IN DIS TREE – 4 WHAT?

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ABSTRACT

The fourth industrial revolution has become a popular topic in nearly every industry in South Africa. But what exactly does everyone mean by this revolution, and what is its potential impact on South African companies? This paper presents thoughts on the history and purpose of the fourth industrial revolution, and compares this with the context, trends, and needs of manufacturing organisations in South Africa. The paper then presents thoughts on how best to integrate the benefits that can be achieved with an internationally oriented view of industrial development, while being sensitive to the implications in a local context.

OPSOMMING

Die vierde industriële revolusie is 'n gunsteling onderwerp in byna elke nywerheid in Suid-Afrika. Maar wat word presies bedoel wanneer daar hierna verwys word en wat is die potensiële impak op Suid-Afrikaanse firmas? Hierdie artikel bied 'n bespreking oor die geskiedenis en doel van die vierde industriële revolusie en vergelyk dit met die konteks, neigings en behoeftes van vervaardigings-organisasies in Suid-Afrika. Die artikel bespreek ook gedagtes oor hoe om die voordele, wat bekombaar is deur 'n internasionaal georiënteerde siening van industriële ontwikkeling aan te neem, te integreer, deur tegelykertyd sensitief te wees tot die implikasies binne 'n plaaslike konteks.

1 INTRODUCTION

The word 'revolution' emerges from the Latin, which speaks about the transit of the stars [1], while 'evolution' is first found to refer to the unrolling of a scroll [1]. These old forms of the words, however, predate the more common modern use.

For 'revolution', the notion of the 'instance of great change in affairs' originated in the 15th century, while the meaning of 'overthrow of an established political system' is first found in the 16th century, following the expulsion of the Stuart dynasty in 1688.

Charles Lyell [2] first used evolution to refer to "growth to maturity", "development of an individual (living) thing", and the idea of "progress". Although credited with it, Charles Darwin used the word evolution only once in his seminal treatise, *The origin of species* [3].

In modern usage, revolution means rapid, and complete disruptive change, generally taking place in a short timeframe, while evolution refers to a slow, incremental change that traces a clear path of development, rather than disruption.

This, then, introduces an interesting question: whether Industry 4.0 represents what is often referred to as the fourth industrial revolution, or whether it is rather a developmental stage in the industrial continuum that we can observe today. Some authors [4, 5] have grappled with these ideas, proposing that the shift to Industry 4.0 is, in fact, an evolution rather than a revolution.
To assess the so-called fourth industrial revolution, it may be useful to delve into previous steps that have occurred that have been referred to as revolutions.

The first industrial revolution is most familiar to industrial engineers. It represents the transition that started in about 1750, when the steam engine entered industry (which did not truly exist up to this point). This revolution contributed to economic change, which in turn has led to the fact that, in industrially sophisticated societies, no famine has occurred since that time [6]. This revolution also represented tremendous societal change. A population explosion was accompanied by improved access to clothing, food, and financial means. Nevertheless, traditional agricultural and other trades were nearly wiped out by the emerging class of factory owners, stratifying the remainder as factory workers [6]. Massive-scale urbanisation resulted from the first industrial revolution, leading to a depletion of rural populations and pauperism within cities.

The second industrial revolution is closely tied to the introduction of electricity and electrical motors. Industrial change, with a focus on organisational efficiency, saw the emergence of Henry Ford's moving production line and Frederick Taylor's emphasis on scientific management [7]. Machines increasingly took the role of people, and the automobile became an ubiquitous feature of modern life. Emerging out of these were industrial-scale chemical, machine, and other works. Scale effects became possible, and mass production became a reality. Recognising the social poverty of factory workers, unions arose powerfully for the first time [6]. Simultaneously, conscious of the lot of the working classes, the thinking that served as the basis for communism emerged. Great societal and economic upheaval was ahead, with the First World War representing a fissure in the (until then) unquestioned social fabric.

The third industrial revolution emerged in the 1960s, when microprocessors and computing power started to become affordable. Automation and control systems started to take the role of specialised artisans. Concurrent with the automation of physical processes, administrative processes — such as ordering, stock control, planning, scheduling, and forecasting — could be automated to an extent previously unheard of. With the evolution from simple administrative systems to material requirements planning (MRP) and later enterprise resource planning (ERP) systems, many organisations were able to diversify complex supply chains, creating globalised footprints for sourcing and manufacture. The emergence of multi-national manufacturing companies, driven by automotives, created market and industrial sophistication in predominantly low-cost countries, where lower wages led to overall organisational benefit [6]. The globalised economy created a more inclusive world, driven also by proxy wars and proxy allegiances necessitated by the Cold War. And so fragile regimes were propped up economically as bulwarks against the spread of communist ideologies [8].

2 INSIGHTS FROM THE LITERATURE

2.1 Is this the fourth industrial revolution?

The Boston Consulting Group [9] has proposed nine seminal pillars of Industry 4.0. These characteristics represent the behavioural and other shifts that enable an organisation to operate according to the principles of the emergent Industry 4.0. These pillars are the use of the cloud, augmented reality, big data and analytics, autonomous robots, simulation, horizontal and vertical integration, the industrial Internet of Things, additive manufacturing, and cyber security [9]. Considering these features, it is not clear in which sense the individual steps represent revolutionary change — or rather, in which existing technologies, practices, and ways of thinking organisations might invest to become Industry 4.0 ready.

This leads to the current question about Industry 4.0: Is it revolutionary, or is it evolutionary? Is it a continuation and maturing of the preceding industrial revolutions, or is it a revolutionary step change that will alter society, as previous revolutions have done? To answer this question requires much speculation, and the realisation that the previous revolutions have been named retrospectively, often with decades or even centuries of perspective, to assess the impact of the shift. The so-called fourth industrial revolution, however, is named presumptively, in anticipation of how things are likely to change.

We view the changes to be largely evolutionary and derivative. For example, cloud computing and big data are merely developments of hard drives and 'small' data. Horizontal and vertical integration were questions that were relevant to Henry Ford and other industrialists of the second revolution

[10]. Automation and 'smart' robotics are an extension of 'dumb' robots, echoing the fears of the first industrial revolution of people being replaced by machines. Cyber security is a necessary enabler for cyber-physical systems [11], but no more revolutionary than the concrete foundations that steam engines needed to drive the first revolution.

All other revolutions were accompanied by tremendous social and societal change: urbanisation, the emergence of the working class, unionisation, communism, the growth of slums, the decline of crafts and individual trades and, in many ways, the collapse of previously existing social orders.

We believe that Industry 4.0 has the potential to effect some societal change that will probably manifest itself most starkly in the loss of many jobs, both blue collar and, for the first time in industrial history, white collar roles. We also see a shift towards the notion that an employee is always 'on' — something familiar to every reader who has email on their smart phone. A utopian perspective on social change is the de-urbanisation potential, with 'work-from-home' or 'work-from-the-beach' work models being made possible by the ubiquity of access to the shop floor.

All previous revolutions also had a discrete technological driver: steam engines, bringing power into factories, and allowing for a centralised power plant to enable mass production of simple products; the introduction of electric and internal combustion motors to enable decentralisation, and control systems allowing the creation of complex plants; and of course, the affordable emergence of IT infrastructure that allowed for greater automation and control, and has been the technological driver for the past fifty years.

That the elements of the fourth industrial revolution represent more than just an evolution of elements that are currently in use is questionable. The only technological innovation that is truly disruptive is additive manufacturing, which represents a legitimately new approach to manufacturing that has always relied on subtractive or forming methods [12].

We conclude this section with our belief that Industry 4.0 is, in fact, more like an evolution. Indeed, the fact that its number has a decimal zero implies a continuum rather than a discrete moment in human and industrial development. Nevertheless, regardless of whether the revolution is well-named, we recognise that the future competitiveness of organisations may depend on keeping pace with global industrial development. We also recognise that it is unlikely that the future of manufacturing will look significantly different from what Industry 4.0 is forecast to look like.

2.2 Where is industry headed globally?

Some of the features of the third industrial revolution are globalisation, the liberalisation of markets, and the shifting of manufacturing opportunities to developing economies [6]. A principal example of this is automotive manufacturers pushing production from their home bases to the developing world. Now, however, countries like Germany[1] wish to grow their manufacturing economy (25 per cent of GDP, giving employment to seven million people; and growing [11]).

The Boston Consulting Group [9] sees the benefit of Industry 4.0 to an economy like Germany's in four key areas:

- Increased productivity by bridging the inefficient practices introduced by the sloppiness of human data processing;
- Revenue growth, a derivative of increased productivity; but also through the establishment of new engineering companies that act in support of Industry 4.0-type interventions;
- Higher employment that is contingent on new companies being established, and market opportunities and market share expansion being realised through better productivity;
- Investment being pushed back [13] into developed economies, particularly Germany, due to rekindled market competitiveness.

[1] It is also telling that most of the seminal work is published by German authors. The Industry 4.0 movement has been driven, since its inception, by German authors, and it almost reads as a strategic framework for the future prosperity of Germany.

The German aspirations can be contrasted with the South African case (13 per cent of GDP, employing 1.2 million people, and declining). This obviously represents a tremendous risk for South Africa, and many developing economies.

A simple PESTLE[2] analysis of South Africa shows that the major systemic risks are political factors and societal elements [14]. Political uncertainty is harmful to long-term investment [15]. This is particularly related to property rights, uncertainty about the stability of the banking sector, and the uncertain long-term tenure of the market-friendly African National Congress [14].

Other major structural risks that persist in South Africa are societal and sociological risks attached to frequent and protracted industrial action by unions, leading to strikes that can last for months. Another societal weakness is the generally low level of education [16, 17], the associated difficulty in accessing higher education [18] and, by extension, entry into the knowledge economy.

Fortunately, measured against economic, technological, legal, and environmental criteria, South Africa is an attractive investment destination; according to the World Bank's Doing Business index [19], South Africa is the 82nd best investment destination out of about 160 countries. Nevertheless, the recent opening of a Volkswagen manufacturing plant in Rwanda [20], producing high-end models for domestic African markets, should be of considerable concern for the industry in South Africa.

3 PURPOSE

This paper acts as a thought leader, and raises the question: Can laying Industry 4.0 over the manufacturing landscape in South Africa future-proof the economy? Or is it not going to fix it? Or worse, is it going to lead to new problems?

To understand this, we describe a decade of mixed method observations of organisations that describe the current weaknesses of the South African industry, and highlight the areas where technological sophistication will elevate South African industry and the changes that must occur prior to implementation taking place.

We want to caution against the thinking that sees Industry 4.0 simply as an implementable panacea that can heal all the ills of industry in this country.

4 METHOD

This paper represents a summary of observations made over the course of nine years, viewing the operations of over 70 organisations, spanning heavy and light manufacturing, fast-moving consumer goods (FMCG), services, mining, healthcare, design bureaux, and large-scale chemical plants. A framework was developed based on direct and participant observations in these environments, characterising the observations in line with the PESTLE framework to understand market strength, vulnerability, and potential risks.

Many of the observations were diachronic, observing companies in their development over many years, while others were point assessments.

5 OBSERVATIONS

The observations will be described in two sections. The first highlights key features of sustainably successful companies, followed by an overview of issues that we believe are currently plaguing the South African manufacturing sector.

[2] PESTLE analysis is an evaluative framework that assesses market risk according to six phyla: political context, economic environment, societal/sociological questions, technological maturity, legal frameworks, and environmental questions.

5.1 Features of successful organisations

Overwhelmingly we have come to realise that there are a number of observable factors that can be a good indicator of the 'health' of a company. These factors may seem simple, but in our experience they are predictors of companies that, if observed over several years, are constantly improving and innovating and growing their customer base and product volumes. And unlike the features required by Goodson's 'Read a plant — fast' model [21], these factors require little training to observe and are difficult to 'fake on the day'. In this paper, we will discuss what we believe to be three of the most important.

The first is factory cleanliness. And this is not a rehash of Lean's 5S — and is certainly not to be seen as the basis for standards, visual management, and improvement, as 5S teaches — but is merely an indicator of how physically clean the organisation is. We have been to heavy engineering companies where you can literally eat your lunch off the floor. We have been to companies that make food and cleaning products where we feel that we need to take a shower after walking around. Factory cleanliness is something that shows deep pride and an active sense of working together in an organisation.

We recall a particular example where a tremendous company had a leadership change. The leadership at this organisation remains among the finest we have seen in South Arica, being empowering and encouraging. The company was recognised as the top supplier to a major car manufacturer — worldwide! The first clue of the organisation undergoing traumatic distress was a shop floor that was no longer spotless, with errant product wrappers lying on the floor, and oil spills that weren't cleared immediately. The manifest absence of a sense of belonging, commitment, and ownership lagged behind the change in the appearance of the shop floor by a year. The leadership decay took time before it filtered through to product quality, and ultimate contract termination, by the original equipment manufacturer (OEM).

Secondly, can the CEO free up his morning to spend time with visitors walking around the factory? In our experience, it is those companies where a CEO can take an entire morning off — not answering calls or frantically looking at a watch — that are the companies in control, with decision-making taking place at the right level, and low levels of 'fire-fighting' taking place. These CEOs are also typically the ones that seem to know the most about the detail on the shop floor, and know the names of their employees, understand how processes and machines work, and know where changes, improvements, or challenges are present.

The third factor is absenteeism. We have been at companies, geographically located three kilometres apart, in the same industry, where absenteeism levels can vary by more than six percentage points, which in this case was more than a fivefold difference. Although many companies may give what seem to be valid reasons for high levels of absenteeism, in our experience, the happiness of employees relating to trust, respect, and an environment that provides them with what they need to do their work typically results in the lowest levels of absenteeism. And it is therefore the happier employees with a greater sense of belonging who enable companies to be more productive, flexible, and conducive to all forms of improvement.

Recalling the example given earlier about the erstwhile spotless supplier to the automotive industry: in this same case, the absenteeism rate more than doubled over the period during which we were engaging them.

Companies that excel do well against these criteria. Successful companies are pristine, not because it is enforced, but because leadership and workers are united in a sense that the organisation is their home. And it remains the most purpose-driven united company that is the most successful, from a micro-enterprise to a multi-national company.

We realise that the three factors presented above are high-level indicators that are supported by a suite of lower level practices and attitudes.

5.2 Practices and attitudes

From our observations we have identified several key issues in South African organisations. These tend to exist across industries and, if not well managed, are harmful to their current prosperity. Most importantly, however, the introduction of Industry 4.0 is unlikely to address any of these issues, and a belief that the manufacturing sector can be redefined or rejuvenated with Industry 4.0 is false and misguided. It is also most likely that the presence of these issues will negatively impact any attempts at Industry 4.0 implementation.

5.2.1 Fear

We see this as the most prevalent issue in South African companies. Stemming from a militaristic management style that originated in the first industrial revolution, sustained in South African gold mining [22], and strengthened by the unnatural stratification of society into 'master' and 'worker' under the apartheid laws [23], South African industry remains beset by fear. In fact, the closest to the reality of many management interactions we have observed is what Bevan calls "soviet type terror" [24]. This fear is pervasive, and causes workers to hide mistakes and be fearful of innovation, experimentation, and change. Such attitudes are profoundly harmful to organisations with 'human eyes', and even more so to the myopia that necessarily emerges from organisations in which artificial intelligences must assess the reliability and validity of data. Ballé *et al.*, in 'The thinking production system' [25], emphasise the importance of a shop floor-driven culture that is common to lean culture [26] and a key evolutionary element of the Industry 4.0 world [13].

We recall a plant where we reported back to management that workers were hiding errors. After initial surprise, and denying the existence of the problem that caused these issues, management enquired why workers were hiding errors. We bluntly informed them that they had created a culture of fear, and that workers would rather 'ship' errors than concede that the machinery with which they were working was incorrectly calibrated. Management unsurprisingly denied creating a culture of fear. We found it tragically poignant that, on leaving the plant, we observed the foreman viciously berating the workers for hiding mistakes. It was clear from the interaction, and the downcast demeanour of the work force, that they would never assist in uncovering improvement opportunities again. And in that one interaction, that foreman had obliterated any opportunity for future collaborative improvement.

5.2.2 Wastefulness

In most organisations that we have been exposed to, there is a tremendous sense of wastefulness. This wastefulness includes time, resources, materials, and the use of human potential in an effective way. We have realised that the attitude to wastefulness in good companies defines the culture of the organisation. For example, we remain amazed by the fact that employees in waste-aware companies turn lights on and off in restrooms — instinctively, without signs or electronic devices. People become aware of all elements of waste, and it becomes part of who employees are to be aware of, and reduce, waste in every aspect of the organisation.

5.2.3 Embedded mistakes

Many industries in South Africa exhibit, and tend to reward, a strong fire-fighting culture. Employees tend to approach each day not knowing what to expect, but knowing that when the inevitable problems occur, they are equipped to 'fix' them. These fixes typically involve running around and making a plan in order to save the day. Due to the highly throughput- and volume-driven environments in which manufacturing operates, this ability to steer a manufacturing process back on track is seen as admirable, and employees who are able to manage these fires are often promoted or incentivised to continue this behaviour. While certainly beneficial to a particular day's production, encouraging this type of culture results in an environment where problems are never properly investigated or addressed. Each day begins anew with new or recurring fires. In extreme cases, new processes and systems are formally introduced to manage these fires on an ongoing basis, thus embedding mistakes, instead of understanding where the system is failing and fixing the root cause.

At a spare parts warehouse, parts were often not picked or delivered to customers due to backlogs in the warehouse and a system that did not prioritise picking or notify the warehouse of new orders placed during the day. Stock on the system was also inaccurate due to gaps in processes associated with picking and dispatching stock. Instead of rigorously analysing the processes to identify what was causing the issues, the company introduced a special call centre where customers could call to have their orders hand-held through the process. This introduced an additional team of staff who

sent extra emails and faxes, made additional calls, and sometimes walked down to the warehouse to check stock and notify pickers of urgent orders. This call centre, although a relief to the unhappy customers who were tired of late deliveries, introduced systems that hid all the underlying problems, introducing extensive inefficiencies, unnecessary capacity, and ultimately driving up costs across the supply chain.

5.2.4 Problem awareness

Driven primarily by wastefulness and systems that are built around embedded mistakes, problem awareness is difficult to encourage. Ballé *et al*. [25] describe four key frames that support any improvement culture. One of these is problem awareness, which speaks to the ability of all employees to walk around with Toyota's 'Muda spectacles' [26], consciously looking for problems and opportunities for improvement — constantly striving for perfection [27]. A culture of problem awareness requires all employees, from management to the shop floor, to question standard practices — to be curious to understand why, and enthusiastic to experiment with different ways of doing things. It also requires a clean and ordered work environment, advocated by 5S, that enables employees daily to sweep their environments with their *eyes* — not a broom, as commonly misrepresented — looking for opportunities for improvement and for potential problems. In our experience, it is rare to find a company where employees actively challenge the status quo.

On a recent visit to a leading FMCG company, we observed a tower of empty boxes that created a virtual skyline alongside the production line. Immediately drawn by the potential that this offered, we went closer to investigate. It turned out that the line was shut down for an hour every day for the eight line employees (a very manual line) so that a 'buffer' of boxes could be hand-built. This was on a line where the cycle time per operation easily allowed for boxes to be made in parallel by one of the operators with some idle time after each box. Unsurprisingly, we visited their sister plant a month later where the entire plant was decorated with box skylines. The paradigm of these boxes was so embedded into the way things are, that nobody saw the potential for improvement.

5.2.5 Problem-solving

Wastefulness, embedded mistakes, and a culture of fear lead to an organisation where employees are blind to, or turn a blind eye to, problems. The next step, after discovering problems, is to cultivate a mentality that recognises the agency that each employee must improve things — to innovate, to solve problems [28]. And problem-solving (rather than problem-hiding) should be the main job of all management-level staff in an organisation. But the responsibility of problem solving should also lie with all other staff, from the shop floor to the CEO. In successful organisations, meetings among managers and those on the floor focus less on finding fault for a problem, and more on finding solutions that will alleviate the problem.

We recall a case at an aftermarket outfitter for commercial vehicles. Previously, deliveries of accessories, such as bumpers or roof racks, would often stall halfway because fixtures, clamps, and shafts had either been lost or had never been included in the shipment. Now, the operators created masks for each product from a corrugated cardboard tray. One tray would contain all the small parts for each assembly, with a hole cut for each little part, to size. This way, operators knew before starting whether there were any shortages, and would not start the job. Parts were now also fixed in place and could not be lost. The speed of the service increased dramatically due to the level of organisation.

5.2.6 Use of data

In our observations, most organisations produce unmanageable amounts of data. From ERP and MRP systems to statistical process control (SPC) systems, control systems, accounting, procurement, and other systems, very, very few organisations use the information even to the level of standard reporting templates or dashboards. Use of data, and reliance on the messages extracted from data, is vital for business management in the new economy. Although scientific management was introduced at the turn of the previous century [7], the use of such tools in management even now remains immature.

We observed a national pharmaceutical supply chain in Africa that recorded the movement of every item from order placement to end-user delivery. Tremendous gains are possible by using scientific, data-based methods to decide on restocking levels, stemming from known consumption data, lead times, variations in ordering patterns, and patient data. Currently, however, all decisions are made

on the gut feel and intuition of the manager, leading to significant stock outs and low service delivery and customer satisfaction rates. It also results in considerable manager over-burden, poor decision-making, and fatigue.

5.2.7 Process awareness

Most organisations have been structured as islands with limited communication and little understanding of the system as a whole. This leads to the mismatch of expectations, which then leads to possibly well-intentioned actions causing conflicting outcomes. This is common, particularly across longer value streams such as in automotive plants and other production line environments. It is, however, also common across hierarchical areas in organisations, such as between procurement and manufacturing, that don't understand one another's needs and nuances.

We observed a fascinating example of this at a major egg producer. The egg producer was supplying an industrial-scale bakery with fresh eggs, delivered daily. To avoid breakage, the eggs were carefully placed into trays, vacuum sealed, and transported using an air-suspension truck to the premises of the bakery, where the eggs were unpacked, creating a significant packaging waste problem. The eggs were then broken and mixed into the cake batter. Only after the parties had understood each other's processes did it emerge that the egg producer could in fact break the eggs before shipping and dispatch them in a bulk container. This reduced the packaging cost and effort and the need for specialised road transport, and reduced work elements at the bakery.

5.2.8 Sharing of gains

In most manufacturing environments in South Africa, a long history of mistrust exists between employers and employees, unions and government, and between companies in similar or even dissimilar industries. Many hours in a business year are spent deciding on how budgets will be spent, which department saved which costs and to which ones savings will be attributed, how operating profits will be distributed to wages and salaries, or who is responsible for paying for new software, capital equipment, or quality checks.

This is always most evident in the relationships between automotive OEMs, their suppliers, and their employees. There is a strong power relationship that occurs at various points in this hierarchy, and it is clear that the OEMs are able constantly to drive suppliers to reduce costs with the threat of alternative supplier opportunities. Although an environment like this could be described as a constant striving towards perfection, it necessarily results in challenges about who bears the cost of improvements and who reaps the gains.

Brettel believes that the potential issues of the sharing of costs and gains are among the greatest obstacles to the implementation of Industry 4.0 [11]. Industry 4.0 strongly encourages more collaborative working arrangements within and across organisations, and overcoming historical barriers to these types of working relationships is key.

6 DISCUSSION

6.1 What Industry 4.0 will change

A move to increased automation and intelligent systems creates an environment in which many roles become redundant. Automation of shop floor jobs is a clear consequence of a well-developed cyber-physical system. Developed economies aspire to move work to support Industry 4.0 implementations, thus raising employment levels. The reality in developing countries with a lower level of education, and as marginal participants in the knowledge economy, will likely be more dire. It will, however, be a universal feature of Industry 4.0 that white collar workers may be replaced by intelligent systems. This means roles in procurement, planning, market forecasting, scheduling, and more strategic functions — including work planning and scheduling — and even some design functions. It is further plausible that most functions of accountants and, in the long term, even lawyers, will be supplanted by intelligent systems. It remains to be seen for developed and developing economies alike whether all of these people will be absorbed into the new industries developed to support Industry 4.0.

An example that we observed was at a FMCG plant that had a visibly appalling morale, work rate, and quality. This explained itself towards the end of the visit, when we were shown the high-tech, fully automated packaging line that was about to be commissioned. That line represented the loss

of employment for only a few workers, but it had sent a wave into the fabric of the workforce's morale that was unmendable.

Industry 4.0 requires considerable investment in people, building the skills and competencies that are required to run and manage complex socio-technical systems. These skills are not currently synthetically taught at either universities or universities of technology. That would mean that this suite of suitable skills would have to be curriculated. Creating a new curriculum is generally a multi-year project, requiring the input of various stakeholders, including the registering council of engineering professions, industries, and university structures. This process will likely consume five years of planning, delivering the first new batch of graduates after about a decade, with the programme only maturing twenty years after planning started, and graduates then needing another decade of experience before they can be thought and practice leaders in these fields. That means that a transition to an Industry 4.0-savvy cohort of professionals requires a generation of development. And this means that, unless early and speculative development enters the higher education model, graduates will persist in being trained for industries of the past [29].

6.2 What Industry 4.0 will not change

Industry 4.0 will not negate the importance of humans in industries. Organisations will remain human endeavours, supported by machinery, intelligent systems, and complex interactions with data, allowing for improved decision-making. The risk of presuming that implementing Industry 4.0 will make 'people issues' disappear is misdirected and false. Unless machinery can entirely replace humans, the human will remain the most definitive actor in the success of the organisation.

And even if all humans were eliminated from a plant, the problems would still not be overcome. We observed this reality at a hyper-automated plant of a major multinational. The imported machinery is frequently in need of repair, recalibration, and support. In almost all instances when the systems fail, expatriate engineers must be engaged to travel to the site to get the plant functional again. Industry 4.0 makes provision for autonomous, learning, and intelligent systems, but none of those can perform the high-level curatorship for which the human will probably always be needed.

Industry 4.0 will not mend dysfunctional social structures in organisations. It will also not negate the need wisely to manage people and their role in the ecosystem that will make companies of the future successful.

7 CONCLUSIONS

Because the fourth industrial revolution has been presumptively named, defining it as a revolution is speculative. We believe that its key elements [9] represent an evolution of current practices and technologies, rather than an "overthrow of an established (political) system" [1].

As a beneficiary state of the third industrial revolution, South Africa has received tremendous foreign direct investment over the past twenty years [19, 30]. Globalisation has been beneficial to the South African economy.

The outlook of the South African economy is primarily limited by some structural issues related to political stability and societal and sociological questions. This presents opportunities for market shrinkage, moving anew to other low-cost countries (such as Rwanda [20]), or returning to developed economies [13].

We conclude that most organisations in South Africa do not yet possess the level of mature, inclusive management that is necessary to embrace the collectivism and the self-organisation that is critical for Industry 4.0 convergence [13].

We also conclude that South African industry will benefit from Industry 4.0, but that it will not resolve issues related to systemic stability; it will not negate the risks posed by protracted strikes; and it will not alleviate low literacy rates — in fact, these may be exacerbated by it.

We believe that an Industry 4.0 economy will result in job losses that will, for the first time in industrial evolution, include losses in the white-collar sector, as tasks such as procurement, planning, scheduling, innovation, layout and design, process optimisation, and other similar tasks will be performed by intelligent systems.

We do, however, recognise that resisting the momentum towards Industry 4.0 will make the domestic economy uncompetitive, both domestically and internationally. Any job losses will have to be offset against productivity and market share gains [9] and the diversification of the economy into a knowledge-driven economy, which includes an emphasis on education.

We are conscious of the latent and current weaknesses of the South African education sector. We specifically realise that education, skills, and a shift in mindset is a generational question that needs to be addressed in anticipation of the future direction of global manufacture.

We recommend that educational policy in South Africa consider forward-looking disciplines such as the traditional science-mathematics-engineering and technology disciplines, but emphasising IT skills, including coding, the Internet of Things and, most importantly, artificial intelligence and machine learning, which are notably absent from the seminal sources as important skill sets for Industry 4.0.

We conclude that Industry 4.0 is not a panacea for South Africa's manufacturing ills, and that the declining workforce and global market share will not be arrested by the introduction of these systems unless deep-reaching, fundamental change also takes place. This caution notwithstanding, Industry 4.0 (or whatever name we wish to give this wind that is blowing the global industry forward) has the potential to leave economies behind if we do not respond with appropriate actions now.

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