Evaluation of the factors which harness firm level innovation for Industrie 4.0 in South Africa

Applied Research Project Article

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Abstract

The purpose of this study was to determine factors that harness manufacturing firm-level innovation for Industrie 4.0 in South Africa (SA). This study is driven by three research questions. Quantitative methods were used to find answers to the research questions and a solution to the research problem. The main research question asked was: what are the factors that harness innovation techniques, the fourth industrial revolution's levers in South African firms? To find answers to the research questions an online survey questionnaire was sent to 105 participants. The participants were IT executives, managers involved in decision making about technological projects and technical personnel dealing with the implementation of IT and automation projects from various manufacturing firms in South Africa.

Theories of Innovation diffusion by Rogers, as well as Classical theory by Karl Marx were used in this study. Based on the literature review and the results gained from the participants responses to the survey questionnaire, the findings of this study showed that local firms need the following skills: Problem Solving; IT knowledge and abilities; Decision making; Ability to interact with modern interfaces; and Data and Information processing and analytics. Following from classical and innovation diffusion theories, the study concluded that availability of the above-mentioned skills; a clear business case that justifies for investments in the firms' IT architecture; difficulty in coordinating actions across different organisational units using the common network brought about by the Cyber-physical production system; courage to push through radical transformation and integration of data from disparate sources to enable Industrie 4.0 applications were essential for Industrie 4.0.

Keywords: Industrie 4.0, Internet of Things, Robotics, Artificial Intelligence, Cyber-physical production systems, Innovation, Automation, Human-Machine Interface.

Introduction

Most discussions on the countries' differences in terms of economic development and competitiveness suggest that the outcomes are directly related to the amount of investment in technology and innovation (Zawislak, Borges, Wegner, Santos, & Castro-Lucas, 2008). As economies develop, they do so depending on the contributions of firms to the country's growth domestic products. This type of economic development towards Industrie 4.0 has substantial influence on the manufacturing industry (Stock & Seliger, 2016). Industrie 4.0 is introduced as a new technological change or stage.The introduction of technological change presents a challenge for South African firms to join in or face stagnant economic growth, declining profit margins, and more.

The technological change comes as a stage in the industrial revolution cycles. The stage follows from other industrial revolutions which ended on the third stage where automation using programmable logic controllers (PLC) was the main thing. Industrie 4.0 is the fourth stage which is about merging virtual reality with physical reality. The introduction of a technological change or advancement, presented as the fourth industrial revolution, promises growth, profitability and employment in the manufacturing sector. In the current manufacturing context, the introduction of new technologies represents a challenge for the national and international manufacturing industries, making them more exposed to market competition (Laudante, 2017).

Investments in these technological changes are no longer a matter of choice, but rather a strategic business decision necessary for a firm's survival. Global firms innovate and take advantage of the Industrie 4.0 benefits, something that local South African firms should consider. The introduction of Internet of Things, Robotics and Artificial Intelligence (AI) are amongst the few tactics that manufacturing firms utilise in this fourth stage of the industrial revolution. This is particularly relevant for how manufacturing processes work and the response of manufacturing firms to the need of smart products, using smart factories. To respond to such, local businesses need to have new and disruptive business models that are evolving around the Industry 4.0 elements. Stock and Seliger (2016) argue that this development towards an Industry

4.0 provides immense opportunities for realising sustainable manufacturing, using the ubiquitous information and communication technology (ICT) infrastructure. Facing the industrial revolution ahead, manufacturing firms need to start developing a comprehensive vision of how they will run their business in the future (Bechtold, Lauenstein, Kern, & Bernhofer, 2014). Like any other country, South Africa's manufacturing industry faces serious economic challenges as a result of the increased pace of societal and technological advancements. Amongst those challenges are access to faster connectivity, robust networks, secured internet connectivity and a relevant skill set that is responsive to the current challenges and opportunities presented by Industrie 4.0. These challenges require local firms to develop innovation and technological capability that will help to manage the whole value-chain in an agile manner. This is necessary for local firms to compete in a fast-moving global market.

Besides producing goods and services, the firm's role is to promote technological change and innovation (Zawislak, Cherubini Alves, Tello-Gamarra, Barbieux, & Reichert, 2012). Teece (2010) concurs that a firm is the most important institution through which technological change is affected. The promotion of technological change and innovation is critical in South Africa, especially in the manufacturing sector. The intention of this study was to identify and evaluate the factors that harness firm level innovation for Industrie 4.0 in South Africa (SA). How the identified factors can be resolved so as to help local manufacturing firms to implement the fourth industrial revolution is also important for this study. This also includes the skill set that will put SA firms in a competitive state, as they exploit the benefits of the fourth industrial revolution.

This paper is organised in such that it gives a background of Industrie 4.0, applicable theories, technological innovations resulting from this revolution and firm performance, as well as their relationships. Following that, the method used in this research is presented and data analysis and results are presented. Lastly, a conclusion and final remarks on this research is made together with recommendations.

The Industrial Revolution

Bloem et al. (2014) proclaim that wherever we get down to do any work – be it on the factory floor, on the railway line, or even if the work only involves doing the laundry or brushing our teeth – there is a silent revolution taking place. This revolution is a result of internet, sensors and embedded systems. This revolution can be considered as the stage where cyber-physical systems (CPS) are taking off (Bloem et al., 2014; Lee, Bagheri, & Kao, 2015). This stage is more of a development from the previous which was about automation and the importance of information technology. From CPS, the Cyber-Physical Production Systems (CPPS) is introduced as an added advantage to the production systems. Deloitte (2014) defined CPPSs as online networks of social machines that are organised in a similar way to social networks. This means industrial networks can now be structured the same way as social networks are being structured in a secured manner for the benefit of firms.

Based on the definition, it is becoming clear that a window of opportunity is opening, where the connections between mental, physical and mechanical activities are taking place. The connection between sensors, systems, humans and the internet is beneficial to businesses in general. However, customers, the public and firms will also benefit. South African firms, as global participants, should thus exploit the opportunities brought by Industrie 4.0 to improve their competitiveness. While this phase is characterised by a fusion of various technologies, there is a clear observation that blurring lines are emerging between the physical, digital, and biological spheres (Schwab, 2015). Succeeding in the next industrial era requires manufacturing firms to define and shape their core value drivers, enabled by digital technologies (Bechtold et al., 2014).

History of Industrial Revolutions

In this study, the use of the terms such as Internet of Things, Industrial Internet and Internet of Everything shall have the same meaning as Industrie 4.0. Such terms are widely used in English speaking countries, while Industrie 4.0 is widely used in the Germanic countries. Industrie 4.0 refers to a further developmental stage in the organisation and management of the entire value chain process involved in the manufacturing industry (Deloitte, 2014). Prior to the first industrial revolution, communities or societies around the world were engaged in farming for subsistence, using hard labour. This era was further characterised by the introduction of mechanical production facilities. As a result of evolution and modernisation, the use of hard labour was reduced, and machinery was introduced (i.e. tractors). Most of the machinery was powered by electrical energy as opposed to water and steam of the previous revolution. New ways of doing things (technology) were introduced and commercialised for the societal good and development. Automation through the introduction of electronics, programmable logic controllers (PLC) and IT came into the picture. Figure 1 is used to show all stages of the revolutions. The focus of the study is however, on the last stage, which merges the virtual reality with physical systems. This merger is very helpful for the manufacturing firms because of the benefits brought about by cyber-physical production systems. Figure 1 below shows CPPS as the fourth industrial revolution.

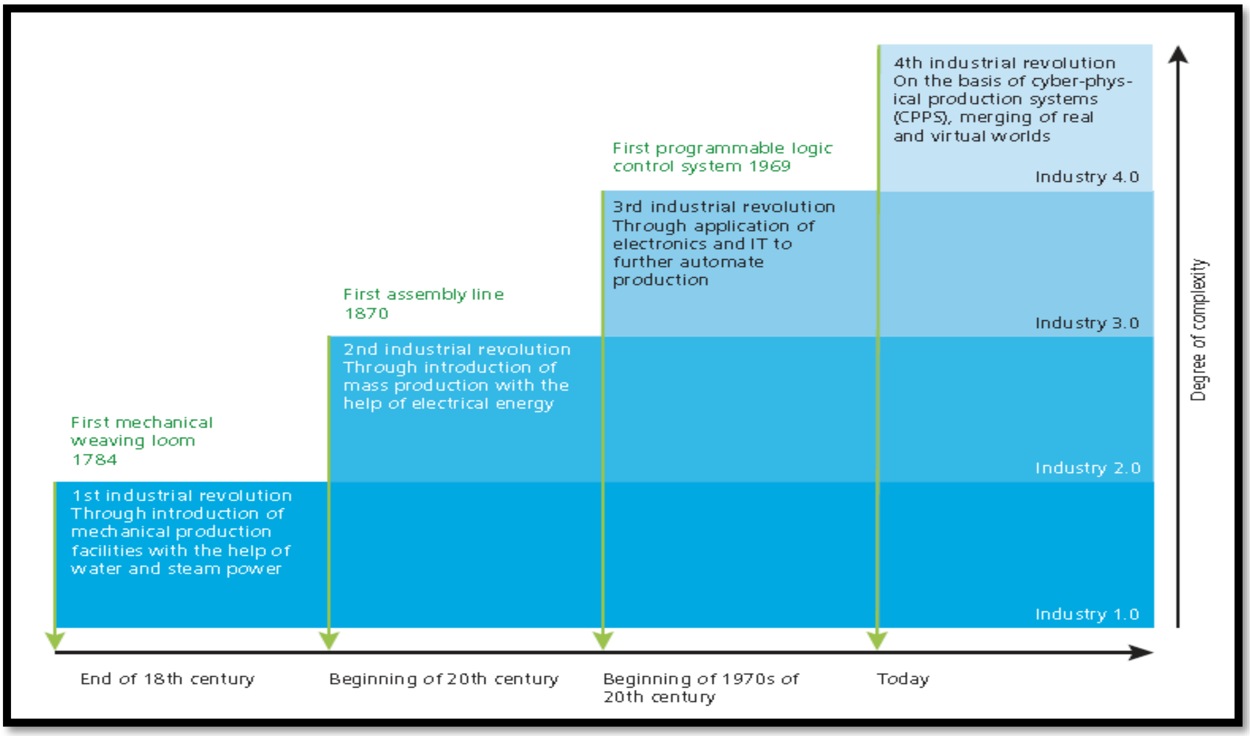

Figure 1: CPPS as the fourth industrial revolution (Deloitte, 2014)

Figure 1 above illustrates that for some time, most industrial processes have increasingly embraced modern information technology (Deloitte, 2014) which goes beyond just automation of production systems. Modern information technology helps one to make decisions because of the availability of data from the factory floor. Figure 1 demonstrates that the stages have always been informed by new inventions, as a result of the technological advancement as societies evolve. Bahrin, Othman, Nor, and Azli (2016) assert that the first industrial revolution was attributable to the invention of the mechanical loom from 1764, while the second revolution was associated with the Ford assembly belt from 1913, the third to the first Programmable Logic Controller (PLC) in 1968. This study is focused on the fourth stage (current stage), which is about advanced technological innovation, internet of things, cyber-physical production systems, etc. In the diagram represented in Figure 1, the first three revolutions shown were all technology-driven and their similar evolutionary developments which suddenly gathered momentum are also shown. Consequently, the revolutions changed the established mechanisms of industrial value creation (Kiel, 2017) and clearly showed that technological innovation driven by Industrie 4.0 is very important in a dynamic society.

Industrie 4.0

This section introduces Industrie 4.0 as a concept, what it entails and its relevance to the study. Benefits of the concept for South African manufacturing firms are identified. The section also identifies the ways in which local firms can take advantage of these benefits. It concludes with the discussion about the four pillars of Industrie 4.0 with specific reference to the two legs that are critical to the study. The future business model and its enablers are discussed in order to give local firms a base from which to start when implementing Industrie 4.0. Industrie 4.0, as a concept, involves the integration of physical and digital technologies with the phases of the product or manufacturing process.

This integration is very important for this study in a sense that it will help local firms to grow their businesses. This technical integration will facilitate fundamental improvements to current industrial processes that firms use in their everyday activities. The processes involved include manufacturing/production, engineering, material usage, supply chain and life cycle management of various projects in a firm. In a way, this stage (Industrie 4.0) is about the next generation of personal computing, whereby objects interact, potentially interdependently, with each other and with their environment (Meunier et al., 2014). In most local firms, there is a problem of firms operating in different networks, where Information Technology and Operational

Technology are separate and expensive to maintain. In simpler terms, the information technology (IT) network is integrated with the operational technology (OT) network. This integration of IT and OT is beneficial to the industry through yielding profits in the following manner:

- Enables predictive maintenance and therefore maintenance cost reduction;
- Introduces Machine to Machine (M2M) communication thereby reducing human labour;
- Improves Human to Machine interaction (HMI).

The basic idea is that there is a network which is intelligent and beneficial to firms. For South African firms to be Industrie 4.0 compliant, this intelligent network would be a better solution to inefficiencies and improved business models. This network would interconnect systems, processes and customers to have integrated production systems. In addition, the network would ensure sustainability with low cost of production and high customer satisfaction for South African firms. Atkinson, Ezell, and Stewart (2012) noted that there is a growing inter-linkage between technological and business model innovation.

The introduction of inter-linkages in manufacturing firms, particularly in South Africa, remains an issue. This is echoed by Kagermann, Wahlster, and Helbig (2013), in that Industrie 4.0 encourages “networked manufacturing”, “self-organising adaptive logistics” and “customer-integrated engineering”. This will require business models that are implemented primarily by what could be a highly dynamic network of businesses rather than by a single firm or a firm. The problems faced by local firms are that there are inefficiencies, less diagnostic capabilities, long set-up times and less optimisation. This is as a result of lack of technological advancement which is in line with Industrie 4.0. This study identifies those factors that harness innovation at a firm level in South Africa; this would go a long way in resolving these problems and therefore bring benefits to local firms.

During the integration of Information Technology and Operational Technology networks, a manufacturing firm can allocate machines efficiently, identify problems quickly, reduce the production bottleneck, optimise processes, reduce defects in products and prevent problems before manufacturing the prototype (Santos, Loures, Piechnicki, & Canciglieri, 2017). The positive gain in this instance is that the integration between these areas (OT and IT) makes more customisation available to the production environment and to the product. This was conducted to benefit customers' by reducing the product development time and yield losses. Yield loss reduction will have a positive impact on the firm's efficiencies, and as a result, to the bottom line. The time required to market the finished product is also reduced.

In line with what Santos et al. (2017) proposed, Industrie 4.0 has very valuable objectives which could be very helpful to local firms to harness the innovation. Amongst the objectives are: better production throughputs that could adapt to low, medium and high demand by varying the production type. Firms could also have the capability or skills that will allow them to do tracking and self-recognition of parts and products through intelligent machines. The better interaction between human and machine interfaces and the radical change in the business model could positively impact on the interaction with the whole value chain. The above objectives can be better explained by the framework that covers all four pillars in detail as illustrated by figure 2.

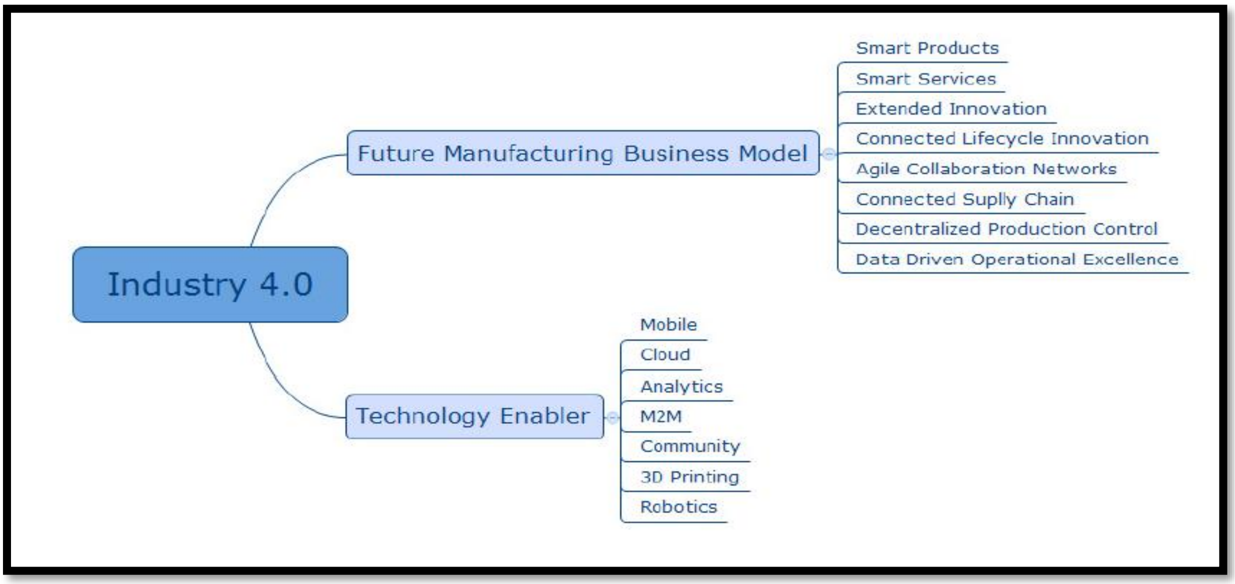

Figure 2: Pillars of Industry 4.0 (Bechtold et al., 2014)

Figure 2 above shows the two legs forming part of the building blocks of the framework for the fourth industrial revolution. The pillars were identified as part of the value drivers brought by Industrie 4.0. The value-drivers formed part of the survey questions. The pillars are the fields in which manufacturers can realise enormous potential by digitising their business models (Bechtold et al., 2014). This framework is critical for the study in that it helps identify technological enabling factors as well as the model required to become an Industrie 4.0 compliant firm in South Africa. The first leg as represented in Figure 2, concerns itself with business models for future manufacturing firms which would have adopted the Industrie 4.0 concept.

Part of the transition is the adoption of smart solutions. Industrie 4.0 technologies allow firms to manufacture smart products and also offer smart services. The question therefore is on the capacity of local firms to render these smart services. The second important point for future business models is smart innovations. Smart innovations are about extended and connected lifecycles. This means the innovations should have a time frame to enter and exit the market. The question therefore, is whether firms have the capability to pursue radical technological transformation projects. The third important point is building smart supply chains in local firms.

To realise the vision of Industrie 4.0, firms should break down the walls of siloed steps to marketing, product development, manufacturing and then to customer. To do this, Industrie 4.0 talks about digitisation which is about a transparent ecosystem built out of integrated network systems. This is about agile collaboration networks and connected supply chain. The network depends entirely on the following technologies: integrated planning and execution systems like enterprise resource planning (ERP's), smart logistics and its visibility, smart procurement and warehousing, spare parts management, and advanced analytics. This can only happen if the IT network and OT network are merged together.

Out of this, the study seeks to understand what is needed in local firms to merge the two networks. Therefore, the question one asks is: could two networks be merged in South African manufacturing firms? The second leg of the framework as represented in Figure 2 indicates that Industrie 4.0 is also a technological enabler. Acceptance of this framework by local firms would radically resolve problems experienced during manufacturing processes. The use of mobile networks as an example can bring a great impact to the manufacturing floor. This means that the mobile network, including Wi-Fi, wireless communications and cellular networks, can be exploited to the benefit of the entire business, therefore bringing customer satisfaction. In a manufacturing environment, operators or process controllers would have the ability to view and control their processes in the palm of their hands. The challenge in most local firms is the long lead time to resolve bottlenecks due to the operators being restricted to the control area. Implementation of this framework means that they will no longer be restricted to control rooms, but rather they can have mobile devices that give them both mobility and control from anywhere at any time.

Cloud computing and data storage would also help in terms of data availability across the world; this is critical for multinational firms operating across the globe while operating locally as well. Acquisition and the skill gap in this regard are critical for this study. Hence, Santos et al. (2017) argue that cloud technology enables this borderless flow of data as a vital aspect of Industry 4.0. As a major prerequisite for value-added mobile services, cloud computing describes the applications, platform and infrastructure solutions delivered as services over public or private networks on a pay-per-use basis (Bechtold et al., 2014). According to Bechtold et al. (2014), Machine-to-Machine Communication (M2M) refers to technologies allowing for the automated exchange of information between the CPS which constitute the Industry 4.0 production environment. South African manufacturing environments are behind schedule in terms of this low hanging fruit.

The reality is that this is also an enabler because it introduces a communication medium. This communication is made easy by the interconnection through the Ethernet network, Wi-Fi, wireless, etc. M2M can be considered the integral technology of the 'Internet of Things' (IoT) (Santos et al., 2017). A significant amount of information is collected by either PLC's, SCADA, and at certain points, by the smart devices which communicate directly using their Ethernet capabilities. Local firms already have PLC's and SCADA systems, however they are not readily available on the wireless, Ethernet and Wi-Fi network for the benefit of the whole business due to being regarded as operational networks. They are separated from the main enterprise resource program/ systems networks. Furthermore, through advanced embedded sensor and actuator applications technology, the entire production floor can communicate (Bechtold et al., 2014). The floor can easily relay meaningful information via whatever form of communications network. This would form the interface between the physical and the virtual worlds. In terms of community, this includes collaborators, human to human interactions, customers and suppliers, etc. The local firm could also have a platform where employees interact with each other. On this platform, the benefit of a dynamic, content rich interaction is achievable not only internally, but also with collaborators and suppliers as well as customers. The framework also covers the important part of 3-D printing and is called additive manufacturing, which, according to Santos et al. (2017), refers to the production of three-dimensional objects directly from virtual models. Due to costs associated with this kind of technology, most firms have not utilised it on a large scale.

As Industrie 4.0 innovations improve these weaknesses, there is a high chance that the use of additive manufacturing will mostly eliminate the efficiency disadvantages of producing individually customised products. 3-D printing is thus going to have game-changing impacts on how, where and by whom products will be manufactured in the future (Bechtold et al., 2014; Santos et al., 2017). Local firms cannot afford to be left behind. The last aspect of the second leg covers robotics in manufacturing industry. This is about advanced robotics that will enhance human productivity on the manufacturing floor. The reality is that robots are introduced to help humans with heavy tasks, repetitive tasks and safety related tasks, in order to protect them and the environment.

Robots are now employable in almost every sector which, as a result of technological innovations, has substantially augmented humans over the past decades. The challenge which South African firms face is the lack of skill to introduce these robotics, program them and train their employees to work alongside them. This reality is prevalent, especially where sensors and machine vision are coupled with improved artificial intelligence. In a way, this allows advanced robots to perform certain tasks in manufacturing plants. The robots function as independent productive units safely alongside manufacturing-floor employees. In Industry 4.0, they will be decisive for process efficiency and reducing complexity (Bechtold et al., 2014). These complexities are currently costly for manufacturing plants, as they impact negatively on yields and machine availabilities and reliabilities in local firms. The study focused on the skills necessary for the implementation of these kinds of innovations.

Applicable Theories

The section below presents two theories used in this study. The first part covers the theory of innovation diffusion by Rogers. Industrie 4.0 in a firm is bringing technological innovation, hence this theory becomes relevant and the way in which it will be implemented in South African manufacturing firms. The second part covers the classical theory by Karl Marx. The theory is critical in that it helps in revealing the value of productiveness as brought about by technological changes and innovation at firm level. This theory also touches on the factors bringing about productiveness. These factors are then used in question formulation to uncover which ones are relevant to harness firm level innovation that is in line with Industrie 4.0 in South African manufacturing firms. The last part of this section covers the benefits brought about by the fourth industrial revolution.

Theory of innovation diffusion

Innovation Diffusion Theory (IDT) concern itself with five main characteristics of innovation: observability, compatibility, relative advantage, complexity as well as trialability. According to this theory innovation is considered better if it replace a particular idea and according to Rogers (2010), this notion is the best one to predict the adoption of an innovation. In this theory, it is noted that most innovations get easily adopted if they are compatible with the end-user’s needs, value system and prior experience. This theory is relevant to the study because it deals with how innovation can be communicated, the channels used and the time factor. Industrie 4.0 in South African firms is a new concept that would need to be investigated thoroughly, communicated and implemented.

Rogers (2010) explains that there are four main elements in the diffusion of innovation, which includes innovation itself, communication channels, time and social systems. As already mentioned in the literature, communication platforms can have a positive effect on the way local manufacturing firms operate. In essence, the innovations brought by the Internet of Things (IoT) follows a similar logic. Diffusion is about communication, sharing of ideas that are new, or an information exchange that encourages new ideas. In the study, one of the significant issues raised is on local firms’ collaboration and sharing of ideas. According to Rogers (2010), a diffusion process concerns itself with four simple steps. The process involves:

- An innovation;
- An individual or other unit of adoption that has knowledge of, or experience with, using the innovation;
- Another individual or other unit that does not yet have knowledge of the innovation, and;
- Channels of communication which connect two or more units.

Based on the above process steps, it would be beneficial for South African firms to adopt innovations from other countries and share the technical expertise with their partners. In this study, the question of skills and capabilities to do this was raised. If the skill gap issue is resolved, the local firms can then create a channel or an ecosystem. The ecosystem provides an environment where learning from each other enhances business models and the countries' competitiveness. Industrie 4.0 is about firms sharing knowledge using IoT as their main communication channel. Failure to take advantage of this would be detrimental to local firms as they would remain walking while the whole world is running at a very fast pace. The connection of two units becomes an enabler. Two units operating in remote areas could be on one communication platform which make it easier to share key knowledge in real time and even help each other resolve problems instantly. As a result, to uncover some of the factors to innovate, the importance of communication channels and collaboration were part of the research questions.

Classical theory-Marx

This theory is based on the fact that the value and productiveness as a result of labour used in the production of certain commodities is very important. In his book, Capital Volume 1: A critique of political economy, Karl Marx, alludes that value of an article can clearly be measured by the quantity of value-creating substance, the labour, contained in it (Karl Marx, 1887). The amount of time spent producing certain commodities helps one to compute in monetary conditions the value of such an article.

Marx like most economists identifies: skills of workmen, state of science, degree of practical application, social organisation of production, extent and capabilities of means of production (that is the process itself) and physical conditions as some of the factors that enables productiveness. The Marxist theory on the critique of political economy emphasises the importance of value and productiveness as a result of labour used in the production of commodities. To uncover which factors harness innovation at the firm level, this theory brings basics to understand the value and importance of labour.

According to Marx (1867), the value of an article can be measured by the quantity of value-creating substance and the labour contained in it. The time spent producing commodities thus helps to calculate, in monetary terms, the value of such an article. The Industrie 4.0 promises to reduce this time extensively. This study evaluates what are the underlying factors to enable productiveness. Marx identified the following key factors that enable productiveness which becomes relevant to the local firms as they innovate and become Industrie 4.0 compliant. These are skills of workmen, state of science, degree of practical application, social organisation of production, the extent and capabilities of the means of production or machinery and the physical conditions. Marx acknowledged that the greater the productiveness of labour, the lower the labour time required for the production of a product, the lower is the amount of labour crystallised in that product.

Once the Industrie 4.0 is implemented, this amount of labour will drastically shrink and therefore translate to increased profit margins for local firms. As Marx alluded, the capitalist society's wealth depends more on goods accumulation. This suggests that there is a transformation of goods into money and later money into goods, which is buying to sell and later selling to then buy, in a proper sense of a word a clear circulation of goods and money. Marx called this kind of circulation "the basic form of circulation of goods". The Internet of Things (IoT) makes this circulation easier, instant, and valuable. IoT is one tactic that local firms can exploit once they become well equipped to implement Industrie 4.0.

In this context, Marx (1867) believed that technology had a way of revealing to men, the way to deal with the environment and the production process. This is done in a way that sustains their lives and establishes social relations. Technological innovation, by extension Industrie 4.0, therefore is a critical condition for adding more value. The use of this theory in the study was to get to the bottom of what the factors leading to this value creation are, and which skills are needed for local firms to champion this radical change. It is technological change and revolutions that nurture the maintenance and evolution of the dynamics of the capitalist system. Innovation takes place in the acceptance and valorisation of goods through the market, the system that would be revitalised by Industrie 4.0 (Marins, 2007).

Benefits of Industrie 4.0

Academic literature notes the potential benefits of the Industrial Internet of Things and gives hope that the future firm will be smart, efficient, fast and innovative. The notion of a smart factory therefore emerges. The literature reviewed helped to identify the following benefits (Kiel, 2017) which should be an encouraging factor to local manufacturing firms as they navigate through Industrie 4.0:

- Optimised value streams
- Orders guiding themselves through entire value networks, autonomously
- Automatic machines' set-up
- Production rescheduling by autonomous machines

Advances in information technology, introduction of artificial intelligence, advanced process control and computer aided designs and manufacturing have so far made it easier for firms to design and produce goods faster and easier. On the other hand, flexible manufacturing technologies have yielded shorter production runs which are economical (Schilling, 2012). Industry 4.0 provides firms with the possibilities to gather and analyse data across machines. This data would enable firms to make decisions to run faster, more flexible and more efficient processes. Flexibility and efficiencies on processes enables firms to produce higher-quality goods at reduced costs.

Therefore, Industrie 4.0 is helping firms to differentiate themselves from their competitors and is about "intelligently" automated factories in which workers, the production system itself, products and even customers are connected (Karre, Hammer, Kleindienst, & Ramsauer, 2017). These kinds of factories are called smart factories.

Smart factories are about self-configuring; knowledge-based, sensor equipped and spatially dispersed networking systems. This factory also incorporates the relevant planning and management systems (Kagermann et al., 2013). According to Schwab (2015), these factories handle complexity and are less vulnerable to losses of production.

The way to reduce costs would be to reduce these losses, and that can be done easily if Industrie 4.0 is implemented with its main characteristics. Deloitte (2014) indicates that the main characteristics of Industrie 4.0 demonstrate the huge capacity that industry and traditional manufacturing have for change. In this study, it is believed local firms are still operating in the third stage of the industrial revolution, hence the study was commissioned. The main characteristics which local firms need to adopt to enter the fourth stage are: Vertical networking of smart production systems; Horizontal integration via a new generation of global value chain networks; Through-engineering across the entire value chain and the Catalyst through which exponential technologies can be accelerated.

Key Levers to Industrie 4.0

Karre et al. (2017) have grouped the number of value creating levers in line with Industrie 4.0, based on available literature as can be seen in table 1. These Industrie 4.0 levers could be very helpful to South African firms when defining their own strategies. This is a process that should make local firms ready to be Industrie 4.0 compliant. In this study, the investigation of these levers is represented by table 1.

Table 1: Industrie 4.0 levers Source: (Karre et al., 2017)

Value Drivers	**Industrie 4.0 Levers**	**Value Drivers**	**Industrie 4.0 Levers**

Asset Utilisation	Routing flexibility Machine flexibility Remote monitoring and control Predictive maintenance Augmented reality for maintenance and repair organisation	**Labour**	Human-Robot collaboration Remote monitoring and control Digital performance management Automation knowledge of work
Inventories	In-Situ 3D printing Real-time supply chain optimisation Batch size	**Quality**	Statistical process control(SPC) Advanced process control(APC) Digital quality management
Resource/Process	Smart energy consumption Intelligent lots Real time yield optimization	**Service/ after-sales**	Predictive maintenance Remote maintenance Virtually guided self-service
Supply/Demand Match	Data-driven design to value Data-driven demand prediction	**Time to Market**	Rapid experimentation and simulation Concurrent engineering Customer co-creation

Table 1 shows some of the factors that could help or hinder the implementation of Industrie 4.0 solutions in South African firms. The opportunities are in terms of sustainability and value creation. This can even be applicable in sustainable manufacturing for the macro-perspective. The opportunities are grouped in terms of five constructs: equipment, human, process, product, and organisation. The next section discusses the constructs and how they were used in this study to illustrate the need for Industrie 4.0 in South African firms.

Equipment

Most of the manufacturing equipment has a long life-span, and therefore is capitalised over a period ranging from 10 to 20 years. The notion of retrofitting is advised in firms with such equipment. This kind of equipment will be characterised by the application of highly automated machine tools and robots (Stock & Seliger, 2016). It will be able to flexibly acclimatise to process variations in the other value creation factors, e.g. the robots will be working together collaboratively with the workers on joint tasks (Stock & Seliger, 2016).

Human

Humans will still be necessary resources as part of value creation in Industry 4.0. Even though certain tasks will disappear, this does not mean that humans will disappear in the manufacturing industry. Stock and Seliger (2016) describe the situation better in that the remaining manufacturing jobs will contain more knowledge work as well as more short-term and hard-to-plan tasks. The workers' role will increasingly shift to that of having to monitor automated equipment. As a result, workers would have to be integrated with decentralised decision-making.

Process

3D technologies, also known as additive manufacturing technologies will be increasingly used in firms as part of value creation processes. This is due to the fact that the costs of additive manufacturing have dropped considerably over the past few years. Speed and precision of this technology are the motivating factors. This allows designing more complex, stronger, and more lightweight geometries as well as the application of additive manufacturing to higher quantities and larger scales of the product (Stock & Seliger, 2016).

Product

Customised batch manufacturing processes will be implemented seamlessly. These mean that products will be manufactured in batch sizes as per customer requirements. Stock and Seliger (2016) argue that this mass customisation of the product integrates the customer as early as possible in the value chain. As part of the newly developed business models, the physical product will be combined with new services, offering advanced and better functionality. The intention here is to ensure that the customer has access to, as opposed to ownership of, a particular product.

Organisation

For sustainable-oriented decentralised organisation, a smart factory should focus on the efficient allocation of resources (i.e. products, materials, energy and water) in a way that takes into account the changing constraints and bottlenecks of the Cyber-Physical Production Systems (CPPS). The implementation of the smart inbound and outbound logistics, the smart energy grid, and the auto-predictive customer demand/supply is achievable. This concept towards a holistic approach to the use of resource efficiency is described in literature as one of the essential advantages of Industry 4.0. Even though the complexities of Industrie 4.0 systems increase daily as people grapple with the concept, its benefits are great and big.

Research Methodology

Quantitative methods were used in this study. An online survey questionnaire was used as an instrument for data collection. This instrument benefits the need of this investigation because it allow the sample group to answer the questions in the survey questionnaire instrument freely and willingly(Carson, Gilmore, Perry, & Gronhaug, 2001; Saunders, 2011). It also allows the sending of survey questionnaires to the participants electronically which optimizes time. I also used the Qualtrics software to track the survey questionnaire responses from the participants. A positivist approach was adopted during the conduct of this investigation. This provided an accurate indication or account of characteristics like behaviour, opinions, knowledge and beliefs of specific individuals, situations or groups. The researcher did not have any form of contact with participants during the time when the survey questionnaires were completed.

Participants Demographics

Participants were selected from LinkedIn, a contact list from Wits Business School and references from those contacted first. The design of the questionnaire was influenced by literature on the fourth industrial revolution and McKinsey's Industry 4.0 Global Expert Survey 2015 study. Below is the table showing the profile of participants.

Table 2: Profile of respondents

Categories	**Description of respondent type**	**Number sampled**
IT and System Integration	Managers	20
Manufacturing, Energy and Oil	Lecturers	5
Mining and Construction	Technological innovation experts	5
Education and Research	Practicing engineers	25
	Automation & software programmers	25
	Talent managers or HR personnel	25
	Total	**105**

Participants' firms were in the following categories: IT and Systems Integration, these were persons who either provide a service to firms in terms of technological migration, networks or system integration in general. Manufacturing, Energy and Oil included people from the Steel Manufacturing, Electricity utility and Oil sectors in South Africa. Mining and Construction participants were from gold, platinum and construction products. Education and Research included technological innovation experts and lecturers from Universities and the research institutes.

Research Instrument

A link containing 15 questions was sent out to 105 participants via email. The first part of the questionnaire was concerned with the composition and involvement of participants when coming to Industrie 4.0. The second part looked at the understanding and believes of participants with regard to effectiveness and competitiveness brought about by the fourth industrial revolution. The third section was looking into the challenges and factors that hinders the implementation while the last part prompted the skills and support that participants requires. Participants were given a full month to respond to questions using Qualtrics software program. An email which served as a reminder was sent at the end of the second week to all participants.

Composition of the survey questionnaire

The questionnaire consisted of 15 items which were grouped in 4 parts: composition and involvement of participants, Competitiveness and effectiveness of the implementation of industrie 4.0 projects, Challenges and factors hindering the implementation as well as the skills and support measures required.

Data collection

During the second week, only a 22% response was achieved; however, there was an increase of up to 60% at the end of the 4th week, when the survey was closed. Therefore, 63 responses out of 105 were received, according to the Qualtrics software. This amounted to 60% response rate. According to Carson et al. (2001), positivist researchers always distance themselves from participants in their research so that they may remain neutral emotionally to see how reason is different from feeling. The rationale here is to apply and use logic, as one seeks to be objective. Thomas (2010) argues that the use of the delivery and collection method provided a high response rate of 85%, as compared to telephone (38%), and postal (21%) when surveying a sample of 500 SMEs.

However, Saunders (2011) alerts us that the delivery and collection survey method is costly, even though it can provide a response rate of up to 98%. This study was self-funded and as a result, higher cost method was not suitable. Based on the information from the above sources and research studies, it is safe to conclude that the response rate may range between 10% and 98%. Based on the above understanding, this study anticipated a response rate of at least 30%. This is because of the costs limitation and type of the instrument used. A 60% response rate was therefore within the reasonable range.

Limitations

The study could not be done using a delivery and collection method due to cost and time constraints, but an email link generated from Qualtrics software program was used. This option was more cost effective because it is free and also is done in collaboration with the university. To answer the question of which factors will harness firm level innovation for Industrie 4.0 in South African firms, respondents were asked the following as main questions that would give detailed responses with clear answers:

- Which of the given factors are hindering the implementation of Industrie 4.0?
- Which factors are of serious concern when coming to implementation?
- Which skills are a must have, should have and could have?

Results

In this section, factors were identified that are critical to innovation in South African firms in line with the Industrie 4.0 technological advancements. This section covers in detail the responses to the three research questions of this study. Analysis of results was done so that the important and critical factors for local firms could be identified in order to evaluate which ones will harness firm level innovation for Industrie 4.0. The results section starts by identifying the demographic composition of the sample participants and their involvement with the concept. The second section deals with the participants' understanding of competitiveness and operational effectiveness brought about by the concept. The third section then deals with the concerns and challenges faced by firms when implementing the Industrie 4.0 technologies and ideas. The section concludes with the identification of factors which hinder implementation, skills and technical know-how and the required support.

Composition of participants

The questions to cover composition related to the sector or the area where participants work as well as the levels that individuals occupy or their roles in management of a particular firm. The aim here was to check clearly where and who was participating in the survey.

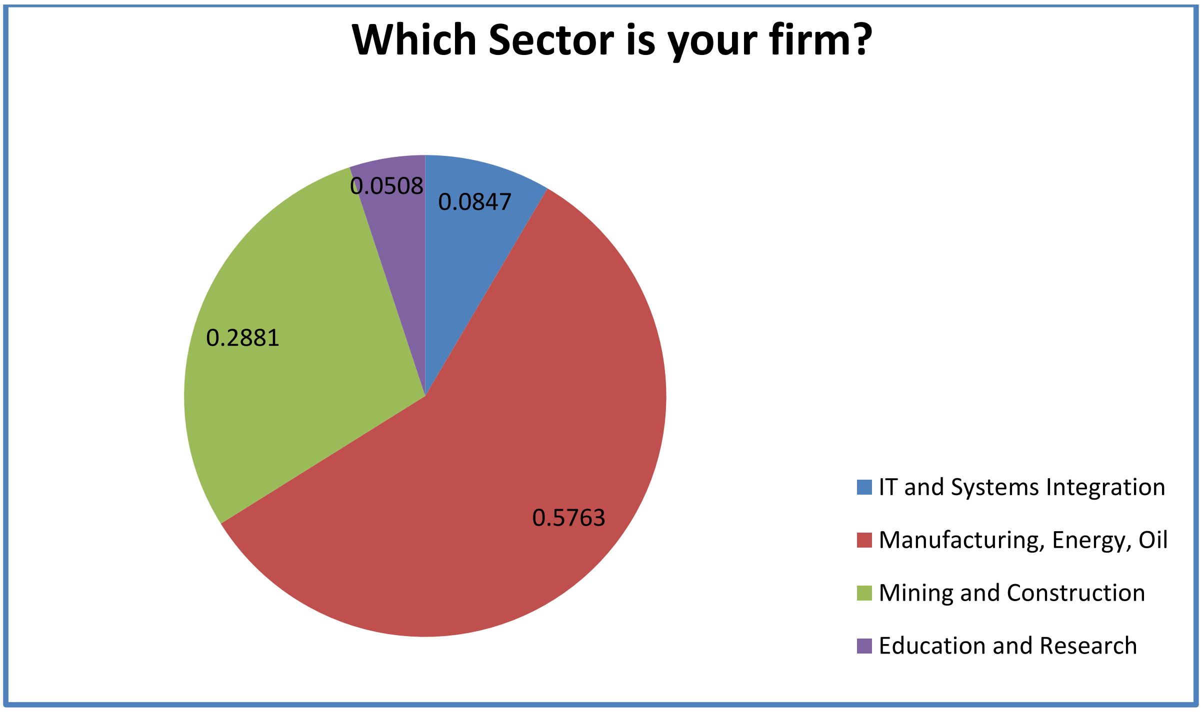

Figure 3: Participant's Industry or Firm.

Looking at figure 3, the majority or 57.63% of the participants were from the manufacturing, energy and oil sector in South Africa; while 28.8% were from mining and the construction industry. IT and System integrators formed only 8.47% followed by 5% from the education and research sector.

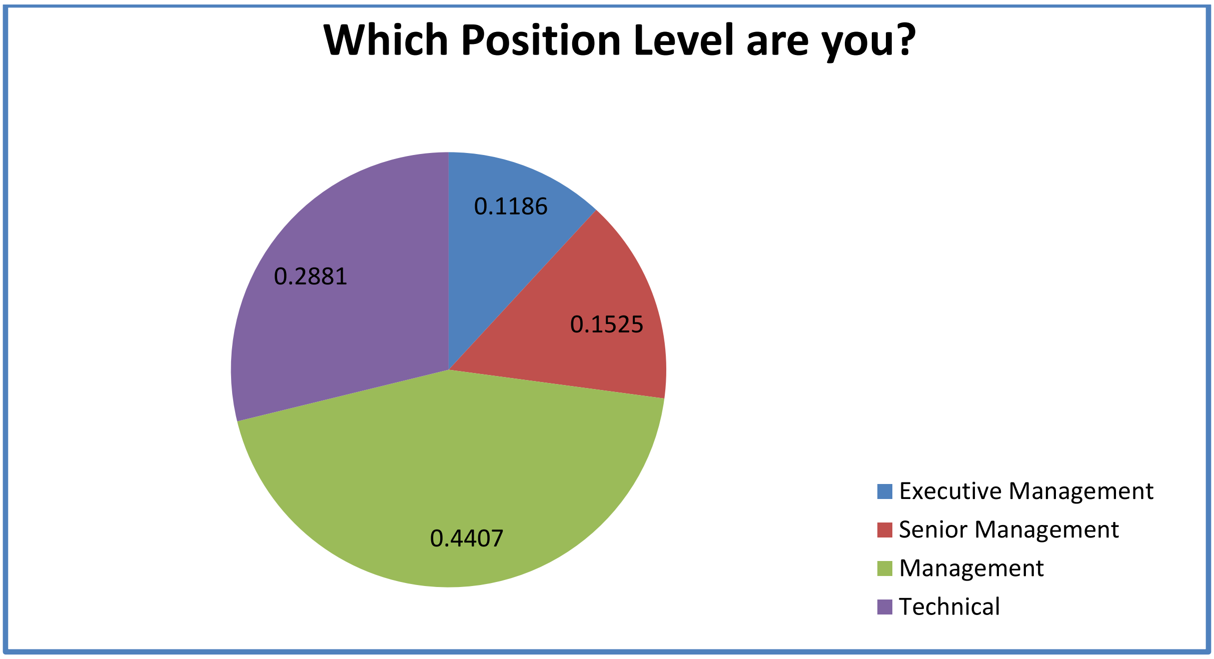

Figure 4: Role Level of participants

Asked about their seniority or level of influence in a firm, figure 4 indicates that the majority of people participating on the survey occupy senior roles. Management roles constituted 44% of participants, whilst about 29% was constituted by technical personnel including engineers, programmers and software developers for various firms. Senior managers were 15% while executives constituted 11.8%. This was quite a good spread of sample that gave a clear indication of where the hindering factors, opportunities and challenges occurred in the organisation when coming to the implementation of the Industrie 4.0 technologies. The results illustrate the view that this topic is critical; therefore, it should form part of strategic discussions in boardrooms, especially if local firms want to transform themselves into digitisation.

Involvement

This part of the questionnaire was about checking whether people know what the fourth industrial revolution is, if they were already taking part and how, if they were already engaged with the concept.

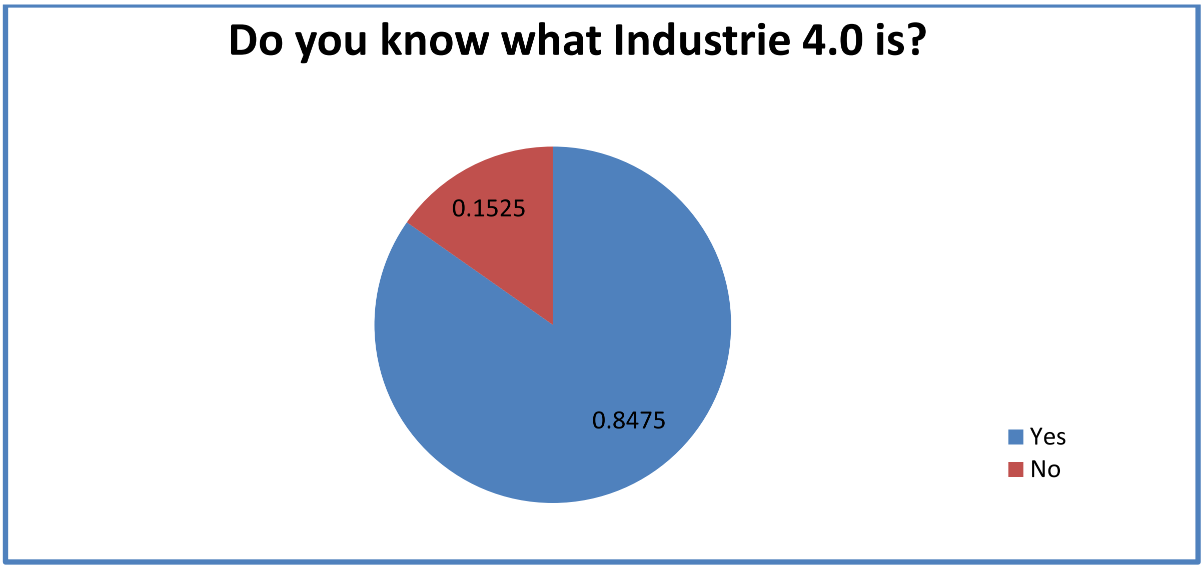

Figure 5: Knowledge of Industrie 4.0

Asked if they know what the concept is, the majority said they do know, as can be shown in figure 5. About 84.75% said they do know, while only 15.25% did not know what the fourth industrial revolution is. Considering the fact that the concept has been around since the year 2011, it is bit concerning that South African firms still have people in their employ who are not keeping abreast with the latest technological developments globally and locally.

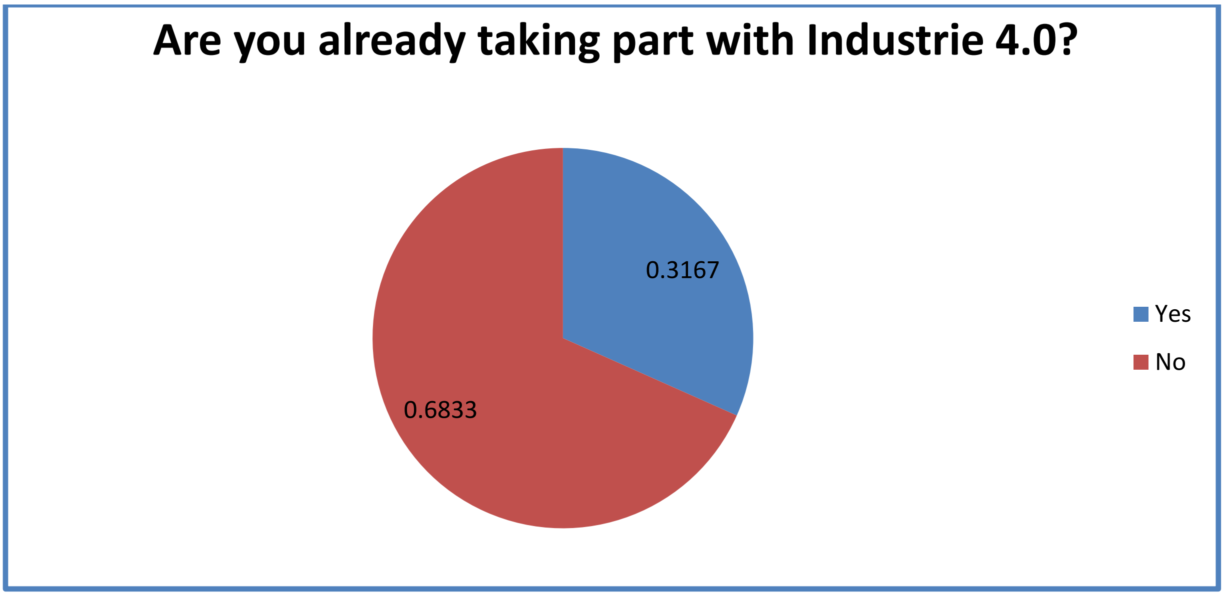

Figure 6: Participation on the topic

Participants were then asked if they are already taking part with the concept; interesting enough while the majority said they are taking part with the topic, quite a significant number said they are not. At least 68.3% of the respondents indicated that they are taking part already while 31.67% said they are not.

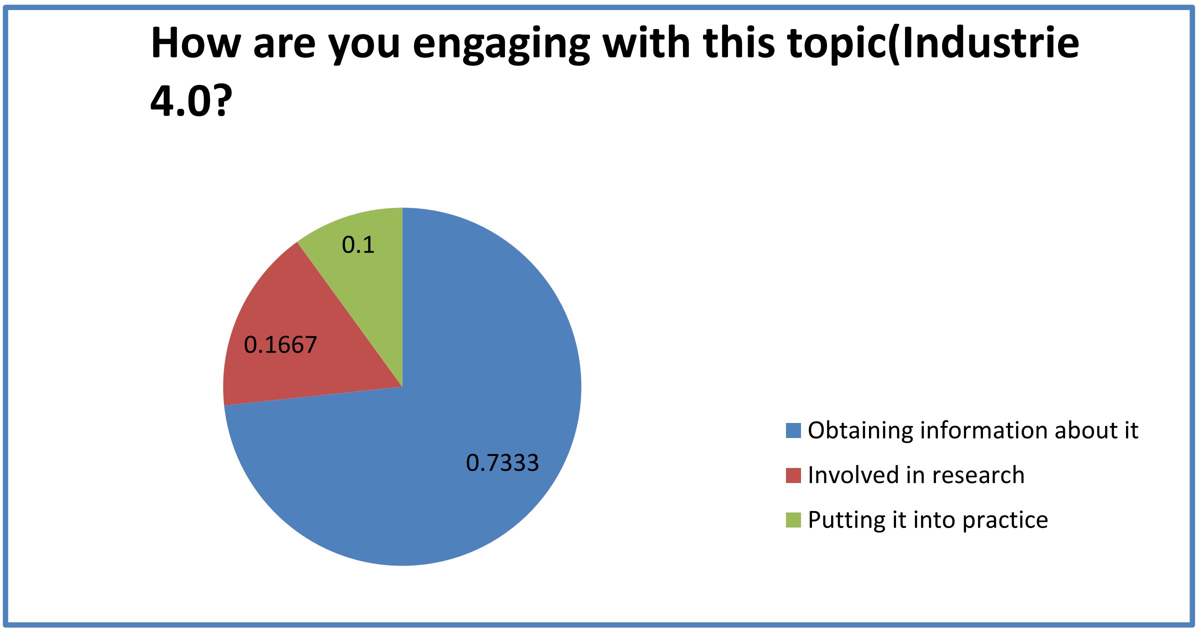

Figure 7: Participants engagement with the topic.

The last part of this section was about the area of participation or engagement. At least 73.3% of participants in the local firms were obtaining information about the topic, 16.67% are involved in research and only 10% are already putting it into practice. These results are concerning, as this could lead to a conclusion that local firms are walking whilst the global firms are running. The question on engagement was re-phrased to ascertain the level of engagement. The results can be seen in figure 8 below.

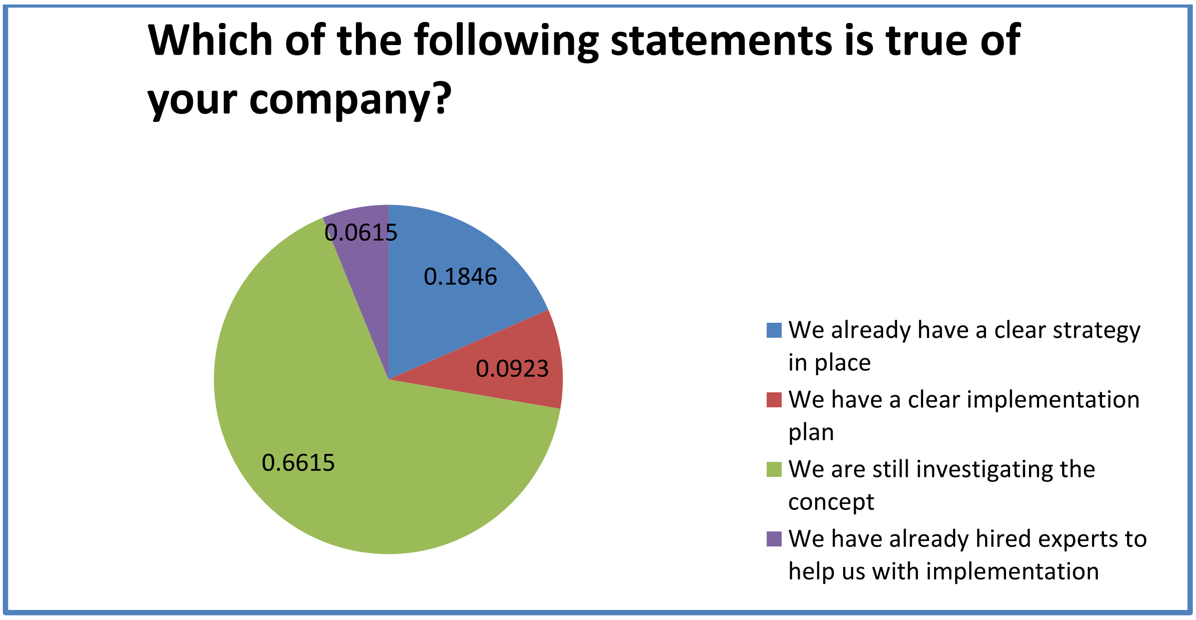

Figure 8: Level of engagement

Looking at figure 8, a majority of participants insisted that they were still investigating the concept. Up to 66% of respondents confirmed that they were investigating what the concept is all about. The interesting revelation is that some amongst the local firms are already having a path to follow. At least 18.46% said they already have a clear strategy in place. Only a small percentage of the participants have a clear executable plan. At least 9.23% said they already have an implementation plan that is clear and only 6.15% of South African firms have already hired experts to help them with implementation. The involvement of experts is a step in the right direction.

Competitiveness and Effectiveness

In this section, the intention was to get a clear indication as to whether participants realise the importance of the concept.

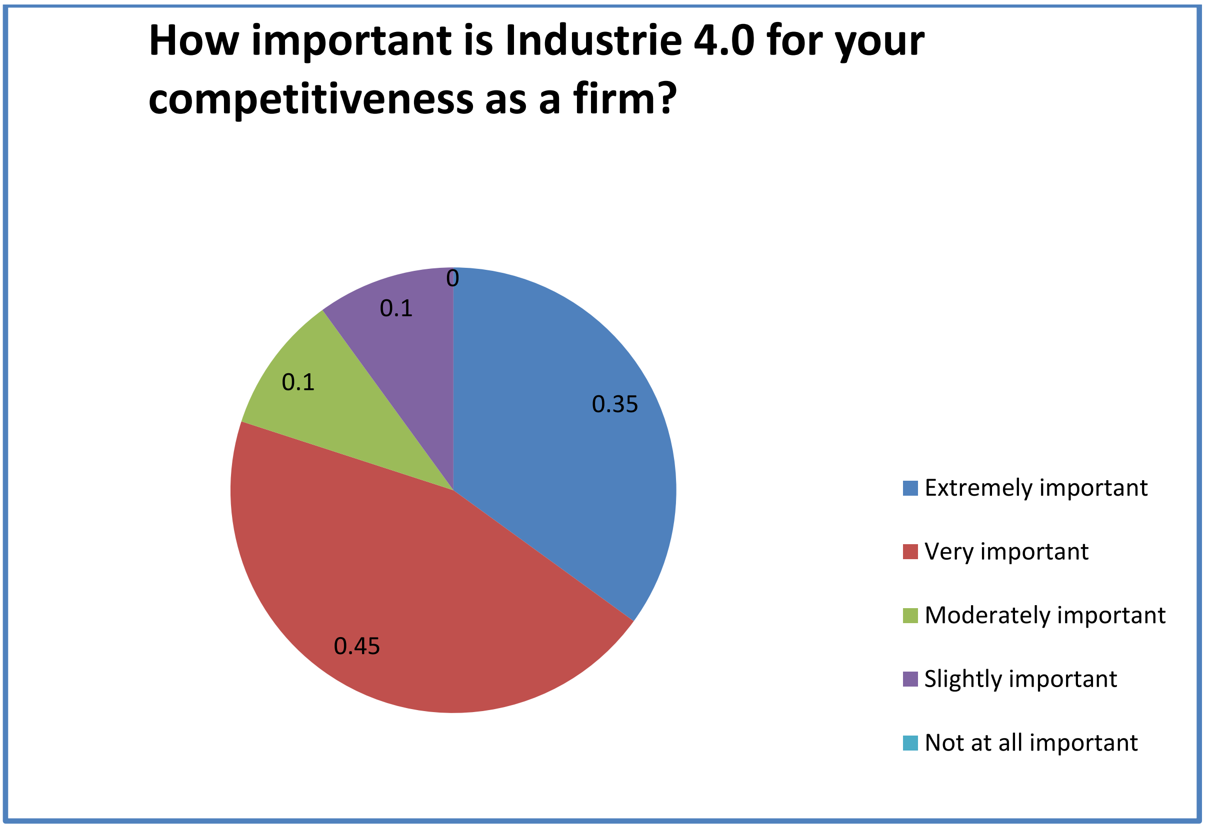

Figure 9: Importance of the topic

From figure 9, it became evident that a majority of firms believe that Industrie 4.0 is very important for competitiveness in their respective firms. About 45% of respondents think that Industrie 4.0 is very important with a further 35% agreeing that it is extremely important. This shows how important this concept is for local firms.

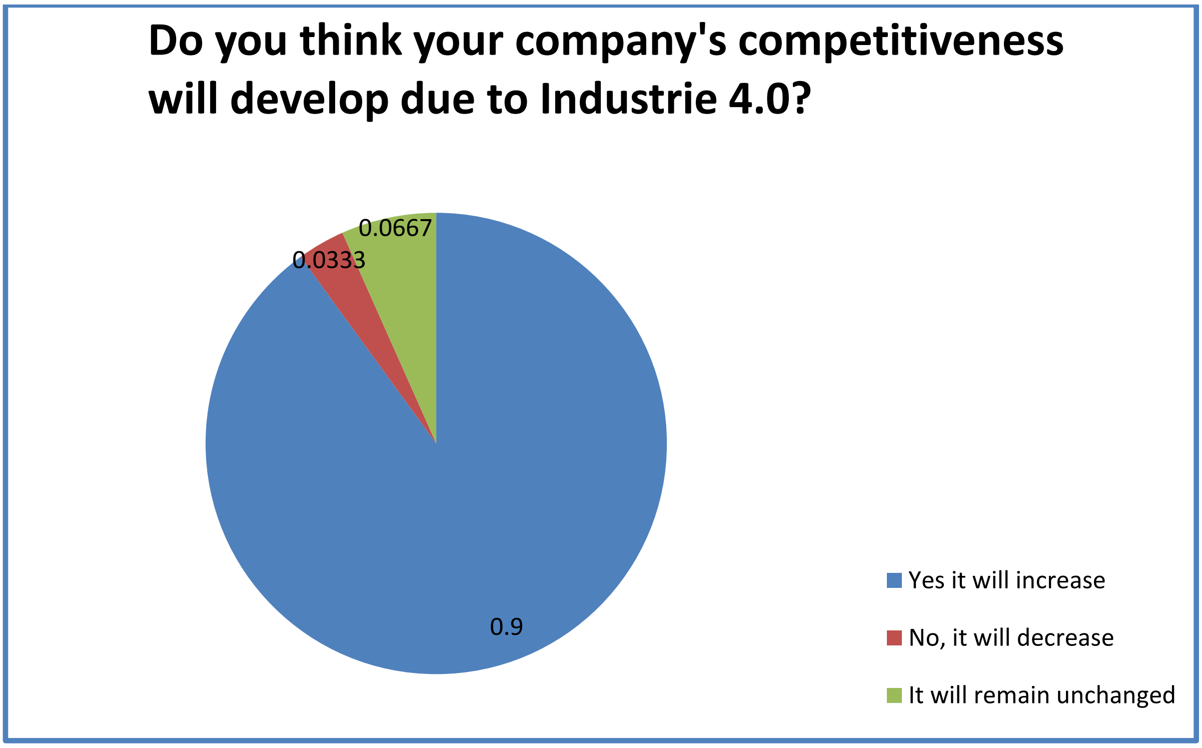

Figure 10: Industrie 4.0 and firm competitiveness

Asked about whether the firm's competitiveness will develop as a result of Industrie 4.0, a majority believe it will. The importance of the concept has an impact on the question of competitiveness. Only a small number of participants believe that there will be no changes. As can be seen from figure 10, about 90% of respondents think the firms' competitiveness will develop. These confidence levels and knowledge that Industrie 4.0 brings competitiveness should be taken to boardroom levels where firms' strategic decisions are taken.

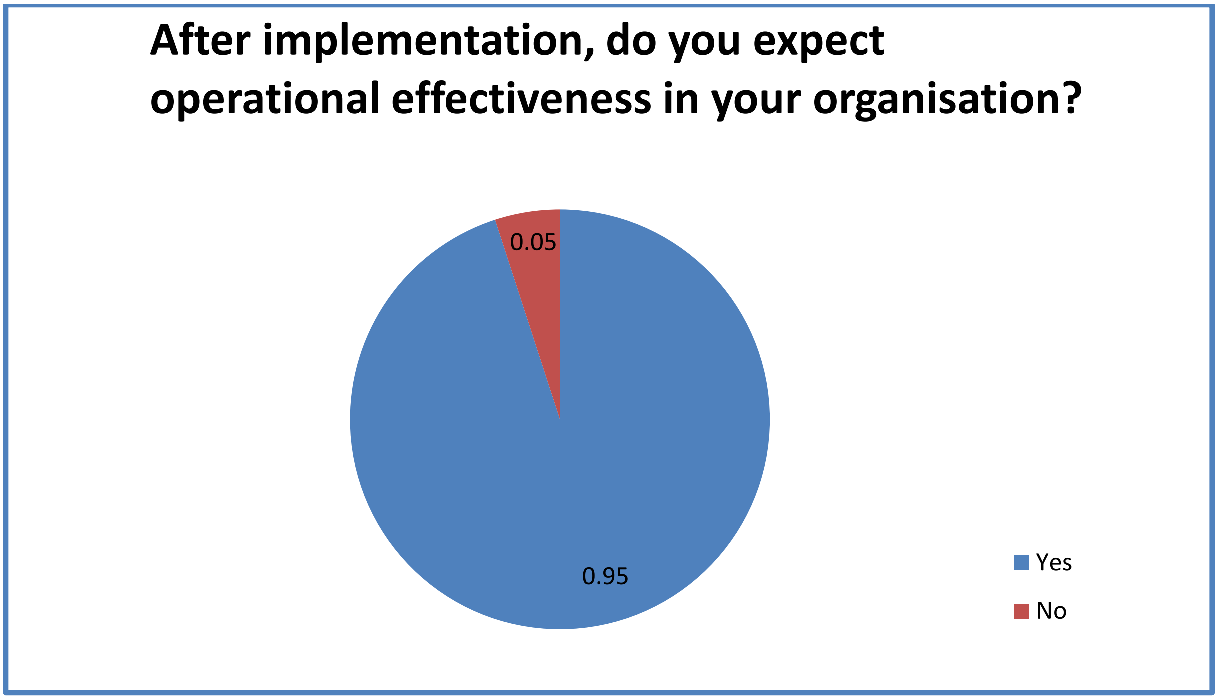

Figure 11: Industrie 4.0 and operational effectiveness.

As part of the survey, people's expectations were assessed. The point here was to check whether participants expect improved efficiencies or effectiveness in their operations. Looking at figure 11, a majority of participants expect operational effectiveness to improve. At least 95% of respondents said they expect improvement in operational effectiveness after the implementation of Industrie 4.0 in their organisation. Only 5% or respondents did not expect a change in operational effectiveness. The study findings clearly indicate that developing an Industry 4.0 vision and mission for local firms is still a challenging task. Although many executives and senior managers are aware of the potential of Industry 4.0 related benefits and technology, they have substantial challenges in developing their firm-specific project plans that can be translated into the firm vision.

Concerns and challenges

Asked which the main concerns are, when it comes to the implementation of Industrie 4.0, most participants are still not comfortable with cyber security, as figure 12 shows.

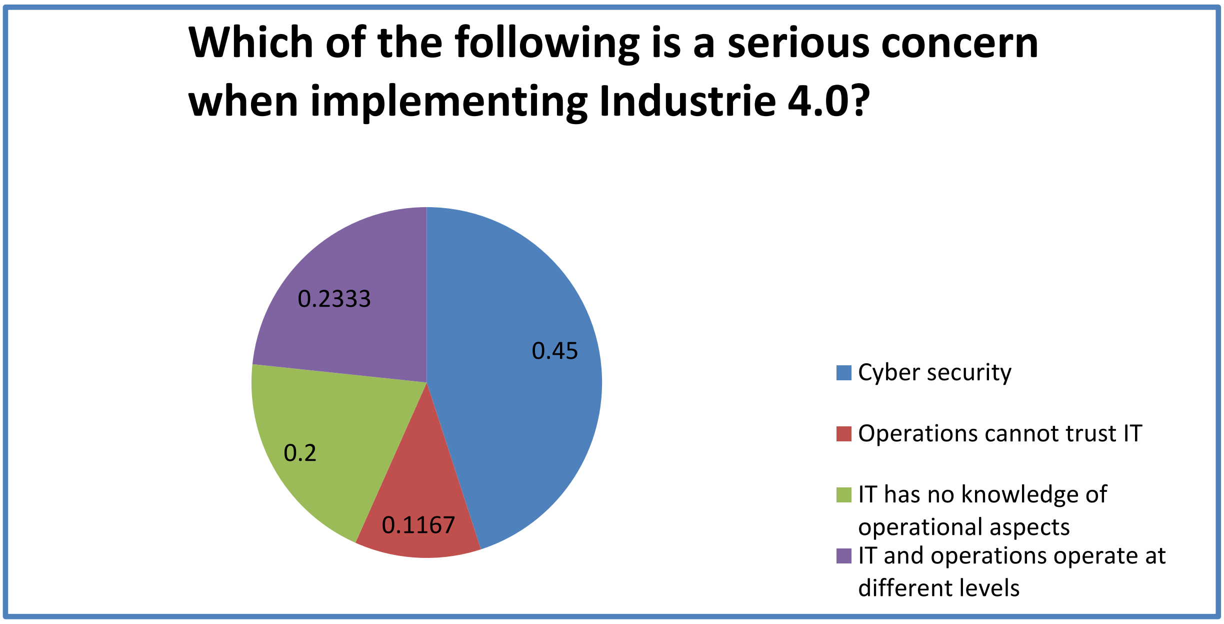

Figure 12: Concerns with regard to Industrie 4.0 implementation.

About 45% of participants indicated cyber security as their main concern. As can be seen from figure 12, the manner in which IT personnel and operational teams work remains a problem in most firms. The sense one gets from this is that, in most firms, the two departments are still working in silos with little collaboration. About 23.3% of respondents believe that in their firms, IT and Operations operate at different levels. To get a clearer picture, the researcher asked the question which is largely investigated. This is about the possibility of merging the two networks in local firms.

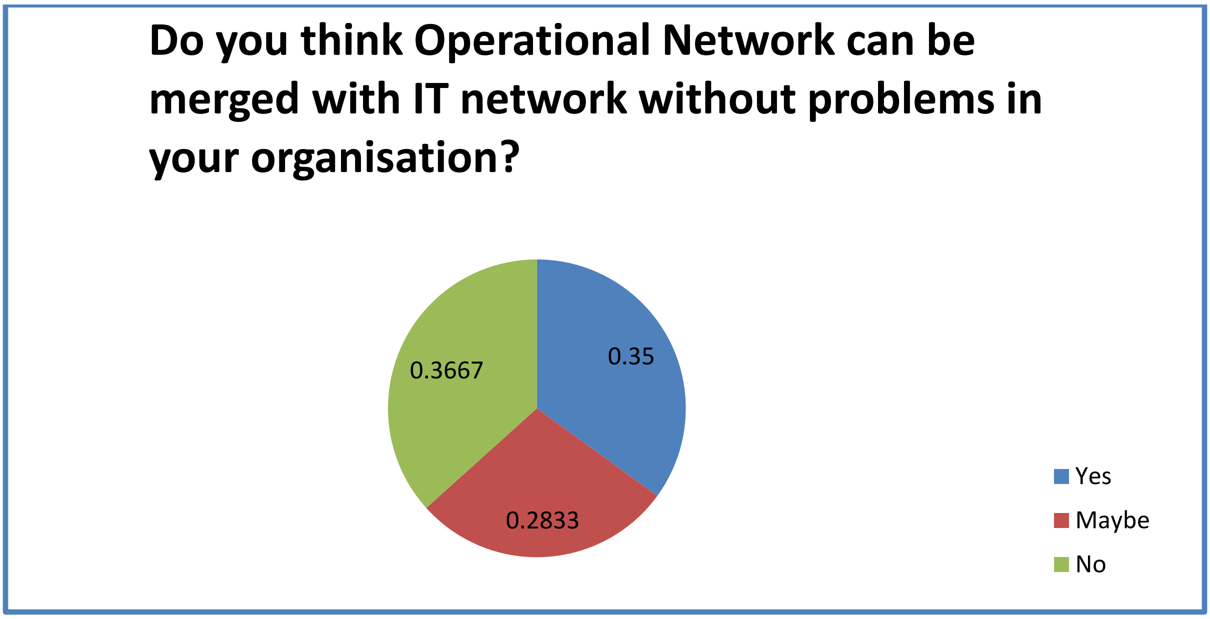

Figure 13: Merger of IT and OT networks

According to figure 13, while 36.67% of respondents thought that this cannot be done without problems, at least 35% agreed that this is doable and 28% was not too sure about the prospects. This 28% could be convinced if those with skills and technical knowledge can develop a compelling business case showing the benefits of this great move. To conclude this section, participants were presented with nine challenges and asked to select only four, which according to them, are critical when the implementation of Industrie 4.0 occurs. Looking at figure 14, the question is presented with those challenges listed. The survey results identified the greatest four challenges. Figure 14 shows that the following are the serious or main challenges that firms face in South Africa when coming to the implementation of Industrie 4.0.

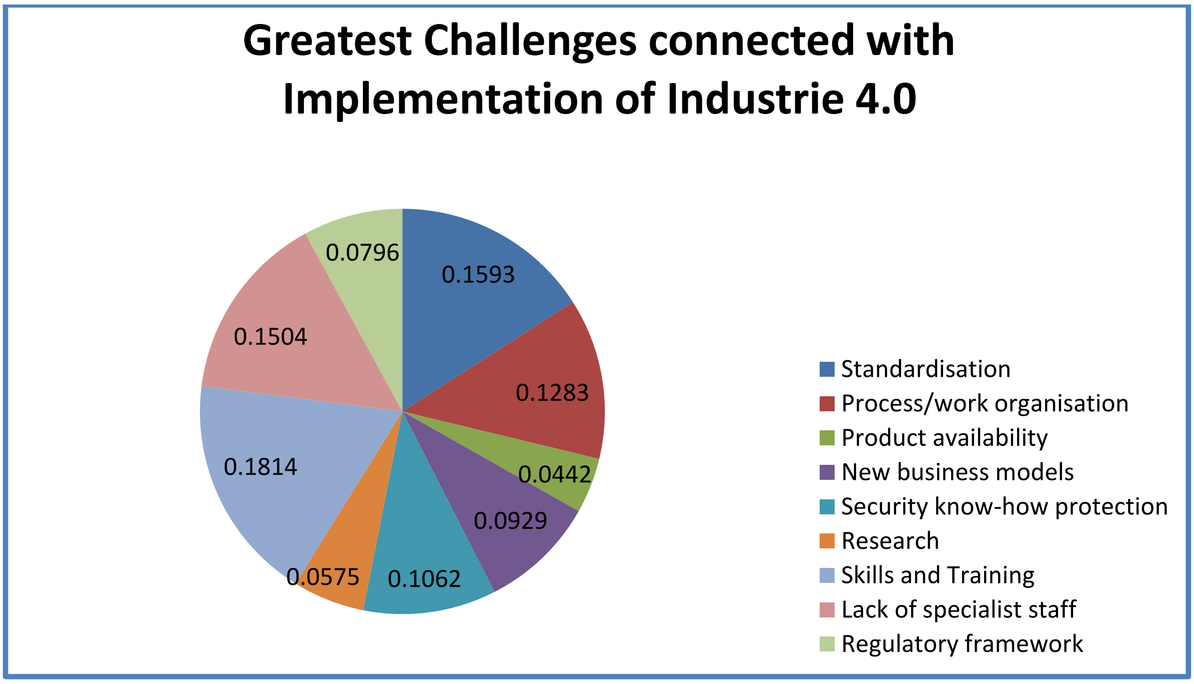

Figure 14: Greatest challenges when Implementing Industrie 4.0.

While security know-how protection would have been thought of as a serious challenge, participants did not identify it as serious. Cyber security issues that were identified elsewhere did not seem to influence participants thinking this time around; instead skills and training, standardisation, lack of specialist staff and process/work organisation was identified as the top four greatest challenges. These results indicate that somehow, one cannot be good with process/work organisation if that person lacks specialist knowledge and skills.

Factors hindering the implementation of Industrie 4.0

Participants were asked to select the five most important factors that according to them hinder the implementation of Industrie 4.0. Eight of the factors were identified from the literature and previous surveys similar to this one. A lack of necessary skills came top followed by a lack of clear business case that justifies investments in the necessary underlying IT architecture and infrastructure. This makes sense because one needs a particular skill set and knowledge to be able to develop and write such a business case.

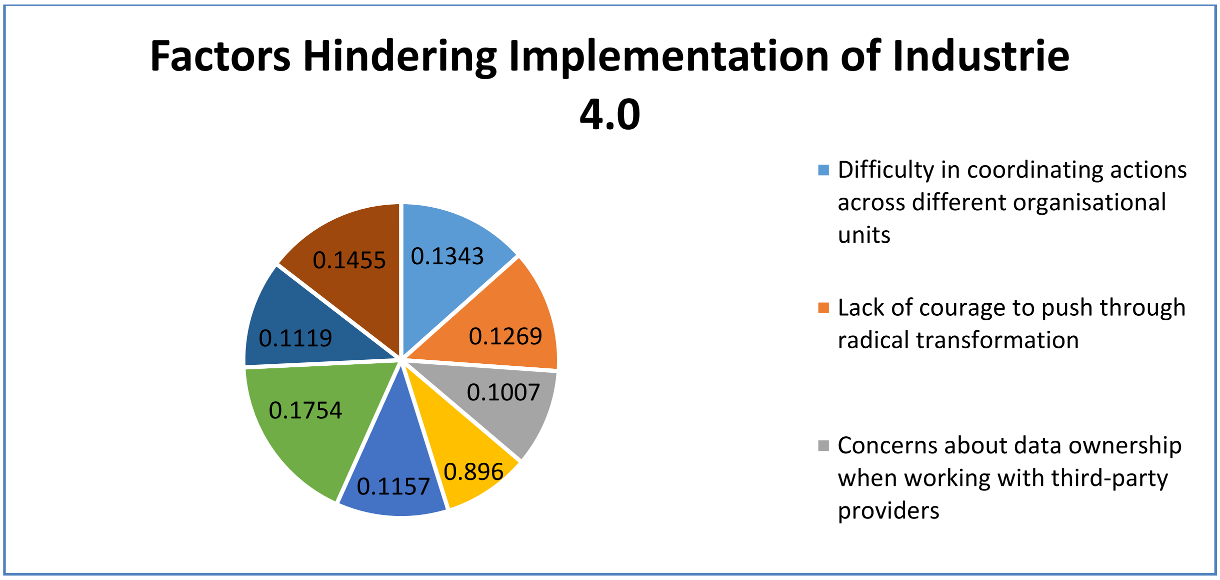

Figure 15: Factors that hinder implementation of Industrie 4.0 in SA

From figure 15, it is evident that the following are the factors that hinder the implementation of Industrie 4.0 in the selected order by participants: Lack of necessary skills comes out top, followed by the lack of clear business case that justifies investments in the underlying IT architecture. Difficulty in coordinating actions across different organisational units is also featuring as a challenge. This is where companies need to exploit the advantages brought about by the Industrial Internet of Things. Participants also identified Lack of courage to push through radical transformation followed by the challenges with integrating data from disparate sources in order to enable Industry 4.0 applications

Skills and technical know-how

In this section of the questionnaire, participants were asked to identify and rate skills and technical knowledge necessary for the implementation of Industrie 4.0. Participants were presented with 16 technical skills that are critical in South African firms in order to move forward. Industry 4.0 is based on the concept of cyber-physical systems (CPS), cyber-physical production systems (CPPS) and the Internet of Things (IoT), which is mainly a technological approach. Industrie 4.0 provokes a change and shift in skills required to run firms and add value. These skills are both technical and personal which affect the shape and form of qualifications of the future workforce. While some skills on the list are directly extracted from previous international surveys such as the McKenzie Global Survey, the inclusion of extra ones which are believed to be critical for South African firms became necessary. The following skills were added: Software development, Instrumentation (PLC) work as well as Instrumentation (Field) work. Software development is about coding or programming different components, things, devices or actuators. Instrumentation in most local firms is divided into field work and Programmable Logic Controllers (PLC) work. Instrumentation (PLC) is a skill required to programme certain PLCs running the manufacturing processes. This includes how to set them up and interconnect them to each other, to SCADA systems and communicate either through Ethernet, Wi-Fi, radio link and/or any other type of communication protocol. Institutions of higher learning are not offering these kinds of skills. They are mostly learned at firm level with few service providers like Siemens, Rockwell Automation and Schneider offering training, based on their product range.

Instrumentation (Field) is about connecting and setting up equipment such as instruments, devices and actuators. Powering them and ensuring that they are correctly mounted can be of better use for the manufacturing plant and business in general. Participants were further asked to rate the skills presented to them in terms of the ones that are a “Must have”, Should have” and “Could have”. Table 3 presents the results from respondents.

Table 3: Skills Ranking for Industrie 4.0 in SA Firms

Ranking	Must Have Skills	Should Have Skills	Could Have skills

1	Problem solving	Specialised knowledge about technologies	Software development (programming and coding)
2	It knowledge and abilities	Instrumentation (plc)	Operator skills
3	Decision making	Knowledge management	Instrumentation (field)
4	Ability to interact with modern interfaces	Instrumentation (field)	Instrumentation (plc)
5	Data and information processing and analytics	Specialised knowledge of manufacturing activities and processes	Specialised knowledge of manufacturing activities and processes

The answers to the question in Table 3 could help firms to identify which skills need urgent attention so that plans could be devised to resolve such a skill shortage. This can be done in collaboration with universities and with other firms that already have such a particular skill set. Should universities and other institutions of higher learning become an option, tailor made curricula are advised. The curriculum should incorporate the fact that more robotics will be replacing manual, heavy loading, and routine, high safety risk jobs. New modules covering the new ways of doing things might have to be developed for universities and further education and training colleges. Data analytics and information processing and decision analysis could be one of the avenues investigated.

The study noted that ability to interact with modern interfaces came out as a must. It is so far, a well-known fact that Industry 4.0 promises to introduce systems with a higher complexity. This is as a result of advanced automation, advanced predictive process control and the interconnections of all elements, organisational and process understanding. South African firms would do better to invest in such skills as they emerge as the most important ones for firm's workers. This comprises problem solving ability as a skill to recognise elements of the overall production system and resolve problems as they arise. These problems could include lack of IT knowledge and abilities that would help in identification of system borders; understanding of functions and relationships within the system and decision making to be able to predict systems behavior and act accordingly. Data and information processing analytics also came through as one of the 'must have' skills. It should be noted that decision making and problem solving have not been identified previously in the literature as key skills that the work force needs for Industrie 4.0. Of interest are the results received on the "Should have Skills" for Industrie 4.0. These are identified as Instrumentation (PLC), Instrumentation (Field), and specialised knowledge about technologies.

Support

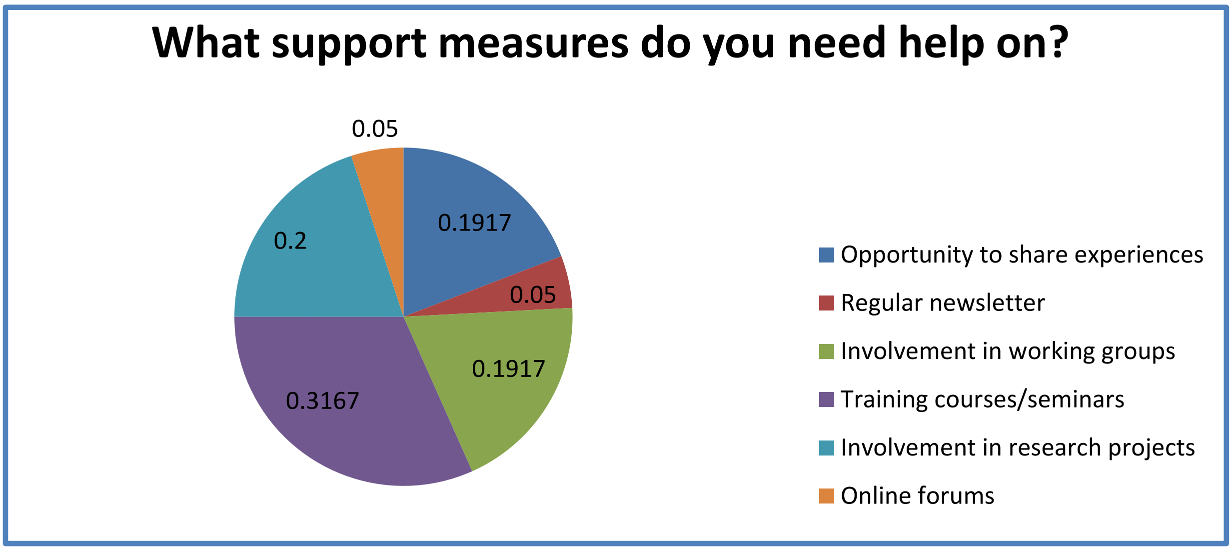

Figure 16: Support Measures needed in SA Firms to implement Industrie 4.0

This section was only to check whether participants need some support or help in their areas of expertise, work, etc. (Figure 16). In line with the flow of the survey, as can be seen in figure 16, the majority of respondents indicated that they would like to be involved in training courses and seminars dealing with the concept. A majority of participants (31.67%) want an opportunity to be in training courses/ seminars, followed by 20% that require involvement in research projects. A further 19.1% indicated that they would love to participate or be involved in working groups that deal with Industrie 4.0.

In essence, all participants want some sort of community where ideas on this kind of information, projects and research work can be shared. This should be made up of all participants from government, private sector, research institutions, institutions of higher learning, systems integrators, IT firms, etc. If the community created is successful, the country can have model simulation plants and Industrie 4.0 technology centres in collaboration with the Innovation Hub and the CSIR, etc. Based on the results from the survey, it was found that most South African firms are making little progress in terms of the implementation of Industrie 4.0. The survey highlights that most firms are still investigating the concept. The study results from the questionnaire also highlighted that these firms need help in terms of training and information sharing so that they are comfortable when adopting and implementing such technologies associated with the concept. Key amongst the findings is the highlighting of skills and training, special skills and cyber security. The findings present local firms with the opportunity to embrace the concept of Industrie 4.0 and also mean that it is time to take action as opposed to permanently remaining in an investigation mode. The other important factor highlighted is risks associated with the concept.

Discussions

This section discusses the results in details and what they mean to South African firms. The section starts by expanding in detail, what was found and later draws from literature on how to resolve some of the apparent problems faced by local firms. It was established from the results section that there are still a few people in firms who do not know what Industrie 4.0 entails. This is despite the fact that the concept was initially introduced to a larger audience in the spring of 2011 during the Hannover conference (Hirsch-Kreinsen, Weyer, & Wilkesmann, 2016). From this survey, at least 15% of participants in SA firms said they do not know what Industrie 4.0 is. While it was noted that people are making an effort to get new knowledge and learn about new concepts, this should translate into pragmatic programmes or projects which will benefit the firms.

Industrie 4.0 encourages and allows manufacturers to acquire and use information from across all business processes, plants and operations. This can only be achieved if the IT and OT networks are merged. One of the critical findings was that in most firms, the two departments (i.e. IT and Operations) work in silos. From the results section, figure 13, while 36.67% of respondents thought merging of IT and OT network cannot be done without problems, at least 35% agreed that this is doable and 28% was not too sure about the prospects. This is a serious concern, because only when IT and operational networks converge, can one reap the benefits of the Internet of Things. The outcomes would be beneficial to local manufacturing firms. This will, amongst other things, help in productivity monitoring, employee efficiency management, monitoring and managing of machinery and business processes. In essence, the firm will access all business-related data or information in real time. However, it is noted that cyber-attacks and malware viruses are a reality. These could have devastating effects on manufacturing plants if undetected. This could be costly because of the potential to bring both production plant and smart networks to a standstill. The point being made here is that firms should have a consolidated view of the networks or ecosystem. This could help in documenting systems and processes into a workflow application and to react swiftly in the event of any problem, because all devices on a network are seamlessly detectable.

The study, supported by literature, revealed that this can only be achieved with a robust Industrial Internet of Things (IIoT) hardware and software infrastructure. The referred infrastructure is the one that can handle high volume data over the network, with high security standard to prevent cyber-attacks. The reality is that once the two networks are merged or integrated with each other, firms can then easily build what are called agile network structures. These kinds of structures would benefit all participants because collaboration would be enabled. Agile collaboration networks would enable manufacturing firms to fully leverage the opportunities arising from the globalised marketplace of skills and capacities (Bechtold et al., 2014). Figure 17 is an example of the agile network collaboration with all its elements that will be beneficial to the future firm.

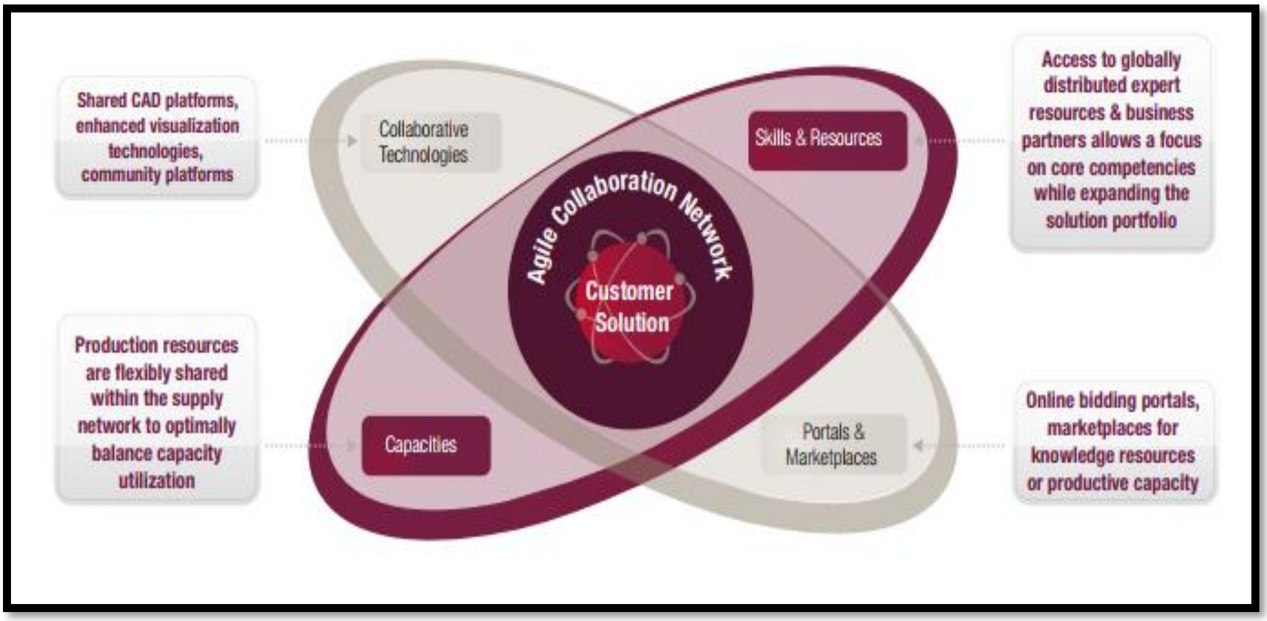

Figure 17: Technology layer and main elements of Agile Collaboration Networks (Bechtold et al., 2014)

Figure 17 illustrates a technology layer and its main elements which, if used, could create an agile collaborative network for local manufacturing firms. The figure is used to indicate further that the issue of merging IT and OT networks would be beneficial to local firms. This is necessary because, based on the survey; local firms have confirmed that the networks in their firms are still largely running in isolation. As an example, from figure 17, a customer solution can be devised using collaborative technologies. This can happen on a project life cycle or on a temporary basis depending on the current customer needs.

The resources and skills required act as a guide to firms that should participate. This is clearly dependent on the firm's capabilities. As an example, while one firm focuses on the components' software and associated services, the other one might focus on customer feedback or voice, while the third focuses on the delivery of the solution to the customer and after sales activities. This is something that could benefit manufacturing firms in South Africa. Industry 4.0 is a cross-cutting topic that runs all areas of the manufacturing plant. However, it has been already noted that most local factories are generally operating in silos. For Industry 4.0, it is of critical importance to collect the combined data and integrate it into systems and processes so that a cross-functional decision-making process is made simpler. To achieve all the combined data and analysis on one platform, IT and OT networks should merge, interconnect all business functions, and also integrate all upstream and down-stream data for customer feedback to be accessible and useful to organisations. The concepts of both vertical and horizontal integration can be implemented easily this way. Local firms could also create what is generally called technology road mapping. The benefits of the road mapping, amongst other things, include: provision of a framework that can help in planning and coordination of technology developments, both within a firm, or an entire industry. In essence, firms will have a process of identifying the needed technologies, and out of that process, identify common needs. A dedicated team can now refine and develop such technologies. The same team can then address critical research and development more effectively while at the same time; collaboratively develop key processes/products which serve the common purpose of the entire industry.

Since there will be collaboration, cost effectiveness becomes a reality as resources are shared, and as a result, the industry becomes more competitive. These should be implemented seamlessly if the Internet of Things is a reality in South African manufacturing firms. Like any other prior industrial revolution, this revolution creates hype and promises wonderful things. It promises to connect people, sensors, things and everything in a digital way. In this instance, real time data becomes a competitive advantage that South African firms can utilise to move the economy forward. Using the current technical knowledge in factories as a baseline is the way to go. Skills development in the direction that will align the firms with global competitors can resolve the question of lack of skills and lack of specialist staff for the smooth implementation of the Internet of Things. This will require private public partnerships. On cyber security as the main concern to the industrial revolution, the answer here lies in tightening the security features that IT personnel would be better placed to install.

Training more people to understand what cyber security is and how to build robust secured networks would be beneficial to the country and firms, in particular. Skills and training were on the top of the priority list. This is also strengthened by the fact that a lack of specialist staff is indicated as the third challenge. South African firms might want to tap into the skill sets of other countries through licencing, strategic collaboration and perhaps acquisitions of high skill personnel. The last option, which is acquisitions of high skilled personnel, could be extremely expensive. In most local firms, technical personnel have limited skill in terms of selling their ideas to those responsible for their project's approvals. This came out from the survey, when most of the respondents said that a lack existed of a clear business case to justify investments in underlying IT infrastructure. To address this, the firms should again train even their best technical personnel on basic management courses so that they know how to structure proposals and feasibility studies for project capital applications. The risk of implementing new and radical technologies in most manufacturing firms is imminent due to the disruptive nature of new and unknown technologies (Bauer, Baur, & Camplone, 2015). This was evidently illustrated from the survey, because most firms confirmed the lack of courage to push through with radical transformation without clear knowledge of what the risks and benefits are, as one of the concerns. This is as a result of a commitment to the traditional way of doing things, which is loyalty to existing processes, assets, and problem definitions. This makes it extremely difficult to explore new things, especially in a firm that is currently performing satisfactorily.

In a fast-moving global market and technological environments, local firms must be ready to continuously reinvent themselves and be relevant. Knowledge work, as illustrated from the survey, involves creativity and innovation. As a result, an independent judgment is required because knowledge work is not about how much information one holds, but rather about the inherent ability and power of ideas to connect with one another (Kastelle, Merchant, & Verreynne, 2016). Industrie 4.0 is about this connectivity for the benefit of all, at all levels of business and society as consumers of produced goods. The immediate issue that can be resolved again seamlessly by the implementation of merging of IT and OT network is the issue of difficulty in coordinating actions across different organisational units. In this era and age, this is disappointing. There are solutions like virtual office communicator, intranet, cloud computing, etc. This is because most firms operate their various units in silos. This is even worse where one firm operates different enterprise resource planning systems.

This would mean that there is no common platform where all information is consolidated and can be used for the business interests. This modus operandi is expensive and remains a recipe for disaster. Bechtold et al. (2014) asserts that firms are encouraged to have a common platform, where all data can be consolidated, transferred and accessible across all units, especially if a firm decision model is based on the dependency of various integrated units. Local firms might even want to revisit their business model to remain relevant and competitive.

Recommendations

The recommendations for the study are presented through three sections namely: recommendations to local firms, recommendations to manufacturing firms and recommendations for academic intervention to bridge cyber security challenges

Recommendations to local firms

Local firms should enter into partnerships with institutions of higher learning, specialist training providers as well as policy makers to develop a curriculum where tailor-made courses can be developed in line with Industry 4.0 skill set requirements. This recommendation is arrived at based on the obtained results as highlighted on table 3 of the results section. From the table it was clear that certain skills can be taught in a classroom environment while other technical skills can only be learned from the work place and it is with this understanding that private public partnership could be more valuable.

Recommendations to manufacturing firms

The second recommendation is that manufacturing firms in the country should form partnerships or a community platform where ideas, research information/studies, and key learnings from Industrie 4.0 projects are shared. This forum can also include the innovation hub of South Africa and the CSIR. This recommendation from the question on support measures necessary to put them at ease with the topic. A majority of participants indicated that they want an opportunity to be in training courses/ seminars, followed by 20% that require involvement in research projects. A further 19.1% indicated that they would love to participate or be involved in working groups that deal with Industrie 4.0. In essence, all participants want some sort of community where ideas on this kind of information, projects and research work can be shared, hence this recommendation is important.

Recommendations for academic Intervention to bridge cyber security

The last important recommendation is on companies to bridge the knowledge gap that exist in terms of cyber security when implementing Industrie 4.0. Companies remain vulnerable to attacks due to weaker IT security systems which could bring devastating effects and even data loss. This came out from the study when asking participants about factors that hinders the implementation or acquisition of industrie 4.0 technologies. In this instance most participants are concerned about the data security as well as concerns over cyber security especially when working with third parties during the implementation phase of industrie 4.0 projects.

Conclusion

The purpose of this study was to determine the factors which harness firm level innovation for Industrie 4.0 in South Africa (SA). A quantitative approach was adopted using an online survey questionnaire. The study provided an insight on the challenges that South African manufacturing firms face in relation to the adoption and diffusion of new technologies brought about by the fourth industrial revolution. The study identified the challenges that local manufacturing firms face when implementing projects that are in line with Industrie 4.0. Factors that need to be prioritised in order for local firms to be in line with Industrie 4.0 were also identified.

The study concluded with the recommendations that could help local firms in moving forward and sustaining the gains brought about by the fourth industrial revolution. Amongst the challenges identified were: Lack of necessary skills (i.e. Problem Solving; IT knowledge and abilities; Decision making; Ability to interact with modern interfaces; and Data and Information processing and analytics.); While security know-how protection would have been thought of as a serious challenge, participants did not identify it as serious. Cyber security issues that were identified elsewhere did not seem to influence participants thinking this time around; instead process/work organisation was added to other challenges.

Interestingly for the local firms, participants mostly said they are aware of what Industrie 4.0 is though they are not fully participating or implementing projects along those lines. As a result, most firms are still investigating the concept even though they already believe that due to the fourth industrial revolution, firms' competitiveness will develop. At least 95% of respondents said they expect improvement in operational effectiveness after the implementation of Industrie 4.0 in their organisations. These confidence levels and knowledge that Industrie 4.0 brings competitiveness should be taken to boardroom levels where firms' strategic decisions are taken. The study concluded that the following factors would harness innovation in line with Industrie 4.0 in South African local firms: availability of necessary skills, clear business case that justifies investments in the firms' IT architecture; difficulty in coordinating actions across different organisational units using the common network brought about by the Cyber-physical production system; courage to push through radical transformation and integration of data from disparate sources to enable Industrie 4.0 applications. Even though, the study was relatively small-scale, confidence in the generalisability of findings is enriched by high levels of consistency in the results obtained from the literature review on applicable theories and previous surveys of this nature. There was also a notable consensus among participants. The high levels of consistency and consensus among participants suggest that the challenges identified may be generic and relevant to other local firms.

Points to consider for future studies:

Cyber security after the implementation phase of Industrie 4.0 projects came out as one of the few points that can be valuable for future research and/or intervention. The other point worth researching further is on collaboration and ownership after implementation of Industrie 4.0 projects. This is to be sure of who will then maintain especially the software and data gathered for use to make business decisions in a firm.

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