INDUSTRY 4.0: A MYTH OR A REALITY IN SOUTH AFRICA?

M.T. Dewa¹, D.Q. Adams², T.G. Tendayi³, L. Nyanga⁴, M. Gxamza⁵ & L. Ganduri⁶

¹-⁶ Department of Industrial and Systems Engineering
Cape Peninsula University of Technology, South Africa
¹dewam@cput.ac.za, ²adamsdq@cput.ac.za, ³tendayit@cput.ac.za, ⁴nyangal@cput.ac.za,
⁵gxamzam@cput.ac.za, ⁶ganduril@cput.ac.za

ABSTRACT

There has been much discussion on the subject of the fourth industrial revolution, also known as Industry 4.0, over the past decade in academia, industry and media. It is generally agreed and documented that the shift towards Industry 4.0 started in Germany and rapidly spread to the rest of the developed economies such as the United States and Japan. What has received little attention or documentation, is the use of Industry 4.0 in developing economies such as South Africa. This paper attempts to shed more light on the state of preparedness of South African companies to embrace and implement Industry 4.0. A comprehensive literature study is conducted, from which the critical technological framework for Industry 4.0 is outlined. From this information, an empirical study is then performed through a survey of carefully selected companies in South Africa. From this survey, the preparedness of the investigated firms with regards to awareness and implementation of Industry 4.0 is identified. The paper then concludes with recommendations on the way forward if South African companies are to ensure that they don’t get ‘left behind the train’ of Industry 4.0.

¹The author is a Lecturer in the Industrial and Systems Engineering Department at the Cape Peninsula University of Technology, South Africa
²Corresponding Author
1. INTRODUCTION: BACKGROUND TO INDUSTRY 4.0

The pursuit of every professional industrial engineer is grounded in three main ideas, the idea that humankind throughout the ages has searched to improve in all areas of their lives, personal, professional and spiritual. The second idea is that of doing things in the most optimal methods with what we have, and lastly the notion of searching for ways to do things better, faster and smarter. The world is changing and there is need to keep up to pace with the fast growing and rapidly changing environments.

This paper focuses on Industry 4.0 (I.4.0). The emergence of the I.4.0 concept began in Germany. As an introduction to the overarching topic, this section serves to shed light on the thinking of I.4.0. The German federal government first initiated “Industrie 4.0” as a strategic initiative that was adopted as part of the “High-Tech Strategy 2020 Action Plan” in November 2011 [1]. The concept started as a consolidated push to improve the countries manufacturing sector. Hermann et al. [2] examines this work and gives the topic a defined area with which to work within and aims to create design criteria for other researchers to follow on developing the concept further. According to the Hermann et al. [2], the increasing integration of the internet and connectivity into the industrial value chain has set the foundation for the next industrial revolution. Kiel [3] also highlighted that the fourth industrial revolution is a present hour reality built on the idea of connecting many things together and have them work in perfect balance. Fundamentally humankind is searching for the next improvement and Hermann et al. [2] believe it will come in the form of connection of humans, machines and processes. A revolution can be defined as the major change to the way thinking and doing something, or a substantial shift in the process of performing tasks. This can happen in small jumps or it can happen in the form of big jumps. It is often assumed that revolutions must come as large explosions. However, a revolution can be in the form of big ideas, and small tasks and improvements getting one closer and closer to that Big Idea. The idea and background of I.4.0 came from the grounding in previous industrial revolutions, as seen in Figure 1 below. Starting from water, steam and machines, to electricity and mass production, finally into with the dawn of Computers and the digital age of IT and machine automation.

Figure 1: Overview of industrial revolutions: Source, Own Illustration based off [1]

1.1 Local relevant literature for South Africa

An investigation of available literature relevant to the South African context was conducted in order to identify what other authors are saying about the readiness of South Africa (SA) in terms of I.4.0. The literature covered focused on studies conducted in South Africa. Most work done to date refers to teaching, learning and education creation and development of frameworks within a learning factory environment [4]. Some reports on the subject were done for the Denel, Food and Beverage, Plastics, Construction, and Mining industries. These reports are
published online in magazine articles. Calitz, Poiset and Cullen [5] do an analysis of the automotive sector of SA when surveying the field of 13 businesses and respondents provide positive signs that indeed the strategies and thinking of using collaborative robots is being investigated and indeed 2 working types can be seen. Other respondents provide confirmation of proof of concept machines being tested.

Dlodlo [6] does an analysis of rural needs in Zambia and SA, [7] and how the internet of things (IoT) can help alleviate some of the challenges by injecting productivity and growth in the agriculture sector. A special report published by Deloitte [8] on trying to ascertain if Africa ready for a “digital transformation”, looks broadly at various companies in the automotive and manufacturing sector on the merging of real and virtual worlds. In the paper, we seek to provide a unique local perspective of the concept I.4.0. Empirical evidence for the South African manufacturing sector remains lacking in the literature, hence leaving a gap for potential researchers to explore. This also leaves businesses and reasearchers unable to gauge where SA as a nation stands with regards to the I.4.0 concept.

There seems to be a an ongoing research process uncovering the description and meaning of I.4.0 for SA as mentioned in the evidence above. However, researchers and practitioners still need to select and explore specific scenarios where I.4.0 can be implemented. In addition to this, a uniquely South African perspective on the readiness of SA for I.4.0 is yet to be determined. The paper will focus specifically on looking at the enabling technologies used in manufacturing firms, in order to establish an assessment tool in order to gain quantitaive understanding of the current state of I.4.0 within the SA manufacturing industry.

2. RESEARCH METHODOLOGY

2.1 Aim, scope and research questions

The primary aim of the research was to develop a tool with which to assess whether the South African industry is ready for I.4.0 concept. The objectives were to identify Industry 4.0’s different dimensions (critical success areas) that are being utilised in available work and the awareness of industry with state-of-the-art enabling technologies to facilitate this concept. Furthermore, another objective involved coming up with a method of rating and assessing companies in different sectors based on the parameters derived from identified dimensions earlier on. To fulfill the above aim, a three-point methodology was followed: (i) Literature search, to study Industry 4.0 and understand its practical aspects and requirements, (ii) Data collection from Industry focusing on Industry 4.0 infrastructure development and future plans, and (iii) Design conceptualisation of a tool (or assessment strategy). The outcome of the literature search was that there are certain crucial enabling I.4.0 technologies that need to be set in place before the concept can be developed further upon. Secondly, in order to precipitate this concept a tool for assessment of the readiness was needed. Warwick University [25] outlined a set of 6 Dimensions indicative pointers towards the areas upon which businesses should be rated.

The outcomes of these processes formed the basis for a survey of Industry partners to determine their orientation and progress toward Industry 4.0 development. The guiding research questions were:

1. What are the key Industry 4.0 technologies, concepts and features facing industry that need to be understood?
2. Are companies/industries aware of the Industry 4.0 concept?
3. How will organisations who are interested in the emerging I.4.0 know if they are ready or not?

The main focus was on the South African manufacturing sector as the assumption is that they would be most “ready” and ‘aware’ with regards to the I.4.0. concept, since it was initiated for the German manufacturing sector. However, a limitation encountered during the study was that of access to research participants. In most cases, it was a challenge for respondents to be open and share their companies’ perspectives and action regarding the shift and strategic direction of thought. Another constraint encountered was that of the profile of the respondents participating in the study being limited to personnel in companies with alumni the department of Industrial and Systems engineering. The industry partner database of all companies where previous students have spent their ‘in-service’ year of work integrated learning module was utilised to identify these companies.

2.2 Method

A pilot study was conducted with 7 manufacturing companies, whereby senior level supervisors were consulted about the awareness of I.4.0 and use of digital technologies in their respective workplaces. The purpose of the pilot study was for refining the data collection instrument. The initial survey involved open-ended questions as described in Section 2.1. Using the open-ended surveys and interviews, a readiness model was developed for the South African context. The aim f the model was measure and assess the companies’ position with regards to implementing the I.4.0 technologies, methodologies, models and frameworks.
After the pilot study, a structured survey questionnaire was sent out to 150 participants. The questionnaire was designed in such a way that the participants would assess their respective organisations for the purpose of determining readiness levels for the concept I.4.0. An examples of a question is illustrated in Figure 2 below.

**Instructions:**
For each of the 6 dimensions, use the readiness assessment criteria to identify your current level of readiness (0, 1, 2, 3 or 4) for each of the sub-dimensions.

An Outsider is a company that does not meet any of the requirements for Industry 4.0 of which Industry 4.0 is either unknown or irrelevant for them. A Beginner is a company which might not meet the requirements of Industry 4.0 but they are aware of it.

A five-point Likert scale was used in most cases for the responses to the questions for each dimension with 0 = outsider, 1 = beginner, 2 = intermediate, 3 = experienced and 4 = expert as illustrated in Figure 3.

**Figure 3: Extract from survey questionnaire, Section B, Dimension 2**

### Section B: Industry 4.0 Dimensions

#### Dimension 2 - Manufacturing Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Level 0 Outsider</th>
<th>Level 1 Beginner</th>
<th>Level 2 Intermediate</th>
<th>Level 3 Experienced</th>
<th>Level 4 Expert</th>
<th>Company Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile devices (Cell phones or Tablets)</td>
<td>Never used</td>
<td>Rarely used</td>
<td>Often used</td>
<td>Very Often used</td>
<td>Always used</td>
<td></td>
</tr>
<tr>
<td>Production or shop-floor Machines connected to the Internet</td>
<td>Never used</td>
<td>Rarely used</td>
<td>Often used</td>
<td>Very Often used</td>
<td>Always used</td>
<td></td>
</tr>
<tr>
<td>Internet of Things platforms</td>
<td>Never used</td>
<td>Rarely used</td>
<td>Often used</td>
<td>Very Often used</td>
<td>Always used</td>
<td></td>
</tr>
<tr>
<td>Radio Frequency Identification (RFID)</td>
<td>Never used</td>
<td>Rarely used</td>
<td>Often used</td>
<td>Very Often used</td>
<td>Always used</td>
<td></td>
</tr>
<tr>
<td>Bar Code Technology</td>
<td>Never used</td>
<td>Rarely used</td>
<td>Often used</td>
<td>Very Often used</td>
<td>Always used</td>
<td></td>
</tr>
<tr>
<td>QR Code Technology (add picture in appendix)</td>
<td>Never used</td>
<td>Rarely used</td>
<td>Often used</td>
<td>Very Often used</td>
<td>Always used</td>
<td></td>
</tr>
<tr>
<td>Advanced Human-Machine Interfaces (HMI)</td>
<td>Never used</td>
<td>Rarely used</td>
<td>Often used</td>
<td>Very Often used</td>
<td>Always used</td>
<td></td>
</tr>
<tr>
<td>3D Printers</td>
<td>Never used</td>
<td>Rarely used</td>
<td>Often used</td>
<td>Very Often used</td>
<td>Always used</td>
<td></td>
</tr>
<tr>
<td>Smart/Intelligent Sensors</td>
<td>Never used</td>
<td>Rarely used</td>
<td>Often used</td>
<td>Very Often used</td>
<td>Always used</td>
<td></td>
</tr>
<tr>
<td>Authentication and Fraud detection software</td>
<td>Never used</td>
<td>Rarely used</td>
<td>Often used</td>
<td>Very Often used</td>
<td>Always used</td>
<td></td>
</tr>
<tr>
<td>Big Data Advanced Analytics</td>
<td>Never used</td>
<td>Rarely used</td>
<td>Often used</td>
<td>Very Often used</td>
<td>Always used</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 4: Percentage of firms who participated per province**

2.3 **Scope of Study**

The questionnaires were distributed to 150 participants across South Africa. 103 participants were from the Western Cape and 21 participants from Gauteng province, made up 83% of the participant pool. The companies were classified into ten main operating sectors, namely “Food & Agro-processing”, “Automotive”, “Chemicals”, “Information & Communication Technology”, “Electronics”, “Metals and Mining”, “Textile, Clothing & Footwear”, “Wholesale and Retail trade”, “Financial Services” and “Other” which include “Consulting”, “Supply Chain Management”, “Aerospace” and “Research and Development”. Figure 4 below illustrates the percentage of firms who participated per province, while Figure 5 indicates the sub-sector percentage of firms which were involved in the study.
The companies visited were also grouped according to number of employees in the company with the following ranges: 0 - 50, 51 - 100, 101 - 500, 501 - 1000 and more than 1000.
The main group of participants were selected to be from a “Senior Management Level”, 67%, with an excess of 10 years’ experience in their given field. Details of the breakdown of the different levels of participants can be seen in Figure 7 below:

![Figure 6: Company size data](image)

![Figure 7: Management levels](image)

### 3. LITERATURE REVIEW

#### 3.1 Search and data gathering strategies

The search strategy employed in the literature review involved first identifying the relevant data sources and key words. These sources included journals, conference proceedings, technical reports, articles from trade journals and company websites. The search field included a significant number of non-journal internet sources, and the search was conducted using a range of keywords and key phrases that could be relevant to the South African context and their potential impact on the manufacturing sector. Examples of these included, but were not limited to: “SA and Industry 4.0” and “Fourth industrial revolution impact on Africa”.

#### 3.2 Technology Readiness Levels

The National Aeronautical Space Administration introduced the technology readiness level (TRL) scale in the 1970s as a tool for assessing the maturity of technologies during complex system development. Since then, it has been used to make multi-million dollar technology management decisions [9]. The TRL scale has been
embraced by the U.S. Congress’ General Accountability Office (GAO), adopted by the U.S. Department of Defense (DOD) and other numerous organizations ([10], [11], [12] and [13]). The scale shown in Figure 8 the progression of a technology from a level where only basic principles have been observed and reported (TRL1) up to a level were the actual system has been proven through successful system and/or mission operations (TRL9).

Most of the existing TRL models focus on specific criteria for manufacturing technologies and for concepts such as Industry 4.0 [14]. Examples of these models include Manufacturing readiness levels (MRL) created by the US Department of Defense [15], the Manufacturing capability readiness level (MCRL) created by Rolls-Royce [6] and the Manufacturing technology readiness level (MTRL) proposed by Peter [16].

![Assessing Specific Technology “Functional Maturity”](image)

**Figure 8 Overview of the technology readiness level scale [10][11]**

A few models and tools for assessing readiness or maturity of I.4.0 have been proposed. Lichtblau et al [17] developed a self-check online tool which companies can use to measure their own Industry 4.0 readiness. The tool uses six dimensions of Industry 4.0 including 18 items to indicate readiness in 5 levels. The company’s self-assessment profile is then benchmarked against the profile of leading Industry 4.0 companies and their target profiles. The barriers for progressing to the next stage are defined and advice is given on how to overcome them. Kagermann et al [18] have a model which focuses on the development of horizontal integration, in addition to vertical integration, through value networks and end-to-end digital integration across the entire value chain. They identified eight key priority areas and gave recommendations on how to implement them. Bitkom, VDMA and ZVEI [19] developed a reference architecture model for Industry 4.0 (RAMI 4.0) as a way of achieving a common understanding of what standards, use cases, etc. are necessary for Industry 4.0. The model contains key milestones focusing on enabling the companies to achieve horizontal integration via value creation networks over the entire life cycle. It also includes vertical integration, networked production systems, new social infrastructures for work and continual development of cross-sectional technologies. Pricewaterhouse Coopers [20] developed an online-self assessment with dimensions which focus on digital maturity in 4 levels. Unlike the model by Lichtblau et al [17], this assessment tool has 6 dimensions. Rockwell Automation [21] developed a five-stage approach to realise Industry 4.0 using a technology focused assessment in 4 dimensions. It gives no details about items and the development process offered.

Roland Berger Strategic Advisory Company developed a country ranking called the Roland Berger Industry 4.0 Readiness Index [22]. It comprises core categories such as Industrial Excellence and Value Network and sub categories such as production process sophistication, degree of automation and workforce readiness innovation intensity. The readiness index ranks European countries into four categories, namely forerunners, traditionalists, hesitators and potentialists. The Forerunners are characterised by a broad industrial base, modernized development-oriented business conditions and application of technologies. Traditionalists have a strong industrial base and still have a healthy structure. Hesitators on the other hand lack a reliable industrial base.
and are struggling, with government finances not being able to transform their economy. Finally, Potentialists have a former strong industrial base which has weakened during the recent years. Viharos et al [23] proposed a non-comparative Industry 4.0 readiness evaluation method that is fully personalised to the manufacturing company evaluated and independent of recommendations of international consulting firms. The Singapore Economic Development Board [24] developed a three building block, eight pillar and 16 dimension readiness index. Onur et al [25] developed a model which consists of 6 core dimensions and 37 sub-dimensions. Its purpose is to provide a simple and intuitive way for companies to start to assess their readiness and their future ambition to harness the potential of the cyber-physical age.

3.3 What other developing countries are doing

According to Gilchrist [26] some of the developing countries that are already preparing for and adopting strategies regarding Industry 4.0 are China and India. In addition to these countries, there are other developing countries such as Singapore, Thailand and Malaysia which are making inroads in this regard. A further distinction can be made between traditional developing countries such as SA, and more advanced developing countries like Singapore as explained by Wilson [27]. What follows is a brief discussion on some of the developments, together with challenges to implementation, that are taking place in these countries and the lessons that SA can draw from them.

Applications of Industry 4.0 go beyond the traditional manufacturing space such as in Singapore where the phenomenon was used to optimise resources within an Eco-industrial park as explained by Pan et al.[28]. In Malaysia, Barhin et al. [29] explore developments around robotic and automation product innovation using industry 4.0 principles. However, most of this innovation was found to be happening mostly amongst the big foreign companies based in Malaysia and not as much within the Small to Medium Enterprises who do not consider Industry 4.0 to be of great relevance to them. The Malaysian government is now actively engaged in addressing this through programmes such as the Eleventh Malaysia Plan.

A suggestion has been made by Zhou [30] for China to develop its own industrial development model which involves the parallel development of Industry 2.0, Industry 3.0 and Industry 4.0. The reason for this approach is based on the argument that it is unrealistic to expect that all industries can immediately achieve an Industry 4.0 upgrade. Thailand is another country that is going through a gradual transition to Industry 4.0 or what Jones and Pimdee [31] describe as Thailand 4.0 which they argue can be achieved by first investigating the legacy of Thailand 1.0, 2.0 and 3.0. Some significant obstacles to the implementation of Thailand 4.0/Industry 4.0 included what they called the middle income and inequality traps. It is the authors’ premise that these challenges are indeed not unique to Thailand and can be observed in other developing countries as well.

It can be seen from the small sample of countries covered that Industry 4.0 has indeed taken off in the developing and so-called advanced developing countries. This has happened with varying degrees of success and with common obstacles to implementation being observed along the way. Valuable lessons can be learnt from the experiences of these countries as SA, which is also a developing country, embarks on the same journey.

3.4 Enabling Technologies

The Industry 4.0 framework, established by Reinhard et al. [32], is used in this paper to formulate the theoretical framework used. In this paper, different classes of currently available digital technologies, which can potentially improve manufacturing operations, are outlined. This model was specifically chosen due to its inclusion of a number of current technologies which fit into the I.4.0 framework.

3.4.1 Location detection technologies

With the Global Positioning System (GPS) technology freely and readily available nowadays, the tracking of object position is now possible. In the early 19th century, barcode technology was commonly employed to record and communicate locational information for objects. However, with the advancement of electronic gadgets, RFID technology is also growing in usage within the manufacturing sector [33]. These technologies allow Automatic Identification (Auto ID) and tracking of objects while collecting specific data of parts moving in an environment [33]. Location detection technologies like RFID devices are known to have many applications in supply-chain related problems, such as creating an Internet of Things framework [34], distributed manufacturing control [35] and mass customisation production [36]. The major drawbacks in the implementation of RFID technology have been as a result of proximity challenges, the effect of metal and water on RFID waves [35] and the high cost of implementation [34]. Due to the high implementation costs, SMMEs rarely use these technologies on the shop floor.
3.4.2 Internet of Things platforms

The IoT is the network of physical objects around us that contain electronic components, software, sensors and networking systems that allow these objects to exchange and acquire information. Hence, an IoT framework comprises of everyday physical objects with attached sensors which send big data streams to the internet for information analytics via a communications or networking channel [38]. To converge this world of devices together in a more efficient way, IoT platforms have emerged [39]. These are readily available online tools for linking sensors to the cloud with analytics capabilities as well. These include the Google cloud, Thingworx, Microsoft Azure, and Jasper (Cisco) platforms [40].

3.4.3 Mobile devices

More recently, mobile devices like smartphones and tablets have become ubiquitous in everyday life [41]. These gadgets have become readily available at low prices, causing a growth in usage in the 21st century. Modern smartphones have become programmable. They also come with a growing number of embedded sensors, such as a digital compass, an accelerometer, gyroscope, GPS, microphone and camera [42]. As a result, the range of data these devices can handle is enormous, including types like text messages, GPS, barcodes, QR-codes, pictures or images, audio and video [43]. Furthermore, nowadays, mobile devices can browse the internet, making them easily part of a global network of other objects. Mobile data can be accessed anywhere at any time, in near real-time [44]. Mobile devices are well-suited for applications in which the data collection is repeatedly done, conducted in a distributed way and a large percentage of the data types collected are quantitative in nature [45].

3.4.4 Augmented reality and wearables

Wearables and augmented reality are two technologies that look poised to empower the worker of tomorrow to be extraordinarily efficient and productive through contextual computing capabilities [46]. These applications are used for maximising the contextual awareness of an individual through providing real-time information, which is fundamental for decision-making. A majority of applications for this technology exist in the medical field where human monitoring systems for pulse rate, body temperature and exercise habits have been developed ([47] and [48]). However, the major drawbacks for the adoption of this technology include limited battery lifespan of devices, design and aesthetics of wearables, data privacy and management, and interoperability among solutions and vendors [49]. Furthermore, the cost of implementing such technologies is very high, while a majority of vendor-oriented integration issues remain unresolved [50].

3.4.5 Cloud computing platforms

According to Careterro and Blas [51], cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This model of technology is a broad field of study with numerous resources which allow the sharing of data over distributed systems. Google has the most commonly used cloud computing resources in the form of Google drive [52]. Microsoft Azure is another commonly used platform for Windows users [51]. Cloud computing platforms have a wide usage in many domains, including business [53], healthcare and manufacturing [54].

3.4.6 Multilevel customer interaction and customer profiling technology

A number of technologies, which enhance the interaction of customers with products and services that companies offer, are emerging on the market [55]. These solutions allow customers to define the product design during the conceptualisation stage and also order items online without having to visit a firm or store [56]. Application areas for this class of technology include the use of self-service technologies (SSTs), such as telephone banking, automated hotel checkout, and online investment trading, whereby customers produce services for themselves without assistance from firm employees.

3.4.7 Big data analytics technology

With the volume and speed of data generated by computers and the internet growing exponentially each year, the field of big data has grown and attracted much attention in academia [57]. The field involves the use of data streams for inferential decision-making. As a result, many domain applications for big data technology have emerged and these include; supply chain management [58], manufacturing [59] and healthcare [60]. A major drawback in the wide adoption of big data analytics technologies is the issue of data security [61].
3.4.8 Smart sensors and 3D Printers
With the ability to embed intelligence in systems made easier in the 21st century, smart sensors are also emerging on the market [62]. These devices can make decisions based on the data they obtain through instrumental recording. Smart sensors have been used widely in academia and research with applications in the transportation and logistics industry [63], manufacturing [64], security [65] and healthcare [66] amongst many other examples. Rapid prototyping has become a key stage in the product development cycle and 3D printers have emerged on the market to fill this gap. Their usage has been broad in fields of construction [67], manufacturing [68] and medicine ([69]; [70]; [71]; [72]and [73]).

3.4.9 Advanced human-machine interfaces
With the growth of embedded sensors in industrial equipment, human-machine interfaces for the real-time analytics of machinery performance have become a present hour reality [74]. Advanced human-machine interfaces are common on current industrial machines with numerous applications, which include motion study [75], and manufacturing [76].

3.4.10 Authentication and fraud detection technologies
The high rate of cybercriminal activities and need for security in specific fields make authentication and fraud detection technologies critical. The retail payments have the highest usage of these technologies [77]. Other applications are found in internet banking [78] and security systems [79].

4. Readiness Level Model Concept for SA Context I.4.0.

The models used by Warwick University [25] and Impuls [17] were used in developing the model used in this paper. An additional level 0 (outsider) was added to the Warwick model to cater for the respondents who did not know about Industry 4.0 or are not interested in implementing it. As for the Impuls model, Level 5 (top performer) was removed. This is because from our preliminary survey, we did not have any companies that had the technology to fully support I.4.0. Six dimensions of I.4.0 were selected namely, Products and Services, Enabling Technologies, Manufacturing and Operations, Strategy and Organisation, Supply Chain Integration and the Business Model. In each of these dimensions the respondents would score their company on a scale of 0 to 4 where 0 is Outsider, 1 is Beginner, 2 is Intermediate, 3 is Experienced, 4 is Expert. The average score for each company per dimension was then calculated then the overall Readiness score was then determined from those averages.

5. Discussion of Results and Analysis

5.1 Results
The questionnaire survey was conducted with 150 participants from different provinces in South Africa (as illustrated in Figure 4). Of the 150 questionnaires sent out, only 30 were returned, making the response rate 20%. However, only 21 of the 30 returned questionnaire were in a usable format, with the other nine inadequately completed. Hence the nine incomplete questionnaires were disregarded and only 21 were used in the analysis.

5.1.1 Enabling Technology
This dimension assessed the frequency of use of the I.4.0 enabling technologies. According to the survey results shown in Figure 9, the most readily used are cloud computing platforms and mobile devices which are on level 3. Bar code technology leads the auto identification technologies in terms of readiness and usage. QR codes are next popular in our survey results coming in at level 2.42 readiness level. RFID is rarely used, possibly due to the high investment costs required to implement it. IoT and Big Data and 3D printers are rarely used according to the results. Internet of things could possibly be low because of lack of awareness, insufficient bandwidth infrastructure and insecurity with regards to cyber-attacks.
5.1.2 Manufacturing and Operations

This dimension looks at the suitability of the manufacturing systems and operations for the implementation of I.4.0. Information Technology (IT) and data security is rated at level 2 as shown in Figure 10, although this is still fairly beginner level of I.4.0 readiness. Computer and IT solutions in the form of high specification computers, servers and firewalls have been invested in or partially implemented. These still cannot link with the basic machinery to invoke much change and integration to the manufacturing systems at large. The results also show M2M, autonomously guided work pieces, self-optimising process, and digital modelling are rated on the lower end of the assessment tool. This indicates that South African firms have basic machinery in their manufacturing systems, which are not yet capable of dealing digital modelling and other such advanced I.4.0 tasks.

Figure 9: Enabling Technologies Results

5.1.3 Strategy and Organisation

This dimension analyses the suitability of the strategy of the organisation for the implementation of I.4.0. The collaboration sub-dimension assessed the level of the organisations with regards to their ability to interact inter-departmentally and also across different companies. The results in Figure 11 indicate that there is interaction...
between departments but there is no cross-functional collaboration between them as indicated by the rating of level 2.4. The current rating can be justified by the fact that departments intrinsically interact on a day to day basis. The investment sub-dimension was rated at level imim1.3 and this can be attributed to the lack of value proposition perceived by businesses on implementing I.4.0.

**Figure 11: Strategy and Organisation Results**

### 5.1.4 Overall Readiness Levels

The following results present the averages for all the 6 dimensions. From the results in Figure 12, it was observed that the aggregate readiness level starts high in the micro (0-50) range, then drops down to the lowest point in the medium (101-500) range. Based on these findings, our assumption is that the small micro company sizes have smart innovative and flexible processes, and when the company starts to have too many employees and staff the necessity for integration and I.4.0 enabling technologies the thematic starts to drop down. As the company size becomes 501 and more a company cannot function without, the internet, cloud-based solutions, mobile technology that is integrated into the entire system of business operations. A reason for this trend could be that small business owners are entrepreneurs who are trying to maximise on the opportunities that I.4.0 will bring to their businesses [80]. However, as they move on they start to experience challenges with resources to fully implement I.4.0. As with the big companies, these are mostly OEMS who have mother companies where I.4.0 is advanced and there is a strategic push for it. This is consistent with other developing countries such as Malaysia as mentioned in the literature above.
According to the findings, a readiness level score of 1.89 was obtained as shown by Figure 13. This score was calculated by using the average of the individual readiness levels from all respondents.

Figure 12: Average readiness level per company size

Figure 13: Overall averages per Dimension
Figure 14: Overall Readiness of Respondents

The yellow line in Figure 14 indicates the overall readiness level according to the responses of the survey, and also in relation to all five levels. Level 0 - level 4. The companies are sitting on the boundary between Newcomers and Learners.

5.2 Analysis

As our Technology Readiness level results have shown South African firms are lagging behind in terms of implementation of I.4.0. One of the basis for the implementation of I.4.0 is the existence of enabling technologies. From the survey done on the frequency of use of enabling technologies, most of the respondents (12 out 21) did not answer the question. This could possibly be due to them not having the technologies, in the case of micro and small companies, or not understanding the use of the technologies, in the case of large companies. This could be the major reason why the companies scored so low in this survey.

Another possible reason could be lack of supporting government policies. Top Government officials have been publicly acknowledging and discussing the need for I.4.0. However, there is no evidence of tangible policies, programmes or engagement with industry. Most of the firms who are trying to implement I.4.0 are entrepreneurs who want to maximise on the opportunities provided by the concept.

6. CONCLUSION & RECOMMENDATIONS

The results of the study show that there is a lack of awareness concerning Industry 4.0 both in academia and in industry. There is therefore a great need to educate the community on the concept and formulate implementation strategies which are relevant to the SAan environment. Government at the top level of government has been heard to support the initiative.

Future work can be conducted on developing a decision-making framework for the implementation of Industry 4.0 in SA.

REFERENCES


[17] Lichtblau, K., Stich, V., Bertenrath, R, et al. 2015, Impuls INDUSTRIE 4.0 READINESS. Aachen, Cologne


