented in Figure 4.6.

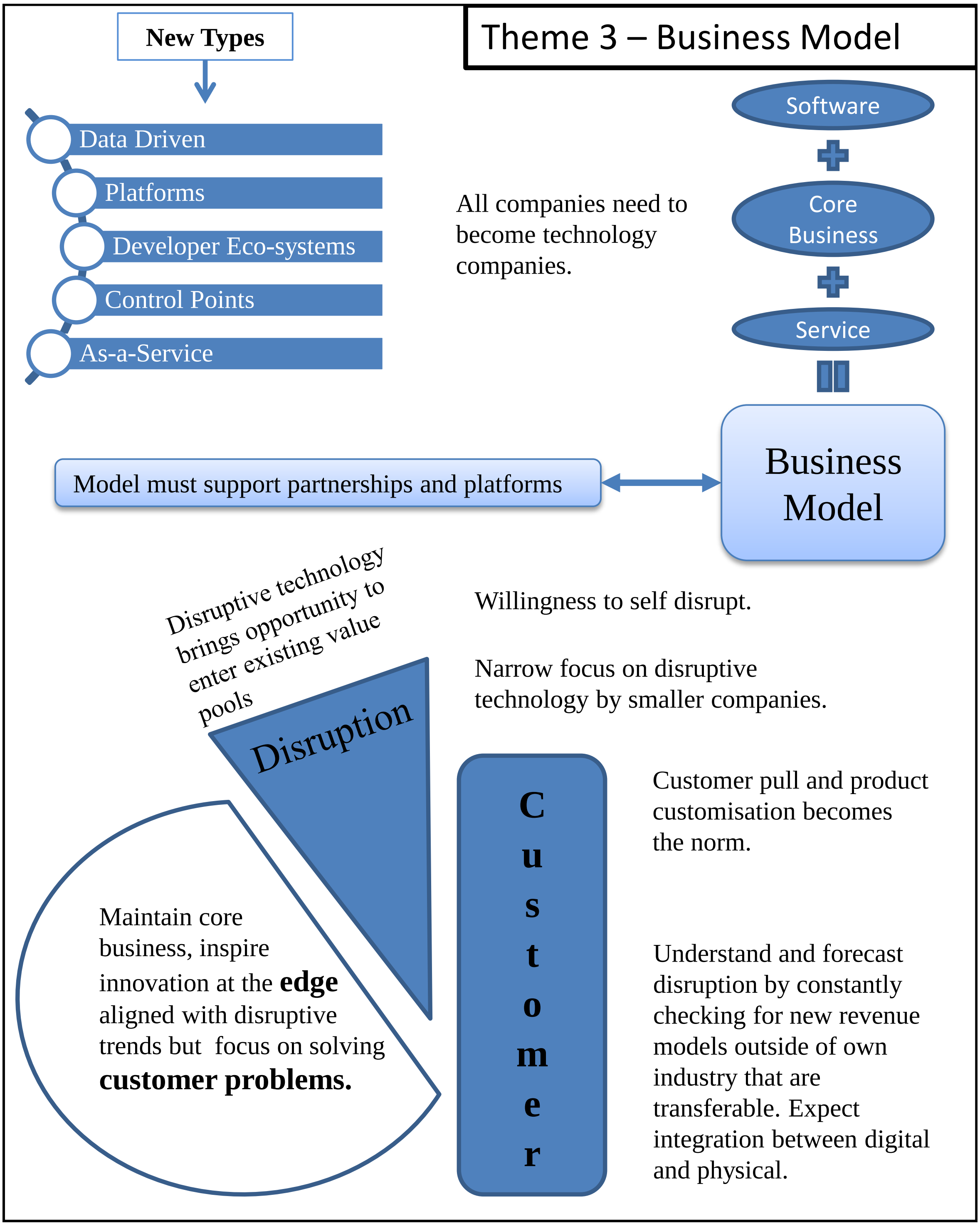

Figure 4.6: Theme 3 - Business Model

The structure of a company's business model play's a significant role towards their competitive advantage.[119, 120] Figure 4.6 shows that companies can expect a significant amount of change to their business models if they wish to remain competitive. Manufacturing companies will need to become more like technology companies.[118] They will need to not only sell a product but also the software and service to go along with it. SMEs may find it difficult to get all three of these areas right. Traditional manufacturing SMEs can look at partnering with other businesses who can handle the software and service elements, or they can operate through platforms that do the same. An example of this is Uber. A driver, who owns an asset (the car) sells movement or transportation. He alone does not have the resources to build a mobile phone application and back it up with live support and service. Instead the driver uses the Uber platform to link his core business with software and service.

There are a number of favourable business models emerging for industry 4.0. These include data driven platforms, control points, developer ecosystems and as-a-service.[120] SMEs need to understand how each model works and judge the applicability according to their own context. The as-a-service model may help SMEs who are growing but struggling to match demand with growth. These SMEs could rent out their extra capacity as a service, helping them cover their fixed costs. Traditionally this would seem like a scheduling and optimisation nightmare, but with artificial intelligence and live inventory tracking, the industry 4.0 ecosystem makes it possible.

Understanding and forecasting disruption will be key to achieving a competitive advantage. Disruption will bring with it new opportunities and SMEs need to be willing to disrupt themselves in the process.[119] A narrow focus on specific disruptive technology will likely be a small business's best chance of achieving advantage. Current SMEs should look to innovate at the edge of their business while maintain their core. Especially in the short term while industry 4.0 adoption is relativity low. SME owners should not only watch the manufacturing industry but also other sectors and understand where business models can be transfer to their own context.[119] A question that will be useful in this regard is "where can digital and physical be merged?"

Regardless of the context, a business should remain customer focused. Disruption or innovation for its own sake may prove costly. New business models must remain attractive to customers by solving their problems and meeting their needs. [121]

4.2.4 Theme 4 - Data

The results for theme 4 are presented in Figure 4.7.

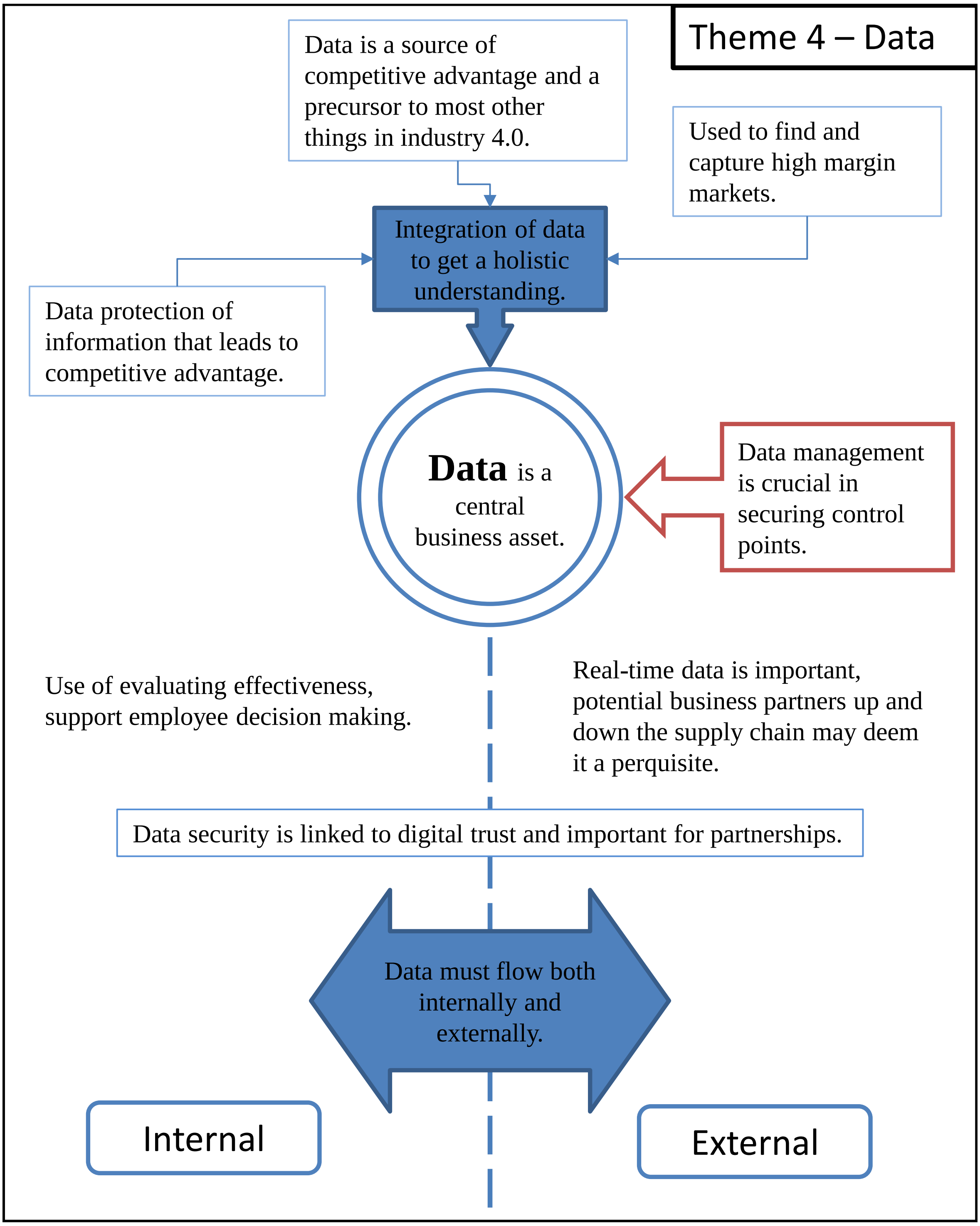

Figure 4.7: Theme 4 - Data

Data will be a significant part of industry 4.0 and if used correctly will be a major source of competitive advantage.[121] Figure 4.7 shows that data should be viewed as a central business asset. SMEs who are able to record and analyse data effectively will gain a significant advantage over their competitors. Data and data analytics will lead to better production efficiencies, stronger relationships with suppliers and customers as well as reduced risk and uncertainty.[118]

The use of data driven insight must not be limited to the SME owner or upper management but rather be used throughout the business to evaluate effectiveness and support employee decision making. Due to the complexity of industry 4.0, it will become increasingly difficult to plainly ‘see’ what is happening. Data will be needed to assist in this regard and should be used wherever possible to simplify complexity.[117]

Real-time data will become important. It will be important for both internally and externally and must flow between these two areas freely. Other businesses in the supply chain may require real-time data for their own production. Not being able to pass and receive data as and when it is needed could work against achieving competitive advantage. [118]

Data security and management will be very important to maintaining a competitive advantage. Any insights or technical knowledge that offers significant benefit must be held securely. A competitive advantage can also be achieved by looking more attractive to potential partners and customers. Good data security ensures digital trust which ensures connections into the network and value streams.[120] SMEs not only offer their customers service but also their partners. This idea links back to the business having to become technology companies. The better the service a business can offer its partners in terms of security, quality of data and value of insight, the more likely it is to maintain them and fend off competitors.

4.2.5 Theme 5 - Decision Making

The results for theme 5 are presented in Figure 4.8.

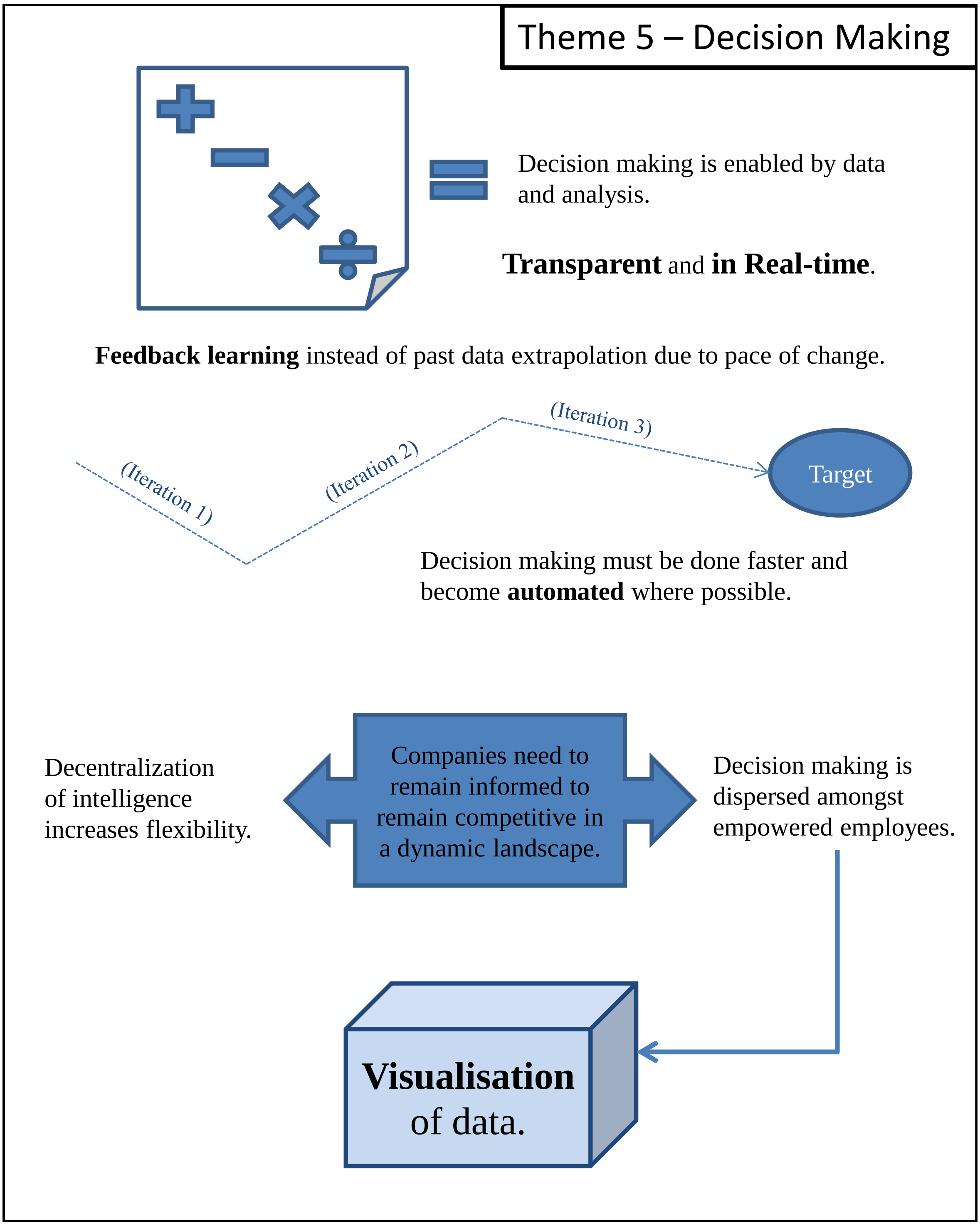

Figure 4.8: Theme 5 - Decision Making

Linked closely to the theme of data is decision making. How an SME makes decisions during the fourth industrial revolution will impact it significantly. As seen in Figure 4.8, industry 4.0 will bring a dynamic operating environment. The optimal position or goal a company should be aiming for will shift whether they are aware of it or not. SME owners may feel like they are chasing a moving target. Making decisions, especially those related to strategy, few and far between will result in a company missing its target. To overcome this, decision making that is based on feedback learning will be critical. This involves trying something new, gathering data, analysing and learning in short cycles.[119] SMEs who do this will be constantly making small adjustments that will prevent them from steering away from a competitive position.

Figure 4.8 also shows that decision making will need to be decentralised. This will give a company the much needed flexibility it requires to stay competitive in network environment. To achieve decentralised decision making SMEs should start by automating current decision processes. They should also hand over decision making to employees.[119] To do this successfully, employees will need to be given the authority and the necessary tools. Data visualisation will be an important tool in this regard and SMEs should work towards a decision making processes that is transparent and in real-time.

In order to make decisions that lead to a competitive advantage, SMEs need to get used to using data analytics to drive decisions. This firstly requires measuring certain business processes with the necessary accuracy and secondly interpreting this data. SMEs have a range of options when it comes to moving towards data analytics. These include online services, employee training and software programs.

4.2.6 Theme 6 - People

The results for theme 6 are presented in Figure 4.9.

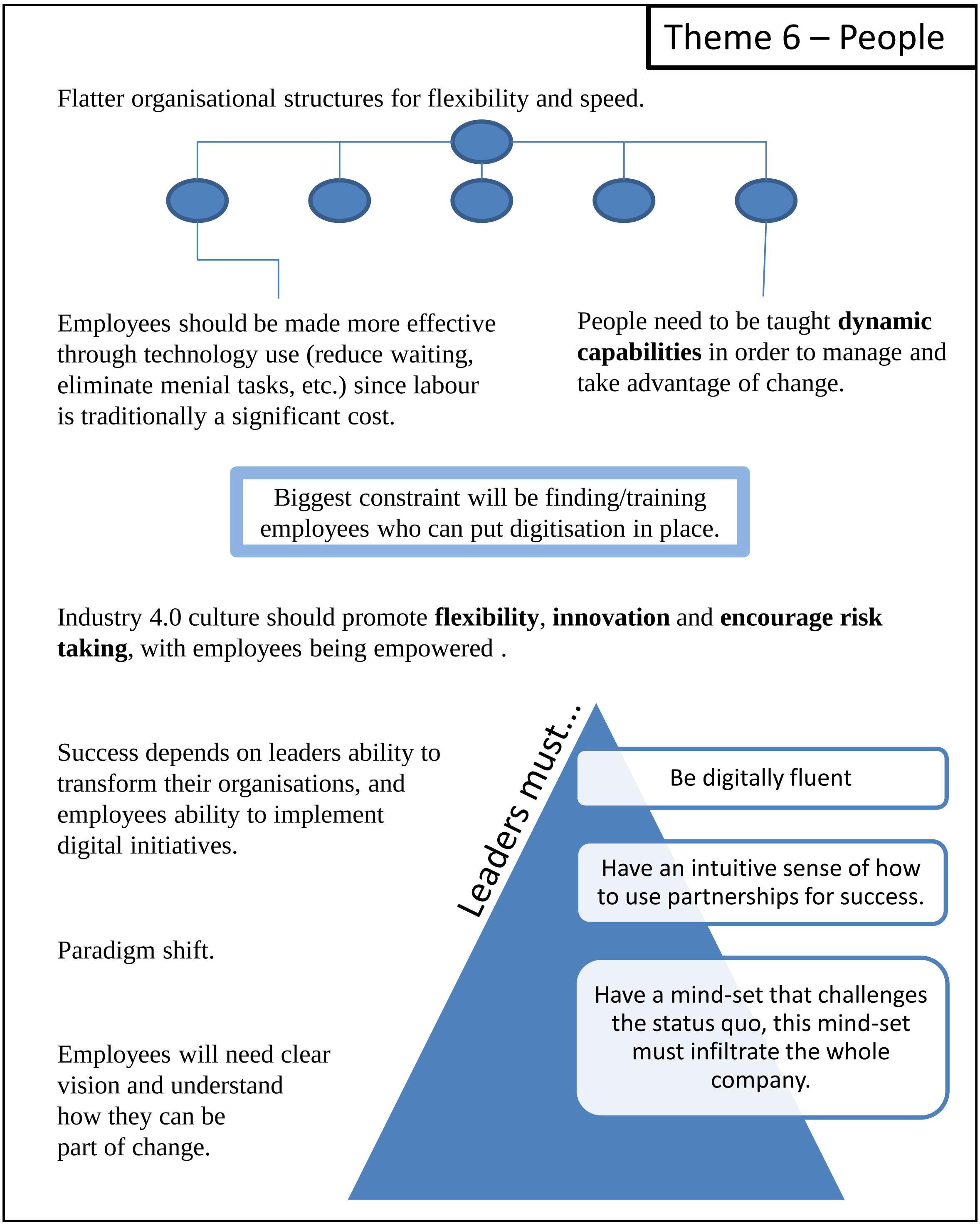

Figure 4.9: Theme 6 - People

The sixth theme, which highlights a competitive advantage based on people, correlates strongly with the dynamic capabilities competitive advantage view. In order for SMEs to be competitive during the next industrial revolution, their leaders and employees will need to manage and take advantage of change as seen in Figure 4.9.

There will need to be a complete paradigm shift for people.[117] Industry 4.0 will challenge traditional thinking. Businesses who are resistant to change may find it difficult to compete. The first big change is realising that people should not be doing work that robots can do but rather offering value where they cannot. Human-technology collaboration must be used to make people more effective and efficient. This can greatly reduce a business's labour cost which is traditionally one of the highest.

In order for businesses owners to get the most from their employees they should promote flexibility, innovation and encourage risk taking. Employees should be empowered to change and provided with a clear vision so that they can understand how they can be part of the change. Success will depend on the ability of leaders in SMEs to bring about change. They should focus on enabling their employees to implement digital initiatives.[119]

As challenging as it will be for employees, even more will be expected from people in leadership. In order for SMEs to achieve a position of competitive advantage, leaders will need to be digitally fluent, have an intuitive sense for leveraging partnerships and they will have to constantly challenge the current state. They should have mindsets towards continuous change and improvement and this mindset should filter through the whole business.[121]

The results suggest that the biggest constraint for businesses will be their ability to find/train employees who can implement digitisation. If this process can be done effectively, SMEs stand to gain a significant advantage over their competitors and they should treat hiring and training as seriously as larger organisations do.[121]

4.2.7 Theme 7 - Organisational Change

The results for theme 7 are presented in Figure 4.10.

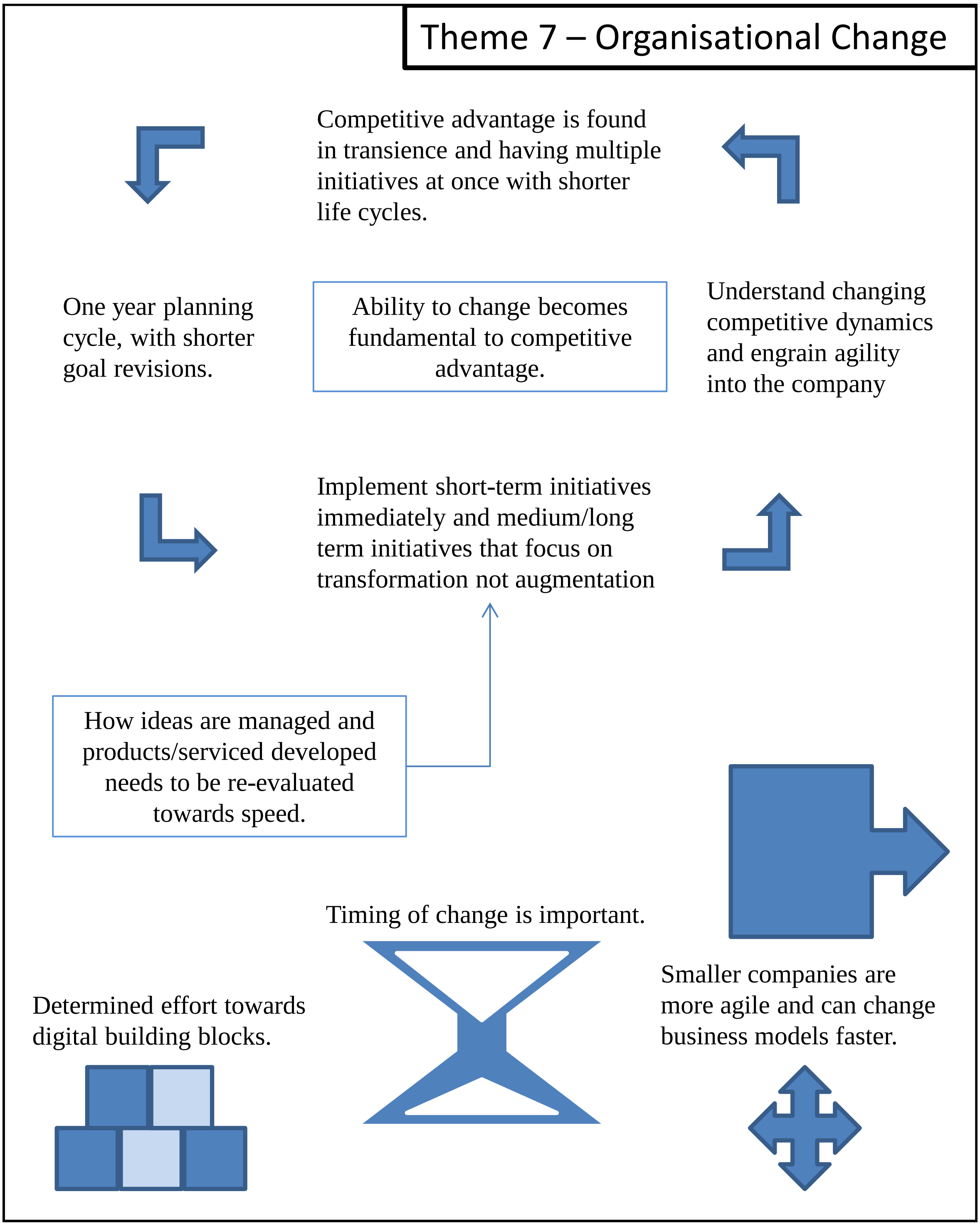

Figure 4.10: Theme 7 - Organisational Change

Organisational change is a theme that came through strongly in literature and is presented in Figure 4.10. Figure 4.10 shows that it is the ability to change that will lead to competitive advantage. A companies competitive position will be defined by the implementation of short term initiatives and medium to long term initiatives. The medium to long term initiatives must be focused around transformation and not augmentation.[120] SMEs will need to leave incremental (first order) change behind and move into a new paradigm where second order change occurs. This will be characterised by the setting of new norms and standards. One such norm may be speed and life cycle shortening which relates to the transient view of competitive advantage.

Industry 4.0 may feel like a constant state of change for small businesses who will need to move towards a one year planning cycle with much shorter goal revisions. Change should be understood and dealt with through business agility. New initiatives and ideas should be evaluated and implemented much faster, with intentional speed being built into business planning. [119]

SMEs hold an advantage due to their size, smaller companies are naturally more agile and they should use this attribute where possible to out compete larger businesses. The timing of change will be important, especially SMEs who don't have sufficient investment for resources. Changing too early can mean significant sunk costs into the wrong thing, while changing to late will mean that too much ground needs to be covered in short period of time. This is where the feedback learning proposed in theme 5 can be extremely useful.

For the short term, SMEs should begin building digital building blocks that they can expand on later. These building blocks will range over the entire business and are both physical and cultural in nature. Building blocks include forming a digital culture, extracting and analysing data, automating mundane and routine tasks and aligning systems towards popular standards.[121] Each SMEs building blocks may be different but a proactive approach in the short term will mean a smoother adoption and fewer risks in the long term.

4.2.8 Theme 8 - Operations

The results for theme 8 are presented in Figure 4.11.

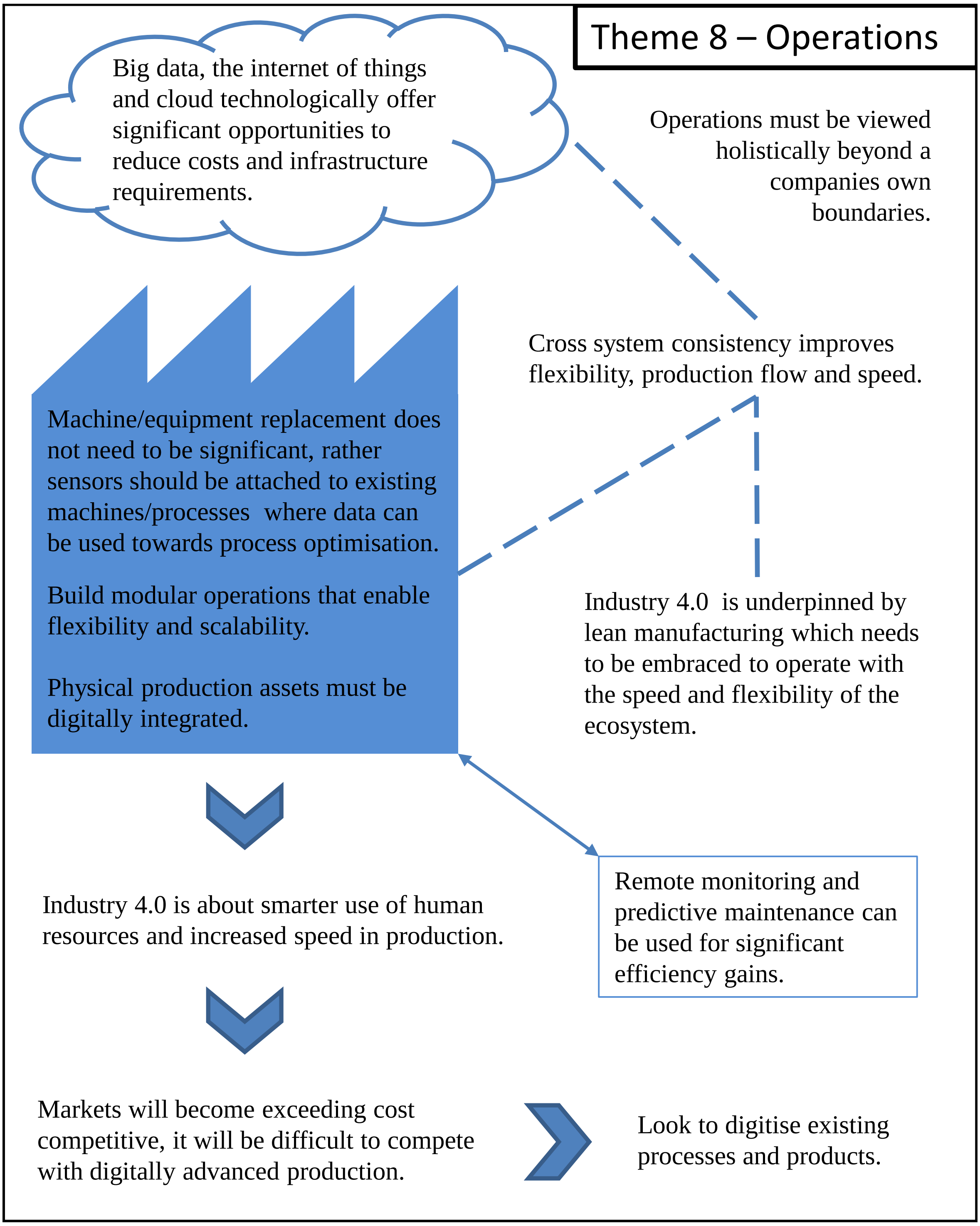

Figure 4.11: Theme 8 - Operations

The final theme, operations, has the closest ties to manufacturing specific business and the results for it are shown in Figure 4.11. As seen in Figure 4.11 industry 4.0 is underpinned by lean manufacturing. The competitive advantage lean offers a business, will be the same industry 4.0 can. The only difference will be that technology will aid and enable lean processes and thinking. This is an important result and suggests that SMEs shouldn't bypass understanding lean as they move towards industry 4.0. [119]

Big data, the internet of things and cloud computing will offer SMEs a significant advantage if they can learn to integrate those concepts and technologies. They provide access to resources that were previously only seen in larger organisations. Anything from simulation and artificial intelligence to tax and financial management.[120] This gives SMEs the opportunity to scale as and when they need without major steps in investment. The challenge will be to link their current processes and operations into the cloud. Figure 4.11 suggest that new equipment is not necessary. Rather the attaching of sensors to existing equipment must be done, creating digitally integrating physical production assets. This data collected from the equipment can then be used to find efficiencies and new insights about production, especially in the region of predictive maintenance and remote monitoring.[120] Operations managers should ensure cross-system consistency so that the business can seamlessly link internally and externally.

Operations must be viewed from a holistic point of view and extend beyond traditional company boundaries. This will ensure that operations can be built for speed and flexibility. It is suggested that a modular design approach be taken for future manufacturing lines and that these lines make better use of human resources.[121]

Countries that are leading the adoption of industry 4.0 will make it even more difficult for South African SMEs to compete. Digitally advanced production will reduce costs for developed countries. Although industry 4.0 may seem like a distant reality, SMEs should start digitising their existing products and processes so that they are never in a position of total exclusion.

4.3 Framework

The 5 key results from the research were compiled into a framework. The purpose of the framework is to be a simple guide that will help decision makers in SMEs to take action that will lead to increased competitive advantage in the future. The framework is not absolute but does provide a starting point for further thinking and discussion.The framework is presented in Figure 4.12.

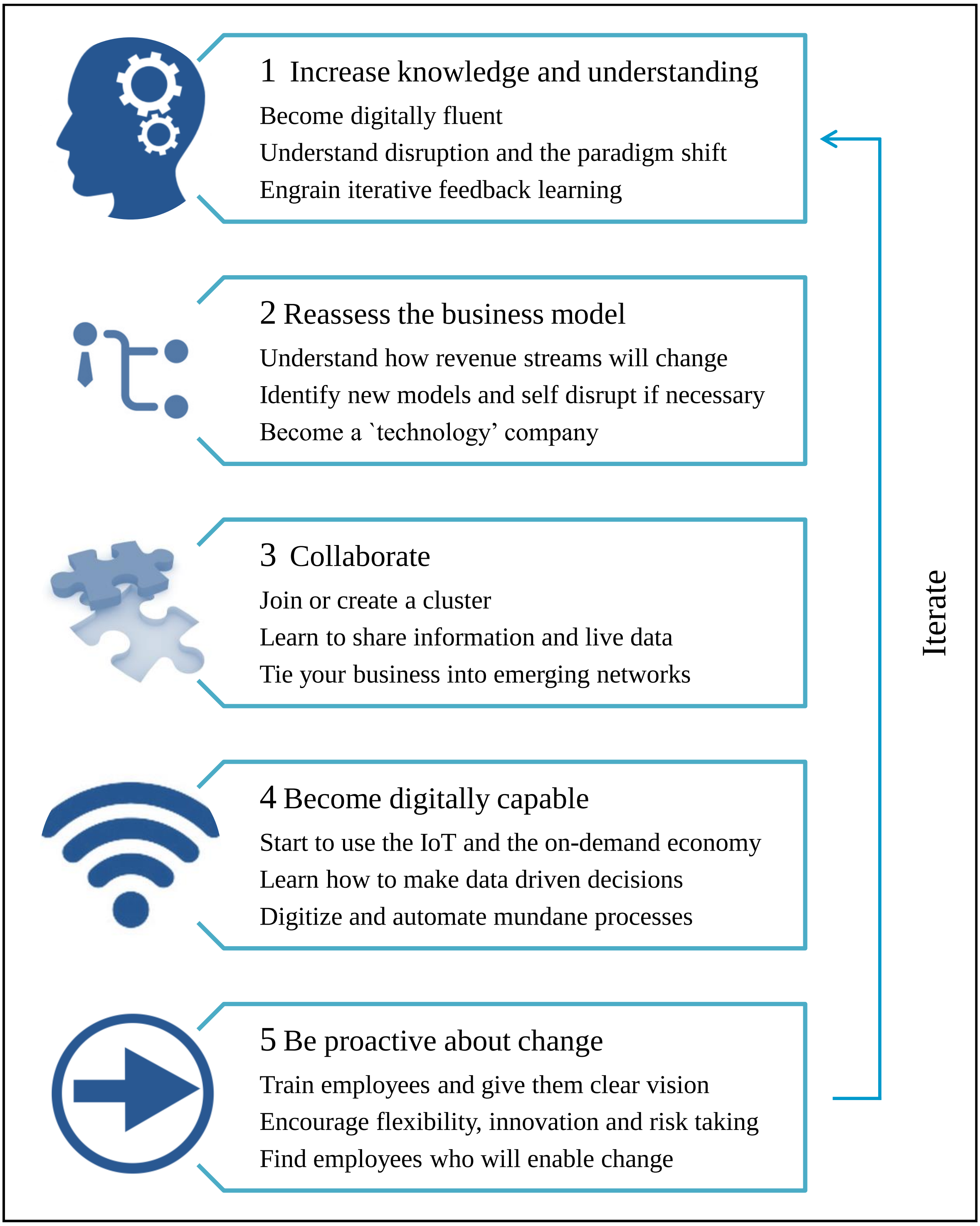

Figure 4.12: Industry 4.0 competitive advantage framework

Chapter 5 Discussion

This chapter outlines the discussion of the results and is broken down into two parts. The first part of the discussion is related to the themes and findings of the report as well as external initiatives that relate to the research topic. The second part of the discussion looks at critiquing the research process and results as a whole. It examines the reliability and validity of the research, the degree to which the research question is answered and whether or not the research objectives have been met.

5.1 Themes

The results presented in the infographics outline a number of means and actions that South African manufacturing SMEs can use to maintain or grow their competitive advantage. The findings from the research were generated using relevant literature on industry 4.0 and competitive advantage. The literary data on industry 4.0 was analysed and examined within the context of South African SMEs with the aim of better defining the knowledge space between the two research areas. For this reason, there exists few independent literary sources that can be used to definitively confirm the findings within the study. This is a limitation of the work and further research should be conducted to verify the outcomes of this report. The research is primarily supported through internal reliability and validity discussed later on in this chapter.

One of the important results presented in Figure 4.4 is the use of clustering to provide competitive advantage for SMEs. SMEs are currently challenged with obtaining necessary skills and knowledge.[4] This challenge could be addressed by leveraging the current initiatives which are promoting and executing partnerships between Universities and Industry to obtain the necessary skills and knowledge. Some of these partnerships include:

- The Technology and Human Resource for Industry Programme (THRIP) this program is a partnership between the government, academic and private sector aimed at improving the competitiveness of South Africas Industry and addressing the shortage of high-level skills demanded from Industry. [122]

- The Industrial Development Corporation (IDC) has an initiative to supports skills development programmes which address skills shortages in Science, Technology, Engineering and Maths (STEM) at technical and vocational education and training colleges (TVET) and Universities. [123]

- Universities South Africa (the organisation representing South Africas public universities) have detailed in their strategic framework from 2015-2019 that one of their goals is to form and strengthen partnerships between Universities and key stakeholders, one of which is businesses. One of their main objectives is to encourage shared research and innovation by developing effective and mutually beneficial relationships between Universities South Africa and the business sector.[124]

By taking advantage of these already established initiatives and including more specific skills required by Industry 4.0, the SMEs will potentially be able to obtain the skills they require to remain competitive.

5.2 Reliability and Validity

Data set

Since the research study made use of secondary data, there exists the potential for inaccuracies, bias and error to be introduced through the literature used in the data set. Although only 5 different literature reports were used in the final sample, these reports were extremely broad in nature and relied on on information from hundreds of subject matter experts, business leaders and industry stakeholders. The data set was also not tied to a specific region but drew on input from at least 26 different countries. This refers a level of confidence that the data was broad enough for the exploratory nature of the study. The fact that all the literature in the data set was intended to service a large international audience means that it is more likely to be accurate, since more care would have been taken to produce relevant and accurate information. The majority of the data set was produced by authors in the consulting industry which may lead to certain authors focusing on certain parts of industry 4.0 because it is aligned with their companies product and service offerings. Although this potential source of bias exists, the data samples used demonstrate a level of consistency and information that can be cross validated in most instances. This source of bias does not seem to have significantly affected the results, especially because information was filtered before use against selection criteria.

One of the verification strategies incorporated into the research process was “appropriate sample”. By focusing on getting information from the right subject matter experts, the outcome of the research can be deemed to be more reliable.[110] The type and selection of samples used for this study was very much based on the quality of information. The data set is highly relevant to the research topic and has been produced by the leading subject matter experts who focus on the competitive business environment and industry 4.0. The use of the “appropriate sample” strategy to some extent ensures that validity of the research and its findings.

Methodology

Shenton [125] suggests that the use of well established research methods is a good way of ensuring credibility in qualitative research. The thematic content analysis method used in this study can be classified as an ‘established method’.[106] Thematic content analysis is a somewhat broad term, which refers to the general process of searching for themes in literature. A number of steps were incorporated into the research methodology to improve process integrity and limit sources of researcher bias. These included thorough familiarisation, guiding conditions for sample selection and quotes extraction as well as a frequency and co-occurrence analysis which are quantitative in nature. The verification strategy of “methodological coherence” was also used as far as possible which ensure the matching of the method, data and analytical procedure with the research question.[110] The research methodology is outlined in detail, with supporting spreadsheet formats and source codes being made available to the reader. This improves the studies dependability which is based on the rigorous documentation of the research method.[125]

The biggest source of error or bias may occur during stages in the research methodology where the researchers interpretations are heavily relied on.[125] For this study those areas may include the formulation of themes, where ‘emergence’ is to some degree dependent on the researchers perspective. Although every effort was made by the researcher to remain neutral and unbiased, this cannot be guaranteed and is a general limitation of qualitative research.[106]

It is believed by the researcher that any bias or error in the final results is within expected ranges and that the results are valid and reliable enough to meet the research objectives. The iterative approach to the research which allowed for concurrent data collection and analysis ensures that the gap between the known and unknown remained as small as possible.[110] Any insight or understanding that was valuable to the success of the research was used and applied to the research process immediately. This helped to ensure that the final outcome of the research could be verified.

5.3 Research objectives

The three research objectives outlined in the introduction section of this report guided the specific direction and processes the research followed. The first research objective was focused on investigating possible sources of competitive advantage during industry 4.0. The second research objective focused on the means and actions SMEs can use to generate competitive advantage and the last research objective was to develop a framework that can be used by decision makers in SMEs.

The conceptual framework on competitive advantage presented in the literature review provided insight and understanding into what competitive advantage is and how it can be achieved. This helped the researcher distinguish between general information about the fourth industrial revolution and information that was specific to maintaining or generating a competitive advantage. The understanding of competitive advantage also helped to ensure that relevant data was found and used for the study. It can therefore be said that possible sources of competitive advantage during industry 4.0 were investigated in the research process. These sources of competitive advantage were specifically examined from the perspective of South African manufacturing SMEs and may be applied differently for organisations within other contexts. Since competitive advantage is dynamic and difficult to quantify under any of the recognised theories, determining whether or not all sources were covered is difficult to establish. The fact that information saturation was reached through the analysis of literature suggests that the available sources of competitive advantage were covered to a large degree.

The second objective is met through the results of this study which outline a number of means and actions SMEs can use to generate competitive advantage. The second objective is met on an exploratory level. Detailed, step-by-step actions are not given in this study and would need to be investigated specifically for a certain SME or group of very similar SMEs.

A framework is presented in the results section that outlines 5 key considerations/actions that decision makers within SMEs should use to generate competitive advantage. The framework is based on the most important findings of the study and meets the third research objective. The framework is limited in the sense that it has not been tested or validated by any specific manufacturing SME and is purely based on the findings from literature.

Through meeting all through research objectives sufficiently, the study has addressed the critical research question to a satisfactory degree. Since the study was exploratory in nature and covered a relativity undefined area of research, the findings from the research should not be used unreservedly. The findings can be used for further study which has the aim of being more precise about specific research conclusions. The rate and speed at which industry 4.0 is progressing and being adopted also limits the research to the time and context it was completed in. As industry 4.0 becomes more widely adopted in South Africa and across the world, its competitive implications for South African manufacturing SMEs will become clearer.

Chapter 6 Conclusions & Recommendations

This chapter outlines the conclusions of the research study and highlights the limitations of the research. It also makes of number of recommendations that can be used for future study.

6.1 Conclusions

- Sources of competitive advantage were investigated using a thematic literature study. Five main literature sources were chosen as the data set and are outlined in Table 4.3. From the data set, 8 emergent themes were found which formed the basis of the results.
- A framework was developed from the results of the research that aims to assist South African manufacturing SMEs to create competitive advantage during the next revolution. It is directed at high level decision makers within SMEs and does not outline detailed actions to take but rather broad guiding actions that should be applied in the specific context of each SME. The framework is found in Figure 4.12.
- The study is limited to an exploratory view of the research space and has not been rigorously tested. There is little independent data on the research topic that can be used to definitively confirm the research findings. This forms a limitation to the study and to the degree in which the research can be viewed as reliable. The validity and reliability of the research is primarily supported through internal means. It is suggested that the findings in the research be further investigated using data sources that are different to literature. Subject matter expert interviews may prove useful in this regard.

6.2 Recommendations

1. Two of the biggest challenges around industry 4.0 for the South African manufacturing sector are the lack of skills and a lack of exposure. It is challenging for businesses (SMEs in particular) to plan for an environment that is currently academic and conceptual. A

South African industry 4.0 learning factory would go a long way in developing necessary skills and exposing business owners to a tangible industry 4.0 environment. Its is recommended that stakeholders in the manufacturing sector investigate the development of an industry 4.0 learning factory. Research by Faller and Feldmúller [126] and Baena et al. [127] can be examined as an introduction in this regard.

2. As supported by Kumalo and Poll [98] cloud computing offers tremendous opportunity to alleviate some of the challenges faced by SMEs in South Africa. Cloud computing will be a fundamental component to industry 4.0 and should be used by government and SMEs as soon as possible. The Cloud offers a way for the mass support of SMEs in the country at a relatively low cost. The government could develop free software packages that would aid SMEs in their accounting, financial management, legal and labour requirements. These kinds of services would give SME owners, especially those in the micro - small range, an opportunity to focus on their core value proposition and grow their business without having to expend excess resources on supporting business functions.

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Appendix A Data Analysis

A.1 Quotes

Table A.1: Project configuration commands and arguments

Source: The Factory of the Future - KPMG [117]	
Page	**Quote on Industry 4.0 related change**
10	More permeable boundaries between sectors, technologies and companies.
10	All the relevant parameters are thus available in real-time, which means maximum transparency and an improved decision-making basis.
10	How quickly the networking proceeds depends primarily on the technological innovation cycles (Moore's Law, Glider's Law), the acceptance of technology and the willingness to invest.
15	Location advantage through technology clusters
17	The value added processes in the "factory of the future" are transparent and flexible...so that free capacity can be identified, accurately measured and consistently used.
18	Displays, user interfaces and visualization tools ensure that operators have constant and easy access to the relevant data
18	For companies in the manufacturing sector, the transition from Industry 3.0 to Industry 4.0 represents a change of more than one digit. It is a paradigm shift that means comprehensive change.
Page	**Quote on "how" to change towards Industry 4.0**

10	Identify existing or potential points of contact between their value chain and that of others and develop these into efficient, standardised interfaces.
13	Not everyone needs all the disciplines or has to master all the abilities. Instead the task is to identify and develop or acquire the disciplines and missing abilities that are actually required.
14	Cross-system consistency and thus global applicability require uniform and general conditions for technologies, systems and processes based on international norms and standards.
18	In order to make full use of the potential of industry 4.0, companies have to be versatile.
18	Realignment of the business model must be carried out across all functions.
18	The company has to define its factors for success (Where is value created? Where are the best cost positions? Are there alternative revenue models or new sales structures?), align itself on its core processes and skills and transfer these these to new application areas and revenue models.

Table A.2: Data collection from Macaulay et al. [118]

Source: The Digital Manufacturer - Resolving the Service Dilemma - Macaulay et al. [118]	
Page	**Quote on Industry 4.0 related change**
4	If manufacturers need to become digital, they must become software and service businesses as wellthat is, if they want to ensure they are not among the ranks of the disrupted.
5	Manufacturers are not themselves "technology companies"; yet services (and digital disruption) increasingly demand they must be.
Page	**Quote on "how" to change towards Industry 4.0**
4	Capacity to change, therefore, emerges as the key to capitalizing on service-orientated revenues and boosting competitiveness.

5	All companies need to become internet and software companies. The industrial world is changing dramatically, and those companies that make the best use of data will be the most successful.
5	Companies the access, process, and share data across an expanding ecosystem the best will thrive.

Table A.3: Data collection from World Economic Forum [119]

Source: Digital Transformation of Industries - Digital Enterprise - World Economic Forum [119]	
Page	**Quote on Industry 4.0 related change**
9	attempts to create a new, viable business model for the digital age will flounder unless a company is willing to disrupt itself.
21	With the pace of change so high, extrapolating from past data to guide future actions is unlikely to be successful. A culture of constant, iterative experimentation is more effective.
25	New collaborations are emerging that stretch well beyond historical industry boundaries, nurtured by mobility, payment systems, open information, energy management and infrastructure development.
30	Over the next few years, one of the most notable changes will be increasing instances of robots and humans working together.
31	The on-demand economy can be beneficial for businesses, enabling them to access a much wider range of expertise and skills that might not be readily available in their existing talent pool. Other benefits include functionality, speed, flexibility and mitigation against inertia and traditional thinking in the organisation.
Page	**Quote on "how" to change towards Industry 4.0**
8	Successful digital transformation demands a culture sponsored by the leadership that promotes innovation, encourages risk taking and empowers employees at all levels of the company.

12	Do not mess with your core business, but inspire innovation at the edge of your company. Look to projects on the periphery of your company that are focusing on new products,services or customer segments that are aligned with disruptive trends in your industry. Rather than funding this project generously, keep investment to a minimum, so that the project team is forced be necessity to focus on leveraging external resources, tying it into the ecosystem.
17	Sense and interperate disruption. Look beyond your own industry. Be prepared to Blur the lines between the physical and digital worlds.
17	Experiment to develop and launch ideas faster. Stop innovating and look to solve customer problems instead. Develop platform for fast and cheap experiments. Find or fund one venture that could most disrupt you.
17	Understand and leverage data. Organize data hackathons. Think beyond big data to consider different types of data. Find new ways to monetize data. Create an analytics team.
17	Build and maintain a high-quotient digital team. Be honest about how digitally savy you and your workforce are create digital boot camps to reskill employees.
17	Partner and invest for all noncore activities. One of the characteristics of effective digital leaders is their intuitive understanding that the journey is not one to be undertaken alone.
17	Organize for speed. Ensure CEO support and the presence of a dedicated central team to drive the new digital growth supported by a team of digitally savvy executes.
17	Design a delightful user experience. User experience drives IT architectures, and not vice verse.
20	Successfully identifying and implementing the most suitable flexible operating model will depend on other changes, particularly to strategy development and culture.

20	Companies need to embrace a leaner organizational setup, moving away from traditional hierarchies to a flatter structure, with higher levels of employee empowerment enabling faster decision making and greater agility. Companies have to emphasize agility. Even mission-critical functions should not be considered untouchable. If there is an opportunity to outsource functions and focus on variable costs rather than fixed costs, it should be thoroughly evaluated. Digital leader's business processes follow a lean approach.
21	Consider moving to an experimentation-orientated focus that uses real-time data to give instant feedback about the effectiveness of their strategic initiatives. A move toward a one-year planning cycle would be beneficial.
21	Companies can't afford to spend month at a time crafting a single long-term strategy. To stay ahead, they need to constantly start new strategic initiatives, building and exploiting many transient competitive advantages at once.
22	Organisations need to speed up their decision making by moving away from a centralized, control-orientated decision-making body leading to decisions being placed in the hands of a few, to a setup where employees across the organisation are empowered to take decisions, leading to increased self-management.
22	Companies do not have the luxury of time to extensively work up their ideas and test prototypes. As a consequence, successful organisations are reinventing all aspects of product development, from how they generate innovate ideas to how they bring them to market.
24	To exploit the potential of new, data-driven business models, companies will need to use data to disrupt their business.
25	Only operating models that support partnerships and platforms will survive in the future.
25	Organisations should identify potential digital partners and ecosystem scenarios in three categories: existing business partners becoming digital partners, new digital partners within your industry, and new digital partners outside your industry.
32	Organizations need to actively develop the skills they need in house but making training a critical component of their talent management strategy.

32	Develop required competencies within the workforce by assessing the skills that are currently needed and creating training strategies that are adapted to these. Do this through mapping out where the high-value work is in three years time versus today.
32	Mine your own organisation for hidden talent by regularly assessing employees' competencies and match these with in-demand skills.
32	Bring new skills into the organization by hiring digital leaders and digital natives. Quickly tap into skills from outside the company for 'just-in-time' competencies by running employee exchange with other digital organizations.
33	Leaders need to hire people with digital mindsets and a willingness to challenge the status quo. Moreover these people need to be placed across all levels of the Organisation to ensure 'real' change.
33	What leaders really need to do is increase their digital fluency, allowing them to effectively articulate the value of digital technologies to the organization's future.
33	Organizations need to move away from a risk-averse mindset to one that accepts failures and encourages employees to take higher amounts or risks.
34	Create environments where humans and robots can work together successfully.
34	Where automation is core to the business, invest in developing internal automation capabilities.
34	If a business does not have the resources to develop its own automation capabilities, it should form string, mutually beneficial partnerships.

Table A.4: Data collection from Wee et al. [120]

Source: Industry 4.0 - How to navigate digitization of the manufacturing sector - Wee et al. [120]	
Page	**Quote on Industry 4.0 related change**

7	Disruptive technologies that are in many cases not linked to major machinery upgrades will enable productivity gains and new business models, and fundamentally alter the competitive landscape
12	This cluster, which comprises big data, the internet of things, and cloud technology, is mainly driven by a significant reduction in costs that makes the ubiquitous use of sensors and actuators possible and allows for affordable yet powerful storage, transmission and processing.
13	Another dimension is the increasing physical interaction between machines and humans, where machines and humans work in much closer physical proximity and where machines can ease previously strenuous tasks for humans....As a result, the worker can conduct a given task for a longer period of time and faster than before.
13	In comparison to the third industrial revolution, the fourth will have high impact despite only limited replacement of equipment.
14	The main requirement will be upgrading existing equipment, mainly in the dimensions of sensors and connectivity.
21	Opportunities are associated with speeding up and potentially automating these decisions, and triggering the required actions.
23	Industry 4.0 enables a more flexible and more modular production through flexible production equipment and automation technology. This will allow manufacturing companies to react faster to changed demand, covering both production volumes and a variety of products.
25	Since labour is an important cost driver in most industries, improving labor productivity can drive significant value. The value can be captured via levers the reduce waiting time (e.g. completion of previous process steps in manufacturing, delayed delivery of a good in manufacturing, or a prototype in R&D) or increase the speed of workers' operations by reducing the strain or complexity of their tasks.
27	Remote monitoring and predictive maintenance will play an important role in capturing value. Both of them are levers to improve asset utilization by decreasing unscheduled downtime.

28	Moving from an analog factory to a digital thread requires businesses to transcend boundaries to transcend the traditional boundaries of functions, production sites, and companies. To enable an information flow, disparate sources of data need to be integrated, from different applications both within and from outside the company. For the short term, this might even imply that the integration needs to be carried out manually via Excel. For the long term, integrated systems with common standards should be implemented.
29	Another driver to increase flexibility can be decentralization of intelligence.
38	New business models are leading to a shift away from physical product revenues towards more service-based revenues, platforms, and developer ecosystems, so this will result In a shift in value pools for both manufacturers and suppliers. While in the manufacturing industry actual production sales have traditionally been the largest value pool in terms of the proportion of overall expenditure, this share is like to decline in the future.
39	Currently , many of the disruptive technologies are driven by small, innovative companies that have specialized in a given (often rather narrow) field. These companies are frequently able to be more agile rather than larger, established companies - and agility is often associated with competitive advantage in environments undergoing significant change.
39	Smaller companies are generally able to implement new business model more easily, while larger ones need to think about how to become more agile.
39	For small and new players, the disruptive technologies provide an opportunity to enter the competitive landscape and capture emerging new value pools.
39	Traditional value chains are experiencing radical transformation. Instead of one company developing and producing an entire product, a higher degree of specialization is likely to occur (disintegration of the value chain).
39	For other companies, a stronger collaboration along the value chain steps (integration) could present more opportunities than disintegration.
41	It is not just a company’s own market environment that is relevant: other markets and industries may also provide insights into potential trends. Companies can identify business models that are transferable to their own industry by analyzing other industries, potentially hoisting themselves into the driver’s seat of new developments.

43	Industry 4.0 is just as much about innovation as it is about effectiveness.
44	One of the main impacts from Industry 4.0 on companies is the increasing need to integrate data and processes from outside the company.
44	From a technological perspective, manufacturing sites as well as global supply and value chains will be highly interconnected and collaborative at a global level, enables by a global digital backbone. The key feature of this new manufacturing paradigm will be collaborative agility.
44	Alliances, strategic partnerships, and cooperation in communities are therefore crucial for building up a network and maintaining competitive edge.
45	With the increasing importance of data, competitive advantage will depend on it to an even greater extent.
Page	**Quote on "how" to change towards Industry 4.0**
7	Manufacturing companies should act along three dimensions to capture the potential of Industry 4.0: drive the next horizon of operational effectiveness, adapt business models to capture shifting value pools, and build the foundations for digital transformation.
8	Success factors for capturing opportunities from the next horizon of operational effectiveness are: integrating and analyzing data across sources and companies, sharing outcomes across the value chain, ensuring integration with physical production assets, and rethinking the design of classical production systems.
8	Success factors in adapting to disrupted value chains. The first is to take current assets as the starting point and develop new business cases based on these. The second is to secure control points in the shifting value chain and avoid areas that are becoming commoditized. The third is to understand the changing competitive dynamics and engrain agility in the company's DNA.
8	Need to drive the digital transformation of their business to succeed in the new environment.
8	Companies need to build digital capabilities. This comprises factors such as attracting digital talent and setting up cross-functional governance and steering.

8	Companies need to enable collaboration in the ecosystems. This requires getting involved in the definition of standards and cooperation across company boarders through alliances, strategic partnerships, and cooperation in communities.
9	Managing data as a valuable business asset will be important in securing crucial control points
9	Companies need to implement a two-speed systems/data architecture to differentiate quick-release cycles from mission-critical applications with longer turnaround times.
21	Companies need to integrate disparate sources of data from different applications to create a holistic view of the end-to-end process.
28	To fully leverage the value of data along the entire digital thread, information needs to be shared across company boarders- both with customers and suppliers. This means that company's need to build structures to exchange and integrate information. Outcomes of analysis need to be shared as real-time feedback across the value chain - from design and production through service and end of life - to allow quick reactions and adaptations.
28	Companies need to close the "digital gap" in production and install sensors and actuators across their production equipment. Data capture at the shop floor forms the basis for industry 4.0 levers such as predictive maintenance and real-time process optimization.
29	To capture the full industry 4.0 potential. Companies need to increase the flexibility of production. This applies to production lines and systems within a company on the one hand, and production networks across companies on the other.
41	Companies need to anchor agility in their organization to continuously be able to adapt to a changing competitive landscape. In a dynamic environment it is important to always be in the know about competitors and new entrants.
43	The digital transformation is a cross-functional effort that needs to be addresses by the whole company.
43	It will be vital to combine data, integrate systems and processes, and make decisions based on cross-functional information.

43	Smart companies will swiftly build a basic understanding of how to deal with industry 4.0 technologies and adapt to shorter innovation cycles for a broad range of employees.
43	Enterprises need to seek data and process experts who can operate at the interfaces between functions and systems and are well connected to the subject matter experts (whether shop-floor mangers, customer relationships managers, or supply chain managers). These experts should draw insights from the different types of information generated in all parts of the enterprise. When developing new (data-driven) business models, these experts are the hub for designing new products due to their broad knowledge of the overall production chain.
44	To gain a competitive advantage, companies should deeply involve themselves in defining future interoperability standards and ensure readiness of their organization and technology. As soon as industry standards evolve, all players will be forced to apply them to their products.
45	Given the importance of data and information, it is important to also treat and develop data as central business asset. This means data needs to be actively managed at all stages of the data lifecycle (ie collected, stored, analyzed, shared and archived) through defined data practices, standards and policies.
45	Management of data must also be fully integrated with core processes of a business model using data.
45	If data presents a competitive advantage - e.g. because data on customer behaviour helps to understand real customer needs - or intellectual property that is crucial for the company to deliver on its value proposition, it should be protected so as not to lose this advantage to the competition.
48	Companies need to act now, launching short-term initiatives immediately and preparing medium-to long-term initiatives that aim at transformation rather than augmentation.

49	Using Industry 4.0 as the path to the future of manufacturing will allow companies to do more than just upgrade their equipment and eliminate inefficiencies to increase their operational effectiveness. It will also give them the freedom to make the right strategic decision and reinvent their business model, preparing them to maintain a competitive edge in the global manufacturing market of the future.

Table A.5: Data collection from Reinhard, Jesper and Stefan [121]

Source: Industry 4.0: Building the digital enterprise - Reinhard, Jesper and Stefan [121]	
Page	**Quote on Industry 4.0 related change**
5	Companies will introduce new industrial products with digital features and augment their existing portfolio.
5	While digital technologies are rapidly becoming a commodity, success largely depends on an organisations Digital IQ1, especially how well its digital leaders like the CEO, CTO, or CIO define, lead, and communicate the transformation. Its also dependent upon the digital qualifications of the employees who need to roll out digital processes and services.
6	Horizontal integration stretches beyond the internal operations from suppliers to customers and all key value chain partners.
6	By integrating new methods of data collection and analysis, companies are able to generate data on product use and refine products to meet the increasing needs of end-customers.
8	Customers will be at the centre of the changes to value chains, products and services. Products, systems and services will be increasingly customised to customer needs.
8	Industry 4.0 will create digital networks and ecosystems that in many cases will span the globe, but still retain distinct regional footprints. Both developed and developing markets stand to gain dramatically.

12	First movers expect to gain significant benefits from their more advanced digital capabilities and greater levels of investment.
13	companies are moving to integrated planning and scheduling for manufacturing. Such systems combine data from within the enterprise from sensors all the way through to ERP systems with information from horizontal value chain partners, like inventory levels or changes in customer demand.
14	If even half of the expectations outlined are realised, some companies may find themselves unable to compete. In an increasingly cost-competitive market, no industrial company can afford to lose out in operational efficiency against their market peers. The next two to three years will be crucial for companies looking to catch up.
14	real-time data availability will enable companies to manufacture personalised products and customise solutions. These customised products usually generate significantly higher margins than mass-manufactured offerings.
14	Digitising products and services within the existing portfolio
14	New digital products, services and solutions.
14	Offering big data and analytics as a service
14	Personalised products and mass customisation
14	Capturing high-margin business through improved customer insight from data analytics
14	Increased market share of core products
14	Real-time inline quality control based on Big Data Analytics
14	Modular, flexible and customer-tailored production concepts.
14	Real-time visibility into process and product variance, augmented reality and optimisation by data analytics.
14	Predictive maintenance on key assets using predictive maintenance algorithms to optimise repair and maintenance schedules and improve asset uptime.
14	Vertical integration from sensors through MES to real-time production planning for better machine utilisation and faster throughput times

14	Horizontal integration, as well as track-and-travel of products for better inventory performance and reduced logistics.
14	Digitisation and automation of processes for a smarter use of human resources and higher operations speed.
14	System based, real-time end-to-end planning and horizontal collaboration using cloud based planning platforms for execution optimisation.
14	Increased scale from increased market share of core products.
15	As Industry 4.0 develops, the traditional model of products pushed out to the market will fade and 'customer pull', with customers intimately involved in a more collaborative relationship with manufacturers , will be much more the norm.
15	Digital integration with the customer and new technological opportunities to move production closer to the customer, for example with 3D printing.
15	The opportunity is there not only to greatly increase the ability to respond flexibly and more rapidly to customer demands but also to anticipate demands, helping the customer move ahead in a range of predictive ways.
19	data-analytics will play an increasingly central role in the future- but it wont fully replace other factors, particularly when it comes to major strategic decisions.
Page	**Quote on "how" to change towards Industry 4.0**
5	With so much change in store, theres area that companies cant afford to ignore: digital trust. Digital ecosystems can only function efficiently if all parties involved can trust in the security of their data and communication, as well as the protection of their intellectual property.
8	Industrial companies need to develop a robust digital culture and to make sure change is driven by clear leadership from the C-suite. Theyll also need to attract, retain, and train digital natives and other employees who are comfortable working in a dynamic ecosystem environment
10	To move forward with Industry 4.0, digital capabilities are all-important. These take time and concentration; a step-by-step approach is important. But move with deliberate speed, so that you dont lose the first-mover advantage to competitors.

10	Evaluate your own digital maturity now and set clear targets for the next five years. Prioritise the measures that will bring the most value to your business and make sure these are aligned with your overall strategy.
10	Design pragmatically to compensate for standards or infrastructure that dont yet exist.
10	Collaborate with digital leaders outside your organisation, by working with start-ups, universities, or industry organisations to accelerate your digital innovation.
10	success with Industry 4.0 will depend on skills and knowledge. Your biggest constraints may well be your ability to recruit the people needed to put digitisation into place.
10	Learn to get value out of data by building direct links to decision-making and to intelligent systems design.
10	Use the data to improve products and their use in the field to offer and build new service offerings.
10	Use partnerships or align with platforms if you cannot develop a complete offering internally.
17	Companies will need to make sure staff understand how the company is changing and how they can be part of it.
18	Expert and effective data analytics is essential to using data to create value. And with so many points of entry, companies need to take a rigorous, proactive approach to data security and related issues and work to build digital trust.
19	Companies need to expand their use of big data
19	To succeed, companies will need to use data in predictive, forward-looking ways that make sense of market developments and customer behaviour to improve products and develop new products and services.

25	It simply wont be possible for companies to achieve advanced digitisation without making a step-change in investment, given the continued rapid progress anticipated by companies who are already leading. The investment required to catch up is likely to be too costly, and faster-moving companies will have a significant advantage when it comes to positioning their offerings as a 'platform of choice' within a digital ecosystems.
25	Companies who jump in too late will find that their internal cultures have lagged behind.
26	To move forward with Industry 4.0, acquiring and rolling out digital capabilities across your company are all-important. This process takes time, so in order to gain or retain first-mover advantage over your competitors, you will need top management commitment and significant implementation investments.

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
Page	Quote	Number	Colloboration	Decsion Making	Real Time	Adoption rate	Technology	Cluster	Transparency	Flexability	Paradigm shift	Organisational change	Efficiency	Digital Capabilities	People	Standardisation	Business Model	Disruption	Feedback learning	Data	Ecosystem	Organisational Culture	Customer Focus	Leadership	Speed	Prcoesses	Transient	Rsik	Physical Resources	Product	Innovation	Control points	Effectivness	Digitise	Customisatiion	Quality	Optimisation	Investment	Modular
10	Mo	1	x																																				
10	All	2		x	x				x																														
10	Hov	3				x	x		x																													x	
15	Loc	4					x	x																															
17	The	5		x					x	x			x																										
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5	Cor	23	x	x					x												x																		
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12	Do	25	x														x	x			x									x	x							x	
17	Sen	26	x			x											x	x											x					x					
17	Exp	27																x	x				x																
17	Unc	28												x	x		x			x										x									
17	Bui	29												x	x																								
17	Par	30	x																					x														x	
17	Org	31												x	x									x	x														
17	Des	32																					x																

Figure A.1: Theme classification 1 of 3

20	Suc	33								x		x					x					x																	
20	Cor	34	x	x						x			x		x		x							x	x	x											x		
21	Cor	35			x														x	x				x			x												
21	Cor	36																						x	x		x												
22	Org	37		x								x			x							x		x	x														
22	Cor	38				x																			x	x	x			x	x								
24	To	39															x	x		x																			
25	Onl	40	x														x																						
25	Org	41	x																		x																		
32	Org	42												x	x																								
32	Dev	43												x	x																								
32	Mir	44												x	x																								
32	Brir	45	x		x									x	x									x															
33	Lea	46										x		x	x																								
33	Wh	47					x							x										x															
33	Org	48										x			x				x									x											
34	Cre	49	x				x								x																								
34	Wh	50					x							x												x			x									x	
34	If a	51	x											x												x			x										
7	Disr	52					x				x						x												x										
12	This	53					x																			x													
13	Anc	54	x				x						x		x										x														
13	In c	55																								x			x										
14	The	56					x														x					x			x										
21	Opp	57		x																					x	x													
23	Indi	58					x			x													x		x				x	x									x
25	Sinc	59											x		x										x	x			x								x		
27	Ren	60		x									x																x								x		
28	Mo	61	x	x												x				x																			
29	Anc	62		x						x																													
38	Nev	63															x				x									x									
39	Cur	64					x			x								x									x												
39	Sma	65								x							x									x													
39	For	66					x											x																					
39	Tra	67	x															x	x								x			x									
39	For	68	x																																				
41	It is	69	x														x	x						x															
43	Ind	70											x																		x		x						
44	One	71	x																	x						x													
44	Fro	72	x							x	x																												

Figure A.2: Theme classification 2 of 3

44	Alli	73	x			x		x																														
45	Wit	74																		x																				
7	Ma	75										x	x				x													x				x					
8	Suc	76	x	x					x				x													x			x										
8	Suc	77								x		x					x	x				x					x		x			x							
8	Nee	78										x		x																				x					
8	Cor	79										x		x	x																								
8	Cor	80	x					x								x					x																		
9	Ma	81																		x												x							
9	Cor	82																							x		x												
21	Cor	83		x																x						x													
28	To t	84	x	x	x					x									x						x					x									
28	Cor	85		x	x								x							x						x											x		
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43	The	88										x					x					x																	
43	It w	89	x	x																x						x													
43	Sma	90					x							x	x												x				x								
43	Ent	91		x										x	x		x			x										x									
44	To g	92										x				x														x									
45	Giv	93										x		x						x																			
45	Ma	94															x			x																			
45	If d	95		x																x								x		x									
48	Cor	96				x						x							x																				
49	Usi	97		x									x				x												x				x						
5	Cor	98																												x				x					
5	Wh	99												x	x							x		x		x				x									
6	Hor	100	x																																				
6	By i	101	x																				x																
8	Cus	102																					x																
8	Ind	103																			x																		
12	'Firs	104				x								x																								x	
13	Cor	105	x	x																x			x																
14	If ev	106				x							x																										
14	rea	107			x															x										x					x				
14	Dig	108																												x				x					
14	Nev	109															x													x									
14	Off	110												x			x			x										x									
14	Per	111																												x					x				
14	Cap	112		x																x			x																

Figure A.3: Theme classification 3 of 3

The following code in Figure A.4 was used to determine the co-occurrences between themes. Its output is seen in Figure 4.2

```
Sub occurrences()

Dim p As Integer
Dim s As Integer

Worksheets("Totals").Range("B4:AL40").Clear
For p = 4 To 40
For s = 4 To 40
Count = 0
  For n = 3 To 146
    If Worksheets("Quotes").Cells(n, p) = "x" Then
      If Worksheets("Quotes").Cells(n, p) = "x" And Worksheets("Quotes").Cells(n, s) = "x" Then
        Count = Count + 1
      End If
    End If
  Next n

  Percentage = (Count) / (Worksheets("Totals").Cells(2, p - 2))
  Worksheets("Totals").Cells(p, s - 2) = Percentage

Next s
Next p
End Sub
```

Figure A.4: Co-occurrences macro code

Table A.6: Caption

Collaboration
Building relationships outside of the traditional value lane.
Outsourcing used as a means of agility with a focus on variable costs
Locating within (or creating) clusters.
Forcing new projects to use outsourcing as means of tying into the ecosystem.
Collaborate with companies who are involved with disruptive trends as a means to survival.
Employee exchange as a means of bringing new skills into own business.
Sharing of outcomes across value chain, end to end planning.
Digital trust is necessary to enter into partnerships

Be part of the definition of standards, or build systems in a way that can cope with future changes in standards. Standardising inline with target suppliers/customers will make your own business and attractive partner.
Digital Capabilities
Develop what is necessary, dont need all of them, align to business model and value proposition
Use the on demand economy for acquiring capabilities instantly.
Train analytical thinking and digital competency into all employees or create teams with these skills
Be aggressive and proactive towards developing digital capabilities.
Most capabilities will promote organisational speed
First mover advantage
Business Model
Understand and forecast disruption by constantly checking for new revenue models outside of own industry that are transferable, expect merge between digital and physical.
Software + Service + Core (Technology companies)
Willingness to self disrupt
Maintain core business, inspire innovation at edge aligned with disruptive trends but focus on solving customer problems.
Business Models: Data driven, platforms, developer eco-systems, control points
Model must support partnerships and platforms
Narrow Focus on disruptive technology by smaller companies
Disruptive technology brings opportunity to enter existing value pools
Customer focus, product customisation, pull becomes norm, 3D printing
Data
Data is a source of competitive advantage and a precursor to most other things in industry 4.0

Real-time data is important, you may not care much for it but partners up and down the supply chain might find it crucial to their performance.
Use of evaluating effectiveness, support employee decision making.
Data must flow both internally and externally
Data management is crucial in securing control points
Integration of data to get a holistic understanding
Must be viewed as a central business asset.
Data protection where it is crucial to competitive advantage.
Used to find and capture high margin markets.
Data security is so important and linked to digital trust.
Decision Making
Transparent and in Real-time (Both internally and externally)
Visualisation of data
Feedback learning over past data extrapolation due to pace of change
Feedback learning for speed
Decision making must be done faster and become automated where possible
Decision making is dispersed amongst empowered employees
Decentralization of intelligence increases flexibility
Companies need to remain informed to remain competitive in a dynamic landscape
Decision making is enabled by data and analysis
People
Paradigm shift
Must have easy access to relevant data
Industry 4.0 culture should promote flexibility, innovation and encourage risk taking, with employees being empowered

Leaders have an intuitive sense of how to use partnerships for success.
Flatter organisational structures for flexibility and speed
Develop necessary skills and actively train talent.
Leaders need to have and hire people with a mind-set that challenges the status quo, this mind-set needs to infiltrate the whole company.
Leaders must be digitally fluent and in the know
People should be made more effective (reduce waiting, eliminate menial tasks, etc.) since labour is traditionally a significant cost
People need to be taught dynamic capabilities in order to manage and take advantage of change.
Success depends on leaders ability to transform their organisations, and employees ability to implement digital initiatives
Biggest constraint will be finding/training employees who can put digitisation in place
Employees will need clear vision and understand how they can be part of change
Organisational Change
Ability to change becomes fundamental to competitive advantage
One year planning cycle, with shorter goal revisions
Competitive advantage is found in transience and having multiple initiatives at once with shorter life cycles
How ideas are managed and products/serviced developed needs to be re-evaluated towards speed
Smaller companies are more agile and can change business models faster
Determined effort towards digital building blocks
Understand changing competitive dynamics and engrain agility into the company
Implement short-term initiatives immediately and medium/long term initiatives that focus on transformation not augmentation

Timing of change (Early unnecessary investment vs Late too much change required to quickly without supporting culture)
Operations
Cross system consistency improves flexibility, production flow and speed.
Traditional process will be stretched in new directions both internally and externally
Speed and flexibility will become expected, lean operating needs to be embraced to operate with the speed of the ecosystem
Big data, the internet of things and cloud technologically offer significant opportunities to reduce costs and infrastructure requirements
I4 is underpinned by lean principals
Machine/equipment replacement does not need to be significant, rather sensors should be attached to existing machines/processes where data can be used towards process optimisation.
Build modular operations that enable flexibility and scalability
Remote monitoring and predictive maintenance can be used for significant efficiency gains
Physical production assets must be digitally integrated
Operations must be viewed holistically beyond a companies own boundaries
Markets will become exceeding cost competitive, it will be difficult to compete with digitally advanced production
Look to digitise existing processes and products
Industry 4.0 is about smarter use of human resources and increased speed in production

A.2 Images

Table A.7 shows the reference for icons used in this report. The references are not included in the bibliography because the icons are not author specific and licensed as ‘open for reuse’. They can be republished freely for creative purposes and only exist as URL links.

Table A.7: Icon references

Figure	Description	URL link
Figure 4.5	World	http://www.freeiconspng.com/img/13145
Figure 4.12	Man	http://www.irc.unrc.edu.ar/wp-content/uploads/2016/04/logo.jpg
Figure 4.12	Business	https://t3.ftcdn.net/jpg/01/71/87/06/240_F_171870678_KRlezyqs5oWkNppa2fi48VgpBXfne0mp.jpg
Figure 4.12	Puzzle	https://pixabay.com/p-1020409/?no_redirect
Figure 4.12	Wi-Fi	https://n6-img-fp.akamaized.net/free-icon/wifi_318-108229.jpg?size=338c&ext=jpg
Figure 4.12	Arrow	https://upload.wikimedia.org/wikipedia/commons/4/45/Right-facing-Arrow-icon.jpg