Article

Industry 4.0: A Systematic Review of Surveys

Manduth Ramchander
https://orcid.org/0000-0002-3827-2349
Durban University of Technology
Manduthr@dut.ac.za

Abstract

The advent of Industry 4.0 has heralded a new era for manufacturing, and hence, the aim of this study was to ascertain the extent to which the phenomenon is being embraced by businesses in different regions of the world. The primary objective of the study was to establish business executives' perceptions on the extent to which their organisations are aware of and the extent to which their organisations would be influenced by Industry 4.0. The secondary objectives were to ascertain business executives' perceptions regarding the areas of business that would be most impacted by Industry 4.0 and their organisation's intention to invest in Industry 4.0. The methodology entailed a systematic literature review (SLR) of 10 industry surveys. The findings from the surveys were synthesised to reveal that there was generally a high degree of awareness regarding the Industry 4.0 phenomenon with the degree of influence being perceived to have the greatest impact on operational effectiveness, productivity and cost reduction. While most organisations have expressed intentions to invest in related technologies, this remains to be translated into equivalent levels of actual investments. The greatest challenge revolves around cyber security followed by the lack of appropriate skills. It is recommended that businesses collaborate with their suppliers and customers who may be more advanced in the digital journey to smoothen the learning curve. It is also recommended that organisations identify individuals within the organisation or recruit individuals who have the necessary skill set to lead change initiatives.

Keywords: Industry 4.0; big data; Internet of Things; cyber physical systems; digitisation

Introduction

Industry 4.0 represents a fusion of relatively new technologies such as big data, the Internet of Things (IoT), digital modelling, and computer-integrated manufacturing. Industry 4.0 has the potential of improving quality and productivity while at the same

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time making mass customisation possible, through increased flexibility (Zheng et al. 2018). While the advent of Industry 4.0 has heralded a new era in manufacturing, the extent to which existing literature has progressed towards clarifying the phenomenon is not clear, in particular, the degree to which the phenomenon has been embraced by business.

Only three systematic literature reviews (SLRs) were conducted to date. Lu (2017) reviewed 88 publications with the focus being on the content and scope of Industry 4.0. The focus of the SLR by Mohamed (2018), based on a review of 45 scientific articles, was to explore the scope of Industry 4.0 definitions, benefits and challenges. The third SLR by Oztemel and Gursev (2018) reviewed publications with the aim of providing a roadmap for digitisation. The aforementioned SLRs were published in journals for target audiences with interests in fields such as engineering, technical or operations, and falls short of a focus on business outlook. Hence, there is a gap in the literature regarding the extent to which businesses have embraced the Industry 4.0 phenomenon.

The difference with this paper is that, firstly, it presents the literature review on the scope of the phenomenon in such a manner that it appeals to a broader audience, and secondly, it focuses on consolidating the findings of various industry surveys. Hence, the aim of this study was to ascertain the extent to which the Industry 4.0 phenomenon is being embraced by businesses in different regions of the world. The objectives of the study were to establish the extent to which business executives/managers perceive: (i) their organisations to be aware of Industry 4.0; (ii) their organisations would be influenced by Industry 4.0; (iii) the areas of business that would be impacted by Industry 4.0; and (iv) their organisation's current level of investment, and intention and urgency to invest in Industry 4.0.

Industry 4.0 appears to be changing the way businesses function and the way in which they compete; thus in deciding on where to invest in new technologies, organisations need to have a full understanding of opportunities and threats (Deloitte 2017a). The significance of the study lies in its value of offering a deeper understanding of the scope of the Industry 4.0 phenomenon and providing some insight into how it is being embraced in different regions of the world. The next section constitutes the literature review, which is then followed by the research methodology. The findings are then presented, ending with conclusions and recommendations.

Literature Review

The literature review contextualises the Industry 4.0 phenomenon by a brief discussion of the industrial revolutions, definitions of the concept and the tracing of its origin. A more detailed discussion on the scope of Industry 4.0 then follows.

The Industrial Revolutions

The underlying thrust for each industrial revolution has been increased productivity (Schuh et al. 2013; Xu, David, and Kim 2018). The first industrial revolution (1760–1840) was triggered by steam power, driven by a need for mechanisation. The harnessing of electricity marked the advent of the second industrial revolution (1870–1940), driven by the need for mass production. Advances in electronics and information technology ushered in the third industrial revolution (1950–1970), spurred by the need for automation with analogue and mechanical systems being changed to digital systems (digital revolution) (Shrout, Ordieres, and Miragliotta 2014). Industry 4.0 has been referred to as the fourth industrial revolution (Kagermann et al. 2013) paving the way for mass customisation and extensive integration between customers, organisations and suppliers (Shrout et al. 2014). The main technology that drives Industry 4.0 is cyber-physical systems (CPS) (Klingenberg 2017). The phrase "cyber-physical systems" was coined by Helen Gill of the National Science Foundation, in the USA, to describe systems where operations are integrated, monitored and controlled by a computational core that is embedded into physical components that demand a real-time response (Baheti and Gill 2011).

Definitions of Industry 4.0

Hermann, Pentek, and Otto (2016) note that, although Industry 4.0 is a top priority for many companies, a generally accepted understanding of the concept does not exist and academics find difficulty in defining it. However, from a manufacturing perspective, it is defined as the application of advanced technologies to deliver new value and services for customers (Khan and Turowski 2016). Also from a manufacturing perspective, it is defined as the technical integration of cyber-physical systems (CPS) into manufacturing and logistics and the use of the Internet of Things (IoT) and services in industrial processes (Kagermann et al. 2013). More generally, Industry 4.0 has been defined as "the collective term for technologies and concepts of value chain organisation which draws together CPS, the Internet of Things, and Internet of Services (IoS)" (Hermann et al. 2016, 3928). This study adopts the manufacturing perspective definition espoused by Kagermann et al. (2013) as it is deemed to encompass all the elements of the other definitions.

Origin of the Industry 4.0

As costs in low-cost economies began to increase, the business case for offshoring was weakened and in view of high local labour costs, it became apparent that something different had to be done for manufacturers in Germany to remain competitive (BDO 2016). The phrase "Industry 4.0" was coined by Henning Kagermann, heading a group of industry executives and scientists in 2011, who was tasked by the German government to advise on the development of its hi-tech technology strategy (Mosconi 2015; Shead 2013). The phenomenon has since gained momentum due to the maturity and affordability of the underlying technologies (Khaitan and McCalley 2015) and more so due to the promise it holds for productivity gains (Sackey and Bester 2016). In recognition of the role Industry 4.0 could play in positioning the country in global markets, a number of government initiatives in different countries followed, such as those led by the General Electric company in North America, "Industrei du future" in France and "Made in China 2025" (Rojko 2017).

Scope of the Industry 4.0

Industry 4.0 is a strategic initiative that aims to transform manufacturing through digitisation and the exploitation of new technologies (Rojko 2017). The phrase is now embedded in the business lexicon as a catchall phrase (BDO 2016) and includes technologies such as big data analytics, advanced robotics, artificial intelligence, smart sensors, cloud computing, IoT, digital fabrication, cyber-physical systems, augmented reality, and mobile devices (Lasi et al. 2014; Ning and Liu 2015). These technologies are often thought of separately but when joined together, they integrate the physical and virtual worlds (Deloitte 2016). Mohamed's (2018) description of the main components of Industry 4.0 has been summarised, for ease of understanding, according to three aspects as illustrated in Table 1.

Table 1: Components of Industry 4.0

Component	Technology	Description/purpose
Identification	RFID	Identification of goods or item characteristics
Location	RTLS	Place of identification is located in real-time
Integration	CPS	The integration of the digital with real workflows through sensors and actuators collecting and sending data-ubiquitous computing
Networking	IoT	That which enables the communication with CPS and between CPS and users
Data collection and analysis	Big data Analytics	Analytics for data that have increased in variety, volume and velocity due to advances in sensor technology together with products with embedded computing capacities
Business service	IoS	Enables service vendors to offer services through the internet

Source: Adapted from Mohamed (2018)

Radio frequency identification (RFID) enhances supply chain efficiency by using a combination of tag, reader and antenna technology to support logistics in real-time by identifying and tracking product information at different points of the supply chain (Zhu, Mukhopadhyay, and Kurata, 2012). A real-time location system (RTLS) uses Bluetooth and GPS to pinpoint the exact geographic location of an asset (Zhang et al. 2016).

Big data analytics focuses on techniques for analysis and value creation that arises from the low value density of data in its original form and the need to analyse data to extract information that can be useful (Bhadani and Jothimani 2016). LaValle and Lesser

(2013) define big data as the collection and processing of complex data sets from a variety of sources, into competitive advantage. The prefix "big" to big data is not simply data scaled up in quantum but relates more with the expansive technology capabilities to connect disparate data sets through algorithmic analysis (Boyd and Crawford 2012). The handling of big data requires extensive analytics to transform the raw data into useful information and, more importantly, into concrete actions to support adaptive and continual self-optimising production processes (Rojko 2017).

Traditionally, big data research focused on human-generated and related data such as sales prediction instead of machine-generated data (Lee, Kao, and Yang 2014). The advent of Industry 4.0 makes possible the extraction and harvesting of industrial data, through advanced sensing technology. Industry 4.0 embeds the virtual world of information and communication technology within the real world of production with traditional industrial processes being optimised by digitisation, thus creating the foundation for the manufacturing of high-quality products (Burger 2017).

CPS refers to a new generation of machines with integrated physical and computational capabilities that enable new modalities of communication with humans (Baheti and Gill 2011). The digital transformation and the resultant exponential growth of CPS make autonomous machine-to-machine and machine-to-human communication an imminent feature of smart factories (Cooper and James 2009). A key feature of smart factories would entail the data exchange between different devices and parties, in real time, about materials movement, production status, energy consumption, customer orders and suppliers' data (Shrout et al. 2014), resulting in flexible production objectives such as time-to-market requirement and production volumes (Urbikain et al. 2017). CPS enables machines to adapt their behaviour to changes in order quantities and operating conditions to reconfigure and self-optimise (Shrout et al. 2014). The sharing of information about stock levels, demand changes, order levels, or faults and deadlines, is coordinated in such a manner to optimise throughput and enhance efficiency (Deloitte 2016).

CPS is not without its challenges, with safety and reliability being ranked the highest due to the very nature of physical components being qualitatively different from object-orientated software components (Lee 2008; Torngren and Sellgren 2018). In this regard, Baheti and Gill (2011) point out that there are stark differences in the frameworks used to represent discrete behaviour and the differential equations used for modelling physical systems. Traditionally, manufacturers did not focus on security breaches due to industrial control systems being isolated from the corporate network infrastructure and the internet (BDO 2016). Khan and Turowski (2016) note that, while the connectivity of devices provides advantages it also poses great security risks, such as viruses, hacking and data security. BDO (2016) contends that the increasing connectedness of systems would increase organisations' attack surface. This could be further compounded due to industrial control systems that generally have long lifespans, exceeding manufacturer support periods, and such unsupported systems would have inherent vulnerabilities.

The IoT refers to a system where physical items, particularly mobile devices, are enriched with embedded electronics or a network of devices, such as sensors, chips and radio-frequency identification connected to the internet (Khan and Turowski 2016; Nagy et al. 2018). Devices are able to connect to corporate networks in such a manner that physical objects become active participants in business processes, communicating information about their status, processes, environment and schedules (Shrout et al. 2014).

The increasing digitising of the entire value chain makes possible the interconnection of people, objects and systems through real-time data exchange. According to Wang, Wan and Zhang (2016) the key features of Industry 4.0 include:

(i) Horizontal integration across the value chain to facilitate inter-corporation collaboration between customers, suppliers and partners.
(ii) Vertical integration within smart factories to foster cooperation between the different hierarchies to adapt to flexible manufacturing.
(iii) End-to-end integration across the value chain to enhance product customisation.

PricewaterhouseCoopers (2016b) state that Industry 4.0 will digitise and integrate processes vertically across the entire organisation spanning purchasing, product development, manufacturing, logistics and servicing, all in real time, and add that the horizontal integration will span across all value chain partners, including suppliers and customers.

Bishop (2017) contends that a relatively small number of organisations have the infrastructure and skills to benefit from big data. Hence, knowledge asymmetries could arise due to there being only a few large organisations that have the necessary resources to dominate access (Asadi et al. 2016). Data about individuals are held in the repositories of organisations that own the databases and have control over the data, who then can analyse, manage, and share the data with other organisations and data brokers for monetary reasons (Martin 2015). The sharing, diffusion and downstream effects of the use of personal data have been identified as areas of concern (Buchanan 2017). When personal data are combined data from a different database, ethical issues may arise when the final owners use the data for different purposes from the initial intention (Asadi et al. 2016).

The promise of considerable savings is accompanied by the risk that is inherent in new unknown technologies that may be expensive, and in this regard, Nagy et al. (2018) note that:

(i) In some industries the rapid adoption of new technologies is unavoidable to remain competitive.
(ii) Some industries may adopt new technologies if others have marked out the path.
(iii) Not all partners may have the necessary resources, technology or risk appetite to fully embrace Industry 4.0.

Industry 4.0 makes it possible for organisations to develop new business models to deliver more value and service to their customers, hence the need to better understand the technology to maximise benefits (Khan and Turowski 2016). Furthermore, Dickmanken (2017) asserts that companies should have an overall awareness of the importance of value proposition adjustments that would be necessary to ensure customer-centric alignment.

Industry 4.0 assumes support of the entire life cycle of products by continuing to provide data about their state during their lifetime to provide the manufacturer vital information for preventative maintenance and reliability of products (Rojko 2017). This is valuable especially for products embedded in larger systems for condition-based maintenance (Morello et al. 2013) or for the monitoring of invisible machine degradation.

Methodology

The research paradigm for this study is quantitative in nature and entails secondary research. The methodology entailed a systematic literature review (SLR) of the Industry 4.0 phenomenon. An SLR is a research method that is executed to review empirical studies (Gough, Oliver, and Thomas 2012) and is viewed as original empirical research as it reviews primary data (Ahmed, Vaska, and Turin 2016; Aveyard and Sharp 2011). An SLR is also referred to as the "gold standard" for synthesising the findings of previous studies on a particular topic (Boland, Cherry, and Dickson 2008). An SLR is considered to be research in its own right by being able to address much broader questions than single empirical studies can, through the synthesis of empirical findings of many studies (Baumeister and Leary 1997).

An SLR entails the systematic identification, selection, evaluation and interpretation of available research relevant to a particular phenomenon of interest (Kitchenham 2004) and more specifically, the synthesis of high-quality research evidence relevant to the phenomenon (Byrne 2016). The SLR for this study is informed by guidelines proposed by Kitchenham (2004) and later adapted by Bacca et al. (2014). The steps adopted for executing the SLR for this study are detailed in Table 2.

Table 2: Steps adopted for the SLR

Steps		Criteria used in this study
1	Selecting databases	Business Source Complete; ProQuest; Google Scholar
2	Inclusion and exclusion criteria	Publications between 2011–2017 Search phrase: "Industry 4.0" in title and "survey" and "executives" or "managers" or "CEO" in text Language = English
3	Study selection criteria	Primary studies Scale: National and international level Population: company executives/CEOs/managers
4	Data extraction	Summative content analysis
5	Data synthesis	Data aggregation Tabulation Descriptive

Source: Author's own construction

The search strategy was automated, wherein a search string, comprising the keywords "Industry 4.0" AND "survey" AND "executive" were deployed within the online databases to search for relevant publications for the period 2011 to 2017. The search was repeated again for the period 2017 to 2018, which was considered necessary to update the article since some time had elapsed between the initial data collection period (2017) and article writing (2018). The identified studies were then evaluated using summative content analysis. Summative content analysis involves counting and comparisons, usually of keywords or content, followed by the interpretation of the underlying context (Hsieh, Hsien, and Shannon 2016). Tabulation was used to synthesise the information according to the following categories: the degree of awareness; perceived level of influence; areas of impact; current investment levels; and intention and urgency to invest in Industry 4.0. Trustworthiness and credibility were enhanced by data saturation, where the searches within databases continued until no new information surfaced. This was achieved by replacing the key word "executive" by the keyword "CEO" or "manager."

Findings and Discussion

Although a large number of studies were identified (479 including duplications), after reading the abstract/introduction, only 10 studies met all the selection criteria set in Table 2. All the studies that were identified were undertaken by reputable consulting firms, many of which are often listed among the top consulting firms in the world. This was not surprising, given that the aim of the study seeks to ascertain the extent to which businesses are embracing the Industry 4.0 phenomenon in different regions of the world. To carry out a large-scale study involving a large number of participants at the national and international level, requires huge amounts of resources, which could be more easily met by consulting firms such as those mentioned. However, for reasons beyond the scope of this study it has been noted that such studies do not often build on or refer to other large-scale studies undertaken by other consulting firms on the same phenomenon.

This study, therefore, aggregates the findings of the identified studies. Table 3 provides a summary of the surveys that were identified. The surveys were conducted in different regions of the world, as detailed in Table 3. Table 3 summarises the results according to: Title; agency carrying out the study; countries surveyed and the participants in the study.

Table 3: Industry 4.0 surveys conducted

Year	Title of study	Agency carrying out the study	Countries surveyed	Participants
2015	The Manufacturer Industry 4.0 UK readiness Report	The Manufacturer Oracle (sponsor)	United Kingdom	100 decision makers (managers, directors)
2016	Industry 4.0: Building the digital enterprise	Pricewaterhouse Coopers	26 countries in: Europe, the Americas, Asia, Middle East and Africa	2 000 senior executives from 9 industrial sectors. In SA 61 interviews across a broad spectrum of companies
2015	Expert survey on Industry 4.0	Deutsche Messe Interactive	18 countries: India, Italy, France, South America, Russia, Spain, Turkey, USA, Germany, Japan, Canada, Japan, Baltic, Arab, Asian and Scandinavian states	150 CEOs, senior managers, department heads, from 9 industrial sectors
2016	Industry 4.0 after the initial hype—where manufacturers are finding value and how to best capture it	McKinsey and Company	Germany, the USA and Japan	300 experts from 11 industrial sectors
2016	Industry 4.0 Report	Binder Dijker Otte and IMechE	United Kingdom	318 engineers at management level and directors in 17 sectors
2016	Industry 4.0 Is Africa ready for digital transformation?	Deloitte	South Africa	15 interviews with leading role players in manufacturing
2015	Survey "Industry 4.0." Results of the Exhibitors Survey	TUV Rheinland	18 countries: India, Italy, France, South America, Russia, Spain, Turkey, USA, Germany, Japan, Canada, Japan, Baltic, Arab, Asian and Scandinavian states	278 interviews with exhibitors

Year	Title of study	Agency carrying out the study	Countries surveyed	Participants
2016	Sprinting to value in Industry 4.0	Boston Consulting Group	USA	380 manufacturing executives in varying industries of various sizes
2017	The Fourth Industrial revolution is here—are you ready?	Deloitte	19 countries form the Americas, Europe and Asia	1 603 executives with revenues exceeding $1m
2017	Is the UK industry ready for the fourth industrial revolution?	Business Consulting Group	Five industrialised countries: France, Germany, USA, UK and China	1 500 executives with revenues exceeding $50 billion

Source: Author's own construction

Three of the studies were conducted in 2015; five were conducted in 2016; and two in 2017. The target population for these surveys was pitched at the level of decision makers, executives, CEOs, role players, industry experts, managers, directors, which was considered to be appropriate as such individuals are deemed to be best positioned within their organisations to relate to the Industry 4.0 phenomenon.

The largest survey (2 000 respondents) was conducted by PricewaterhouseCoopers (2016a) within nine major industrial sectors in 26 countries. Two studies were conducted in the UK among managers and directors. Both the Deutsche Messe (2015) Interactive survey and the TUV Rheinland (2015) survey were conducted amongst respondents from the same 18 countries. The Deloitte (2016) survey was conducted in South Africa with leading role players such as CSIR-Meraka Institute, Department of Science and Technology, International Data Corporation, Manufacturing Circle, and executives from CAD House, Ford, Hulamin, Nampak, Nissan and Toyota. The Deloitte (2017b) survey was conducted within 19 countries from the Americas, Europe and Asia. The Business Consulting Group (2017) survey was conducted in France, Germany, USA, UK and China.

Table 4 summarises the degree of awareness of participants and the extent to which respondents perceive Industry 4.0 would influence their organisations. The scaling used in the different surveys were different and in this study the scaling was collapsed to fewer points by combining the scales used in the original surveys that tended to capture similar items. This was done so that the data could be compared and consolidated. The numerical data were analysed separately from the categorical data and where an item was not sufficiently explored in a particular survey, not applicable (n/a) was inserted.

Table 4: Degree of awareness and perceived influence of Industry 4.0

Study	**Country**	**Degree of awareness of Industry 4.0**		**Degree of perceived influence**	
		Very aware, Somewhat aware/ Being discussed	**Not at all aware/ little or no understanding/ Not being discussed**	**High, Important/ A priority/ Will have a big impact**	**Low, Not important, Not a competitive threat**
The Manu-facturer	United Kingdom	62%	38%	69%	31%
Binder Dijker Otte (BDO)	United Kingdom	44%	56%	44%	56%
Deutsche Messe Interactive	18 countries: India, Italy, France, South America, Russia, Spain, Turkey, USA, Germany, Japan, Canada, Japan, Baltic, Arab, Asian and Scandinavian states	54%	46%	81%	19%
TUV Rheinland	18 countries: India, Italy, France, South America, Russia, Spain, Turkey, USA, Germany, Japan, Canada, Japan, Baltic, Arab, Asian and Scandinavian states	86%	14%	89%	11%
McKinsey & Company	Germany, USA and Japan	60%	40%	62%	38%
Deloitte	South Africa	Increasingly being discussed by industry leaders	Mind-sets of many not yet geared towards Industry 4.0 shift	Majority-strong influence	n/a

Study	Country	Degree of awareness of Industry 4.0		Degree of perceived influence	
		Very aware, Somewhat aware/ Being discussed	**Not at all aware/ little or no understanding/ Not being discussed**	**High, Important/ A priority/ Will have a big impact**	**Low, Not important, Not a competitive threat**
Boston Consulting Group	USA	Most recognise potential	n/a	Majority- strong influence	Some not a competitive threat. Some are still debating the degree of impact
PwC	26 countries in: Europe, the Americas, Asia, Middle East and Africa	Most are aware of the phenomenon	A number think that digitisation is simply expanding the scope of IT departments	Majority- strong influence	Some not sure what it actually means for their organisations

Source: Author's own construction

The numerical data from Table 4, representing the degree of awareness of Industry 4.0, are illustrated in the box and whisker plot in Figure1 (below).

The numerical data from Table 4, representing the degree of perceived influence of Industry 4.0, are illustrated in the box and whisker plots in Figure 2 (below).

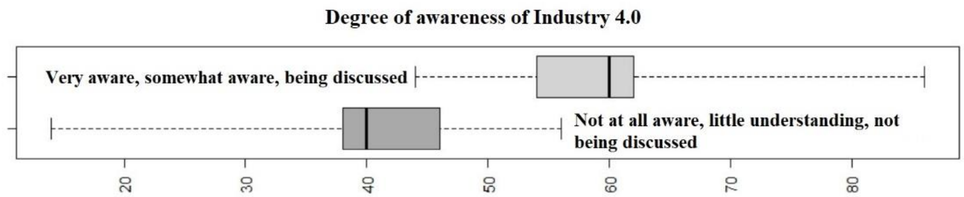

Figure 1: Degree of awareness of Industry 4.0

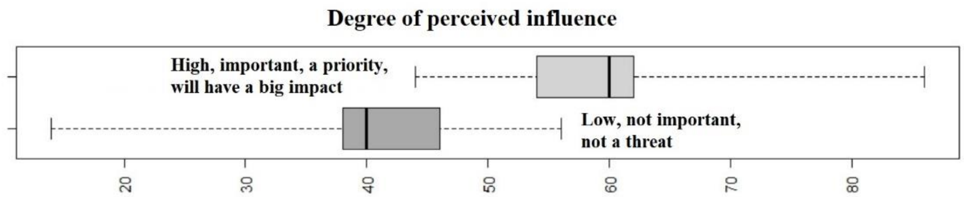

Figure 2: Degree of perceived influence

More executives are aware or somewhat aware or perceive that the Industry 4.0 phenomenon is being discussed within their organisations, as opposed to fewer that are not at all aware, have little understanding or it is not being discussed. The categorical data support the numerical data confirming that most are aware or awareness is on the increase regarding Industry 4.0.

More executives perceive the influence of Industry 4.0 on their organisation as being high or important or having a big impact, as opposed to fewer that perceive the degree of influence as being low, not important or not a threat. The categorical data support the numerical data, with the majority perceiving the influence on their organisations as being strong.

A more recent survey (Deloitte 2017b) of 1 603 global executives of organisations with revenues exceeding $1 billion, representing 19 countries from the Americas, Europe and Asia, revealed that just 14 per cent are highly confident that their organisations are ready to fully harness the changes associated with Industry 4.0. Another recent survey (Business Consulting Group 2017) of more than 1 500 executives with revenues exceeding $50 billion in five industrialised countries (France, Germany, USA, UK and China), revealed that while most companies are aware that Industry 4.0 will change their corporate structures, cultures and practices, only a few have made any advances in this regard.

Table 5 summarises the areas of impact Industry 4.0 will have on organisations.

Table 5: Areas of perceived impact

Study	**Countries**	**Business model/ increasing revenue streams**	**Operational effectiveness, productivity and cost reduction**
The Manufacturer	United Kingdom	Low	62% maintenance, 56% logistics, 64% R&D
Binder Dijker Otte and IMechE	United Kingdom	Medium 44%	64% production, 25% logistics, 45% R&D
Deutsche Messe Interactive	18 countries: India, Italy, France, South America, Russia, Spain, Turkey, USA, Germany, Japan, Canada, Japan, Baltic, Arab, Asian and Scandinavian states	High	Very high
TUV Rheinland	18 countries: India, Italy, France, South America, Russia, Spain, Turkey, USA, Germany, Japan, Canada, Japan, Baltic, Arab, Asian and	n/a	77% production and machinery focus

Study	Countries	Business model/ increasing revenue streams	Operational effectiveness, productivity and cost reduction
	Scandinavian states		
BCG	USA	28% increased revenue 13% new business model	89% productivity, 47% reduction in manufacturing cost, 43% improving quality
Mckinsey and Company	Germany, USA and Japan	80%	89%
Deloitte	South Africa	n/a	Stronger use of advanced analytics within automation and automotive sectors not being explored by manufacturers in other sectors
PricewaterhouseCoopers	26 countries in: Europe, the Americas, Asia, Middle East and Africa	See gains in terms of digital revenue growth by digitising product and service portfolio	Majority: see gains in terms of operational efficiency, cost reduction and quality. Companies expect to reduce operational costs by 3,6% a year, while increasing efficiency by 4,1%

The majority perceive the area of greater impact to be in operational effectiveness, productivity and cost reduction and less so from revenue growth. The most recent Deloitte (2017b) survey confirms that still many executives continue to focus on traditional business operations, as opposed to focusing on new value creating opportunities related to Industry 4.0.

Table 6 illustrates the current investment levels, intention and urgency to invest in Industry 4.0.

Table 6: Current investment levels, intention and urgency to invest in Industry 4.0

Study	Current level of investment, levels of adoption/ strategy in place	Intent to invest/ investment	Investment urgency/ responsibilities assigned
The Manufacturer	n/a	56% positive, 12% negative, 32% not sure	n/a
Binder Dijker Otte and IMechE	20% some strategy, 48% no strategy, 13% draft strategy, 19% did not need a strategy	43% planned some level of investment in automation in the next 24 months	n/a

Study	Current level of investment, levels of adoption/ strategy in place	Intent to invest/ investment	Investment urgency/ responsibilities assigned
Deutsche Messe Interactive	27% highly advanced, 51% advanced, 19% poorly advanced, 3% non-existent	63% positive, 22% negative, 15% not sure	n/a
TUV Rheinland	Two thirds of companies—Industry 4.0 is already in use	50% have started with manufacturing prototypes, 45% have realised research projects	55% discussion at strategic and operational level. 39% has 4.0 reps at board level
Pricewaterhouse Coopers (PwC)	A third-rate level of digitisation as high, expected to rise from 33% to 72% within the next five years (CRM). In South Africa, from 27% to 64%	On average, to invest 5% of their annual revenue on digitisation ($907–billion) SA expects to invest 6.8% a year over the next 5 years SA invest 5.2% of capital expenditure in digital operations	50% have dedicated data analytics function, 35% have data analytics embedded within specific functions and 14% dedicated department serving many functions. 38% rely on single employees, 9% have no capabilities at all, 5% 0utsourced
Mckinsey and Company	56% Germany 50% USA 16% Japan	50–56% of USA and German and made substantial progress in implementation. Japan—16%	24% have clear responsibilities assigned. 33% driven by unit heads, CEOs are driving in 19% of countries
BCG	Few have implemented the full range of technologies	Implementation is underway, but the pace is uneven across technologies	n/a
Deloitte	Adoption level of smart technologies at foundation stage	Some investment by CSIR and government	Hesitance exits, focussed on the here and now

With the exception of the TUV Rheinland (2015) and McKinsey (2016) surveys, all other surveys indicate that, at best, only a third of the organisations have a current strategy in place with respect to Industry 4.0. While the majority express a high degree of intention to invest in Industry 4.0, this has not translated into equivalent levels of actual or planned investment. In South Africa, adoption levels can be best described as being at the foundation stage (27%) and with plans to increase to 64 per cent. Regarding being challenged vs. prepared, executives understand they need to invest in technology to drive new business models; however, they have a hard time making the business case for that investment because of a lack of internal strategic alignment and short-term focus.

The most recent Deloitte (2017b) survey reveals that only a few executives could confirm that they have a strong business case for investing in advanced technology, with the majority pointing to challenges such as the lack of internal alignment, a lack of collaboration with external partners and a focus on the short term. The Boston Consulting Group (2017) contends that the trickle of early adopters will become a deluge in the next few years, and going by the lessons of the previous industrial revolutions, cautions that slow starters may find it virtually impossible to catch up.

Table 7 summarises the challenges associated with Industry 4.0.

Table 7: Challenges associated with Industry 4.0

Study	Lack of understanding/ changing culture	Lack of talent / skills	Cyber security breach
The Manufacturer	n/a	n/a	n/a
Binder Dijker Otte and IMechE	44% lack of understanding	52% had some of the right skilled people, 17% correctly skilled, 17 % did not have skills	Will increase risk of cyber security (73%) breaches, 5% no, 12% don't know
Deutsche Messe Interactive	n/a	n/a	n/a
TUV Rheinland	n/a	Most relevant topic is staff qualifications	IT security/data security
BSG	40% see changing culture as a challenge	Finding the right talent internally and externally a constraint	n/a
McKinsey and Company	n/a	Know-how for employees	Data security and safe-guarding systems. Uniform standard for data transfer
Deloitte	n/a	Major talent challenges—need to retrain and upskill	Concern around cyber security and privacy. IP rights and industrial espionage main concerns. Connectivity and accessibility challenges

Study	Lack of understanding/ changing culture	Lack of talent / skills	Cyber security breach
PWC	Largely dependent on digital IO—how well executives lead and communicate transformation	Over 50% indicated that the biggest challenge is a lack of digital culture and skills in their organisations. SA—lack of digital culture and training, insufficient talent	SA 53% cyber security breaches, reputational damage and loss of trust due to data loss (40%)

The challenges identified revolve around the lack of understanding and resistance to change, lack of talent and skills, and cyber security breaches. Cyber security breaches have been identified as the greatest challenge, with many citing concerns around risk, data security, IP rights, reputational damage and loss of trust. The threat is real, due to the multiple sources and formats of data, points of contact and entry. Lack of skills, talent and culture are viewed as the next greatest challenge.

The most recent Deloitte (2017b) survey revealed that only 25 per cent of the executive have confidence that they have a workforce with the right skill set for the future, and despite the majority recognising the need for a better prepared workforce, only 17 per cent see developing talent as a priority.

Recommendations

The recommendations that arise from this study follow from the synthesis of findings and recommendations made in the individual studies, after taking into account the strengths and weakness of each.

The recommendations that emerged from the various studies resonate around similar issues and can be crystallised as follows:

(i) There is a need for manufacturers to gain a deeper understanding of how they can use Industry 4.0 for value creation and to build additional revenue streams by gaining insight from digital factories that are already in operation or taking digital "treks."

(ii) There is a need for organisations to articulate a bold vision to applying digital technologies and to define a plan for digital transformation to accelerate the pace of adoption. In the absence of such vision, there will be a lack of support from individuals within the organisation and splintering experimentation in the long run would not yield desired results. A major barrier to entry is that there is no clear digital operations vision or support for it within the businesses. When companies embark on digitisation they are often experimenting without having a clear plan as to what they want to achieve.

(iii) The innovation and creation of new business models need to take place at the edge of the current business rather than within the core business or outside the organisation and need to be scalable so that it could be pulled from the edge into the core so that the edge would eventually become the new core.

(iv) It is paramount that innovations of scalable business models are not restricted just to the area of product innovation that traditionally focuses on product offerings, but in areas of company structure, processes, networks and profit models, together with customer-facing functions, such as services and distribution channels.

(v) There is a need for a rigorous and proactive approach to develop clear guidelines for data integrity and security, and the need for cyber security governance to implement and monitor appropriate controls to address cyber security breaches.

(vi) In order to address the lack of skills, steps need to be taken to close the skills gap by improving in-house data analytics capabilities, investing in existing talent, retraining and tapping the pool of digital talent.

(vii) Connectivity requires old and disparate IT systems to be ungraded or replaced to introduce new Industry 4.0-ready IT infrastructure. Costs are a key factor.

With regard to recommendation (i), it is not easy to get access to other organisations as some of them may even be competitors. A more practical approach could be to collaborate with suppliers and customers who are more advanced in the digital journey to smoothen the learning curve. With regard to recommendation (ii), in order to yield tangible results, efforts need to extend beyond vision. It would require the right type of leadership to inspire individuals within the organisation to embrace the digital journey. It would be prudent to identify individuals within the organisation or recruit individuals who have the necessary aptitude, attitude, passion, and courage to tackle change head-on as initiatives may involve step-change objectives, instead of incremental or scattered initiatives.

With regard to recommendation (iii), the approach is questionable as it seems to stand in contrast to other recommendations, in particular when the benefits of digitisation are maximised when it spreads across the organisation and all functional units as indicated by recommendation (iv). Hence, this study does not support this recommendation.

To add to recommendation (vi), business could work together with universities and colleges to develop a curriculum and practically train students to ensure “fit” upon qualification. Transforming the workforce is not an easy task, as it would require significant levels of investment and efforts that extend beyond organisational boundaries. In South Africa, further research is required to ascertain how the Sector Education and Training Authorities (SETAs) plan to reshape the skills strategy to prepare workers for the future.

Connectivity refers to the measure to which networks are connected to one another and the speed at which this is possible. On the positive side, South Africa could leapfrog itself into an Industry 4.0 scenario, as it is not burdened by significant existing infrastructure investments. However, this requires well-choreographed moves on the part of all stakeholders.

Conclusion

A quantitative study was conducted through an SLR to establish how organisations in the different regions of the world were embracing the Industry 4.0 phenomenon. Ten empirical surveys were analysed and the results were synthesised. The synthesis of the different survey results was dealt with according to the following categories: the degree of awareness and perceived influence; areas of perceived impact; current investment levels; intention and urgency to invest in Industry 4.0. It was found that there was generally a high degree of awareness of the Industry 4.0 phenomenon. The highest level of understanding of the phenomenon exists in Germany, USA and Japan, with it being lower in the UK and at a foundation level in South Africa. The degree of influence was perceived to have a greater impact on operational effectiveness, productivity and cost reduction than on new business models or revenue streams. While most organisations have expressed intentions to invest in related technologies, this remains to be translated into equivalent levels of actual investments. The greatest challenges revolve around cyber security and are followed by the lack of skills. The South African manufacturing sector should take note of the recommendations to posture itself to overcome challenges and take advantage of opportunities in harnessing the potential of Industry 4.0. Further research is required to ascertain how business, universities, science centres and science institutions, colleges and SETAs, in South Africa, could work together to reshape the skills strategy to prepare the worker for a digital future.

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