COMPETITIVE ADVANTAGE DURING INDUSTRY 4.0: THE CASE FOR SOUTH AFRICAN MANUFACTURING SMES

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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 internet of things and cloud computing can significantly reduce infrastructure requirements and promote a competitive advantage.

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1. INTRODUCTION

One of the key drivers of knowledge capital and economic prosperity in a country is manufacturing [1]. According to Kaldor [2], an increase in manufacturing output leads to a direct overall increase in gross domestic product and an increase in productivity from sectors outside of the manufacturing sector. Manufacturing is one of the few sectors that exhibits this characteristic, where a net positive output leads to growth both within and outside of the sector. It is, therefore, one of South Africa’s most important sectors for overall economic growth.

Small to medium enterprises (SMEs) contribute 40% of South Africa’s manufacturing gross domestic product output [3]. SMEs are a vital component of the South African economy and provide a large portion of South Africa’s much-needed jobs [4]. SMEs in South Africa have traditionally operated in a challenging environment, facing issues such as limited access to skills, funding and developed infrastructure as well as crime and strict regulation [3,4].

With the dawn of the next industrial revolution (Industry 4.0), manufacturing as a whole is expected to undergo significant change. Industry 4.0 differentiates itself from the third industrial revolution by having technology link operations and make localised decisions through the internet. This will enable “intelligence” to be built into operations with production items such as machines making decisions [5]. Industry 4.0 is linked to technologies and concepts such as cloud computing, artificial intelligence, 3D printing, cyber-physical systems and smart factories [6]. Through industry 4.0, manufacturing processes and resource allocations will significantly change giving manufacturing SMEs the opportunity to develop and provide downstream services [6,7].

With the expected change and disruption that industry 4.0 will bring, along with the challenges that SMEs face in South Africa, there exists a very real threat for the small to medium manufacturing sector in South Africa. It is therefore important to understand how industry 4.0 will affect manufacturing SMEs and what can be done to retain or grow their competitive advantage. This study explored how South African manufacturing SMEs can remain competitive during the fourth industrial revolution. This was achieved by investigating possible sources of competitive advantage during the fourth industrial revolution and determining the actions and means by which manufacturing SMEs can generate competitive advantage during the fourth industrial revolution. A framework for decision-makers in SMEs was finally developed that will assist the creation of competitive advantage during the fourth industrial revolution.

2. LITERATURE REVIEW

2.1 Small to Medium Enterprises

SMEs in South Africa are defined as businesses that have no more than 200 employees and generate a maximum revenue of R40 million per annum [8]. Some of the challenges SMEs face in South Africa include; access to finance [9], labour law [10], crime [10], access to necessary resources [11], access to markets [12], research and development [3], regulation and policy [13] and unskilled labour [3].

2.1.1 Growth and Competitive Advantage

The International Trade Centre [14] 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 certificates, 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, Figure 1, shows that there is a strong positive correlation between SME size and competitive performance. Figure 1 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%.

SAIE29 Proceedings, 24th - 26th of October 2018, Spier, Stellenbosch, South Africa © 2018 SAIE
2.1.2 The potential impact of industry 4.0

It cannot be said for certain that industry 4.0 will have a negative or positive effect for South African SMEs especially those within the manufacturing sector. There are very real threats that industry 4.0 poses such as increased competition from the global market, loss of unskilled jobs and an increase in financial commitment. There is evidence to suggest that technology has had a positive impact on SMEs and that cloud computing could actually alleviate many of the challenges SMEs currently face [15,16].

2.1.3 Adoption of industry 4.0

Industry 4.0 adoption by SMEs in South Africa and other BRICS countries is relatively low, with the focus of industry efforts being put towards skills development and preparation of the workforce for industry 4.0 [17]. Although South African SMEs face a number of barriers to industry 4.0 adoption, many international SMEs face similar challenges, even those in industry 4.0 leaders such as Germany [18]. One of the biggest challenges facing all SMEs is the considerable amount of investment which is required to adopt industry 4.0 [18].

As this study explored how South African manufacturing SMEs can remain competitive during the fourth industrial revolution, the concepts of competitive advantage and industry 4.0 will be elaborated on through the literature.

2.2 Competitive Advantage

Competitive advantage is an area of knowledge with many theoretical views and theories. Two academic definitions of competitive advantage are:

“Competitive advantage is obtained when an organisation develops or acquires a set of attributes (or executes actions) that allow it to outperform its competitors” [19].

“The degree to which a firm has reduced costs, exploited opportunities and neutralized threats” [20].

The following list serves as a brief summary of each theoretical view covered in the study with Figure 2 outlining a conceptual framework of competitive advantage theories.
Market-Based View: External factors and a firm's positioning in the market predominantly effect its performance [21].

Resource-Based View: Internal process and management of resources affect the performance of a firm [22].

Knowledge-Based View: Knowledge is the most important resource and separate from other resources [23].

Capability-Based View: The use of resources through distinct capabilities governs competitive advantage [24].

MBV and RBV ‘fit’: The necessity of both internal (resource-based view) and external (market-based view) perspectives [25].

Relational View: A firm's relation within the network leads to competitive advantage [26].

Transient View: Opportunities for competitive advantage are transient and long-term perspectives can no longer achieve sustainable competitive advantage regardless of whether or not an internal or external view is taken [27].
2.3 Design Principles of industry 4.0 and key components

There is no generally accepted working definition of industry 4.0 [28]. There has however been a set of industry 4.0 design Principles outlined by Hermann, Pentek and Otto [28], which are useful for understanding the fundamentals of Industry 4.0. The design Principles are:

2.3.1 Design Principle 1: Interconnectedness

The connection of people, machines, devices and sensors to create a networked ecosystem is fundamental to industry 4.0. Without interconnection, the sharing of information in real-time cannot happen and many of the efficiency benefits gained through industry 4.0 will not be realised. Interconnection also forms the backbone of collaboration between businesses and supply-chains, allowing them to share information (design principle 2) and achieve data-driven decision making [28].

Two important technologies that relate to the design Principle of interconnectedness are cyber-physical systems and the internet of things. Cyber-physical systems can be defined as “a new generation of systems with integrated computational and physical capabilities that can interact with humans through many new modalities” [29]. These systems take into account the interaction and interdependency between what would have traditionally been seen as a physical system and a cyber-system [30]. They can be roughly thought of as the merger between the physical environment and the internet.

The internet of things is “a network of internet-connected objects able to collect and exchange data using embedded sensors” [31]. Chebudie, Rotondi and Minerva [32] found that there are certain fundamentals to the internet of things. These are:

- The connection of objects - For the network to function the connection of the “things” is necessary (design principle 1). Each object must also be uniquely identifiable and have sensing/actuation capabilities often making it a smart device.
- Ubiquity - The network is available anywhere or anytime and there is a continual link between the network and the internet.
- Embedded intelligence - smart devices exhibit their own emergent behaviour.
- Self-configurability - Each object connected the network manages its own configuration, software requirements, resources and energy consumption. Allowing the network to scale to a large size.
- Programmability - Refers to devices in the network that can execute different tasks without having to change physical form.

2.3.2 Design Principle 2: Information transparency

Industry 4.0 requires almost unrestricted data sharing, with information transparency increasing tenfold relative to industry 3.0. A true industry 4.0 state will exist when hundreds of sensors are capturing data and feeding that information into plant and supply chain models, creating a virtual copy of the physical world. These models will be filled with “context-aware” information, allowing participants in the network to make hyper-informed decisions in real-time [28]. Two key components linked to information transparency are Big Data and Cyber Security.

Big Data is defined as data sets (or streams) that are “not only big, but also high in variety and velocity, which makes them difficult to handle using traditional tools and techniques” [33]. Due to the large number of sensors and information streams in industry 4.0, significant data analytic capabilities will be necessary for businesses to make correct decisions [33].

Cyber-crime will be one of the greatest threats for business during industry 4.0 [34]. Although companies will share large amounts of internal information with the network, there will be data that is sensitive and important to that companies success. With all the connection points into the network, companies will need to strengthen their cybersecurity in order to protect data that leads to competitive advantage [34].

2.3.3 Design Principle 3: Decentralised decision making

Once interconnection (design principle 1) and information transparency (design principle 2) have been established, decentralised decisions can be made. “Decentralised” refers to an object in the network having a form of local intelligence to operate and make independent decisions [28]. Decentralised decision making will require artificial intelligence and the in many cases the use of cloud computing.
Artificial intelligence is simply machines (or virtual machines such as bots) exhibiting human-like cognition [35]. It is an extremely broad field but a critical component to industry 4.0 and one of the distinguishing factors from industry 3.0.

The access and “sharing of web infrastructure for resources, software and information over a network” is known as the Cloud or Cloud Computing [36]. It is simply the pooling of IT infrastructure, storage and computing power. It will enable businesses to access key digital capabilities from almost any geographical location in a manner that will allow scalability. The Cloud in many instances runs off a pay-per-use business model which will allow businesses of all sizes access to very important industry 4.0 capabilities such as data analytics and artificial intelligence [36].

2.3.4 Design Principle 4: Technical assistance
The role of people will begin to shift from operators to strategic decision makers as industry 4.0 matures [28]. With the vast amount of connections and data streams, people will rely on systems to support and assist them, presenting information in usable formats for problem-solving purposes [37]. Robots will also carry out difficult, unsafe and monotonous tasks on behalf of people [28].

Industry 4.0 is expected to change the nature of work, with a shift towards human-machine collaboration. Jobs that require repetitive non-skilled tasks are at greatest threat of being made redundant by robots [38]. Many jobs will be lost to industry 4.0 advancement, but a net positive increase in jobs is expected. New forms of work will be created in the areas of IT and data analytics [38]. The challenge from companies will be re-skilling staff to make the shift towards industry 4.0 [38].

3. RESEARCH DESIGN AND METHODOLOGY

The nature of this study is substantially 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 [39]. Exploratory research can normally also be classified as inductive research because it moves from the general towards the specific [40]. 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 [39].

It was 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 [40]. 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. For many companies, adopting an industry 4.0 state right now would be too expensive. 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. 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.

3.1 Literature search and selection

Literature was found through keyword searches and snowball sampling [41]. Keywords were used in multiple combinations and included the terms; industry 4.0, Industrie 4.0, digitisation, manufacturing, competitive, advantage, industrial, revolution, smart factory and future. Google Scholar was used along with databases such as E.I Compendex, Inspec, National Technical Information Services and Scopus. Literature was then selected on the basis that it was relevant to the research objectives in part or in full and two additional criteria [42]. The first criterion was concerned with the target audience. Literature that was written for business leaders and
managers was favoured to ensure that the research would be targeted at decision makers within SMEs and offer practical value. The second criteria related to the diversity of thought. Literature that covered a broad range of the research topic was favoured in order to ensure that a holistic outlook on the subject was met and that research remained exploratory [43]. The search and selection process was done in parallel to the analysis of the research so that the selection could stop once information saturation had been reached [44].

3.2 Analysis

The research data was analysed using thematic content analysis. There is no single method for conducting a thematic analysis but rather used by research as necessary [45]. This type of analysis has been criticised for being open to reliability errors due to researcher interpretation and understanding [46]. It is however well suited to large qualitative data sets [46]. The literature analysis process involved reading through the research several times for familiarisation. Direct quotes were then extracted from the literature that related to competitive advantage under any of the theoretical views examined through the literature survey. These quotes were then classified into a set of initial themes. These initial themes were refined through a co-occurrence analysis and a set of final themes were selected.

4. RESULTS

A total of 36 emergent themes were found in the literature. A co-occurrence analysis was done on the quotes to understand which themes frequently occurred together in the same quote. Themes that had a 60% or higher co-occurrence rate another theme were considered to be sub-themes. After refinement 8 final themes were used toward the final results. Table 1 below shows the theme and its ranking by frequency of occurrence.

<table>
<thead>
<tr>
<th>Theme Ranking</th>
<th>Ranking</th>
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<tbody>
<tr>
<td>Collaboration</td>
<td>1</td>
</tr>
<tr>
<td>Digital Capabilities</td>
<td>2</td>
</tr>
<tr>
<td>Business Model</td>
<td>3</td>
</tr>
<tr>
<td>Data</td>
<td>4</td>
</tr>
<tr>
<td>Decision Making</td>
<td>5</td>
</tr>
<tr>
<td>People</td>
<td>6</td>
</tr>
<tr>
<td>Organisational change</td>
<td>7</td>
</tr>
<tr>
<td>Operations</td>
<td>8</td>
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</table>

The results of the final themes are presented in Table 2.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Findings</th>
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<tbody>
<tr>
<td>Collaboration</td>
<td>• Employee exchange as a means of bringing new skills into the business.</td>
</tr>
<tr>
<td></td>
<td>• Sharing of outcomes across the value chain.</td>
</tr>
<tr>
<td></td>
<td>• Collaborating with companies who are involved in disruptive trends as a means to survival.</td>
</tr>
<tr>
<td></td>
<td>• Building relationships outside of the traditional value chain.</td>
</tr>
<tr>
<td>Digital Capabilities</td>
<td>• Use the on-demand economy for acquiring capabilities.</td>
</tr>
<tr>
<td></td>
<td>• Only develop digital capabilities that are necessary and align with the business model.</td>
</tr>
<tr>
<td></td>
<td>• Be proactive and aggressive towards developing digital capabilities.</td>
</tr>
<tr>
<td>Business Model</td>
<td>• All companies need to become “technology” companies.</td>
</tr>
<tr>
<td></td>
<td>• The business model must support partnerships and platforms.</td>
</tr>
<tr>
<td></td>
<td>• Understand and forecast disruption by constantly checking for new revenue models outside of the current industry that are transferable.</td>
</tr>
<tr>
<td></td>
<td>Expect integration between digital and physical.</td>
</tr>
</tbody>
</table>
Maintain the core business, inspire innovation at the edge aligned with disruptive trends but focus on solving customer problems.

Data
- Data is a source of competitive advantage and a business asset.
- Data security is linked to digital trust and important for partnerships.
- Data should support employee decision making and create a holistic understanding of the business.

Decision Making
- Should be based on feedback learning instead of past data extrapolation due to the fast pace of change.
- Must be done faster and automated where possible.
- Companies need to remain informed to remain competitive in a dynamic landscape.
- Decision making is dispersed amongst empowered employees.

People
- Employees made more effective through technology.
- Leaders must become digitally fluent and have an intuitive sense of how to use partnerships for success.
- Success depends on leaders’ ability to transform their organisations, and employees’ ability to implement digital initiatives.

Organisational change
- Ability to change becomes fundamental to competitive advantage.
- Implement short-term initiatives immediately and medium/long term initiatives that focus on transformation, not augmentation.
- Smaller companies are more agile and can change business models faster.

Operations
- Big data, the internet of things and cloud technology offer significant opportunities to reduce costs and infrastructure requirements.
- Operations must be view holistically and beyond a company’s own boundaries.
- Industry 4.0 is underpinned by lean manufacturing which needs to be embraced to operate with the speed and flexibility of the ecosystem.

4.1 Framework
The results were refined into a framework that can be used by decision-makers in SMEs which is shown in Figure 3.
Figure 3 - Industry 4.0 framework

5. DISCUSSION

The research findings presented in this paper offer ideas and thoughts towards maintaining or growing a competitive advantage from the perspective of manufacturing SMEs in South Africa. The findings presented are by no means exhaustive or applicable in every case, they merely offer a starting point to further investigation and should be used as such. The research thus has a number of limitations that should be considered:

- The research is purely based on literature, which limits its practical application. Although there are few true subject matter experts with knowledge of both manufacturing SMEs and Industry 4.0, there are people who have expertise in overlapping or similar fields. Their contribution would offer an ever further diversity of findings and possible make the research more practically applicable.
- The research is positioned as an introduction to further work and therefore lacks a degree of detail to make it practically sound. This is especially true for the framework presented in Figure 3. The
framework is primarily used towards simplifying the main findings and translating them towards high-level intentions a manufacturing SME can take. The specific details of application are not included in this study and should be investigated further as developments within industry 4.0 unfold and true adoption occurs in international locations.

Related to the limitations of the research, there are also a number of limitations and constraints for SMEs in taking steps towards industry 4.0. These limitations are mainly governed by the current state of SMEs in SA and include access to finance, physical resources, knowledge and skilled labour [3,9,11]. These factors constrain the adoption of industry 4.0 and make implementing any findings from the research challenging. Despite these limitations, there will be some degree of change that SMEs can begin to make. The strategic level actions and intentions presented in Figure 3 will offer guidance to this change and provide a fixed point that can be worked towards while Industry 4.0 develops further.

The most prominent themes were collaboration and digital capabilities. The idea that collaboration is fundamental to competitive advantage during industry 4.0 is not surprising since industry 4.0 will essentially be the development of a giant network or ecosystem [47]. A businesses ability to tie into the ecosystem will be crucial, where each new connection (or relationship) will be an opportunity to offer value. As the number of routes to market increase and become more flexible, traditional linear supply chains will be less common. A single business may be a node for many different routes to market and thus sharing information much further up and down the supply chain becomes important. Digitally integrating operations with partners up and down the supply chain will ensure a business remains relevant.

The idea of collaboration goes past just business-to-business relationships. Collaboration between humans and the cyber-physical environment will also be an important element of survival. Business who understand how to use their current workforce in partnership with technologies such as artificial intelligence and robotic will outcompete firms who choose to ignore these advancements. It is difficult to determine when the most economical point in time is to make an investment into these kinds of technologies but business should prepare themselves for integration and ensure their knowledge and understanding of these technologies remain current. Clusters (partnerships between universities, industry and government) where resources are shared and new technology can be tried and tested will be a good way of ensuring a business remains informed [48].

The last major source of collaboration will be through outsourced capabilities. The on-demand economy and cloud services offer small business the opportunity to scale and pick-up necessary skills as and when they need them. This leads directly to the theme of digital capabilities. Companies will ultimately remain competitive by developing digital capabilities that will allow them to remain relevant keep up with the manufacturing efficiency and quality of the world market.

Digital capabilities speak directly to the resource-based view of competitive advantage, where above normal opportunities are produced through the management of internal resources such as knowledge and machinery. For small businesses, obtaining all digital capabilities is not necessary. Rather capabilities which align to the business model should be actively sought after and developed [47]. First mover advantage will be important. A business that starts to acquire digital capabilities early on will build up internal knowledge on these capabilities much faster than a company that delays. With the rate at which industry 4.0 will bring about change, there may be a critical point where learning and development needs to happen faster than what a business can actually manage. Business should develop digital capabilities as soon as possible to avoid being left behind.

6. CONCLUSIONS AND RECOMMENDATIONS

Two of the biggest challenges that face the South African manufacturing sector is the lack of skills necessary to implement industry 4.0 along with a lack of exposure to industry 4.0. South African industry 4.0 learning factories, which simulate an industry 4.0 environment as far as possible, could potentially address these challenges and should be explored by relevant stakeholders. These factories should be set up within clusters so that knowledge and understanding is shared across academia, business and government.

Cloud computing also has the potential to alleviate some of the challenges faced by SMEs. [16] It can potentially be used by the government to offer mass support to SMEs (within all industries) through the development of free software packages that assist in core business functions such as accounting, financial management, legal and labour requirements.
7. REFERENCES


