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A Review of Hurdles to Adopting Industry 4.0 in Developing Countries

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Abstract. The world is experiencing the fourth industrial revolution, and developing countries are experiencing it differently than developed countries. Developed countries have an advantage over developing countries in that they adopted industrialisation early, and this created a large gap between the two. Developed countries are not necessarily sustainable. Sustainable development is equally important in both developed and developing countries, but in different ways. Developed and developing countries will try to achieve sustainability development goals in different ways. Developed countries will most likely use the fourth industrial revolution to integrate technology into achieving their goals, while some developing countries might first need to catch up on industrial revolutions that they have skipped. Industrialisation, specifically that of the current revolution, will occur differently in developing countries. This paper describes this and discusses some of the hurdles that might hinder developing countries from adopting Industry 4.0, and develops an initial framework for readiness assessment.

Introduction

The pace and breadth of technological progress are increasing at a surprising rate. In the second edition of the book "The Second Machine Age" published in 2016, Brynjolfsson and McAfee (2016) say that even they, as digital technology experts, were just as surprised as many other players by their underestimation of how fast the technology landscape would change. The second edition appeared about three years after the first! The Second Machine Age is also known as The Fourth Industrial Revolution (a concept introduced by Germany at the Hannover Fair in 2011), or Industry 4.0 for short. This paper uses the term "Industry 4.0" to cover all aspects related to this societal and technological change.

From a Systems Engineering perspective the key position is that Industry 4.0 will be connecting people and man-made systems in an integrated fashion, and this promises to revolutionise everything from our daily lives to the way we do business (Schwab, 2017). Modern system design will most likely include Internet-of-Things (IoT) and Artificial Intelligence (AI) components with non-linear behaviour and interactions (Davenport and Ronanki, 2019). This development is all good and well in a developed country, but what are the implications of such a technological revolution in a developing country? In this paper, we look at what the previous revolutions were and how they shaped the advent of Industry 4.0. The literature concerning developing countries with regards to their fears and barriers to adopting Industry 4.0 is also studied. The authors finally propose a possible framework to establish readiness of enterprises for success under Industry 4.0 change.

The following section provides a brief history of the first three industrial revolutions and how they paved the way for Industry 4.0. After that the divide between developing and developed countries is explored with a short literature survey on the barriers or hurdles that prevent developing countries from adopting Industry 4.0. The authors provide their recommendations on how such barriers or hurdles can be mitigated before concluding the paper with a few final remarks.

Industrial Revolutions Through the Ages

A brief description of the Industrial Revolutions is presented as context in this section. Figure 1 presents an infographic of the four major industrial revolutions. It illustrates the symbiosis between the different aspects and areas that become interconnected through Industry 4.0. The first industrial revolution started around 1760 with the advent of the steam engine. The rapid progress in technology and associated societal change over the next 250 years brought the world to a tipping point of automation, connectivity, and the production of incredibly intricate artefacts.

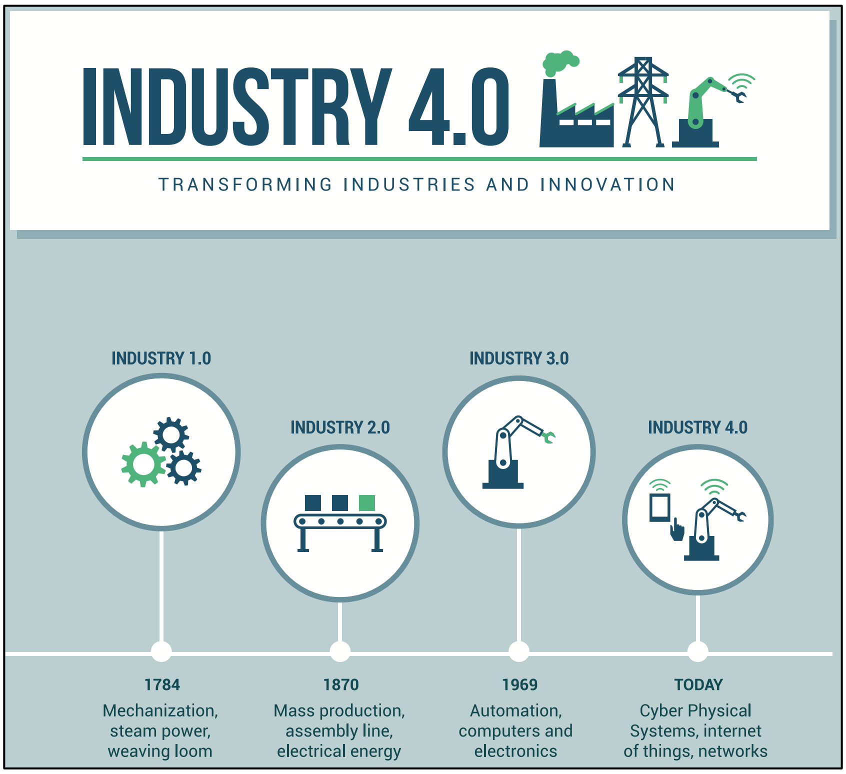

Figure 1. Industrial Revolutions (elenabsl/Shutterstock.com).

The Age of Mechanical Production. The first industrial revolution, also called the "Age of mechanical production", started in 1760 and its main contribution was steam-powered machines and textile manufacturing. The cause of the first industrial revolution can be traced back to the development of capitalism, the start of coal mining, and the agricultural revolution of the 1600s. Capitalism laid the foundation for industrialisation and free market capitalism specifically was very important. The government could no longer interfere as much in the economy and individuals were free to conduct their own business with freedom.

Another reason for the start of the first industrial revolution was the mining of coal. Coal was needed to power steam engines, which were a main contribution of this revolution. Powering steam engines with coal also had the increased benefit of helping to mine coal more efficiently. The combination of coal reserves, a way to efficiently mine it, and steam engines gave Britain the necessary building blocks to build one of the greatest technological advancements in transportation: the railroad locomotive and rail networks (McCraw and Mac Craw, 1997). Extensive rail networks connected the production hinterland with cities and centres of consumption. Mechanical production replaced manual labour in many areas and this lead to social unrest and migration of people off rural farmland to the production centres and cities.

Electricity and Mass Production. By the late 19th century the advent of electricity and the use of electricity distribution networks ushered in mass production and the assembly line. Owing to the rapid advances in factories and production brought on by the first industrial revolution, farmers and producers could now make and sell more products than before. The advent of the second industrial revolution was mainly due to an ample workforce, natural resources, railroad networks, and new power sources. What is often forgotten is that a wide range of fossil fuels became available for general use during this time, making the generation of electricity cheaper. Food production, the availability of powerful medicines and sanitation benefited humanity and longevity increased at the same time as the population started to explode. The economy world-wide relied on physical trade supported by land, sea and even air infrastructure. The 9-to-5 job became the way the majority of people took part in the economy.

The Transistor and the Digital Computer. The development of semiconductors was the catalyst for the invention of the concept of digital computing devices, leading to big “mainframe” computing devices in the 1960s and personal computing by the late 1970s. Structured high-level programming languages became available and methods for design and engineering of complicated systems became available.

The world became used to cellular and satellite communication systems connected seamlessly in what can be termed a true digital convergence. This era was a true revolution in terms of data sharing and information availability. A new “e-economy” was emerging and it rapidly started to supplant the resource-based economy. It had the ability to increase per capita productivity, it created employment for skilled labour and left unskilled labour on social support systems and /or in abject poverty. Cyberspace became a new transnational zone beyond governmental regulation and accessible by the masses – where there was access to this space through fast internet connectivity.

Some countries that were locked into poverty or based on primary industries like mining and agriculture acted pro-actively during this revolution and Ireland, for example, moved from no tradition in technology to one of the largest information and communication technology hubs in Europe (Fisher, 2006). But, by 2001 only about 6% of the world was using the internet! It meant that the divide between those that embraced the opportunities of the Third Industrial Revolution successfully and those that were late to the game would increase rapidly.

Cyber-physical Connected Smart Systems. It was clear by 2011 that a new Industrial Revolution was underway and Germany coined the term “Industry 4.0” at the Hannover Fair to describe how the global value chains will change (Gutiérrez and Ezponda, 2019). The initial concept was focussed on how manufacturing would be impacted by smart and connected machines, but by 2019 all new radical technologies like Smart Robotics, Internet of Things (IoT) and Big Data, amongst others, were seen as part of the concept. Enabling technologies include Artificial Intelligence, nanotechnology, gene editing and engineering, additive manufacturing, and quantum computing, to name a few. The vast advances in communications infrastructure and technology like 5G for mobile and cellular systems play a major role in Industry 4.0 (Figure 2).

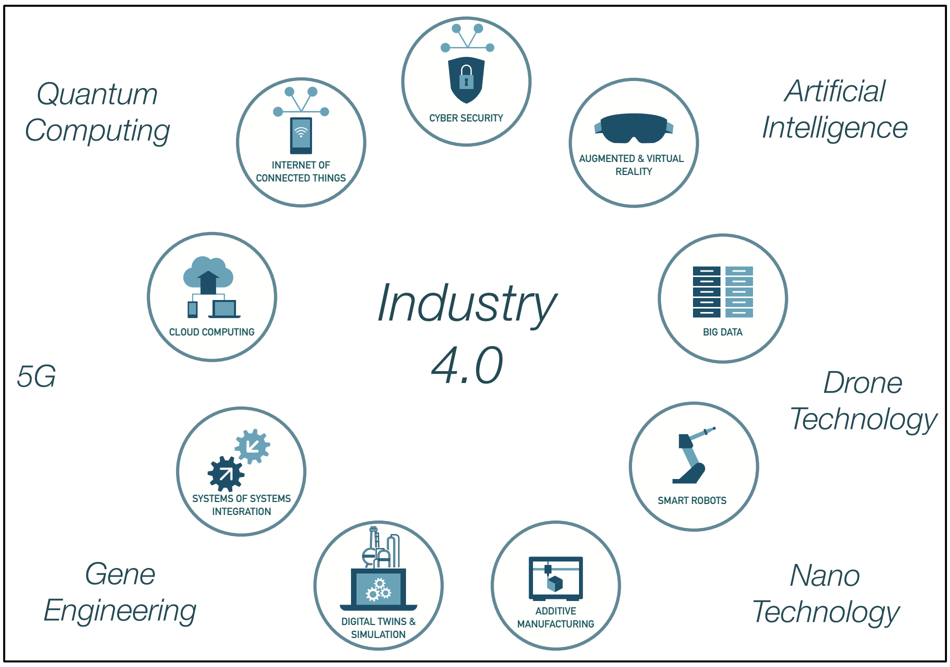

Figure 2. The Industry 4.0 Complex.

In the next section the developing chasm between developing and developed countries will be considered. There is little room in a short review paper to cover all the aspects that drive the chasm. However, it is important to at least mention some of the deep, philosophical driving forces that are not immediately obvious and that play a significant part in engineering of system solutions. Three related aspects are considered briefly in the current section: Science, Technoscience and Innovation. Finally, Society is considered, making sure the socio-technical-ecosystem context is clear.

Science. Broadly speaking, science consists of verifiable knowledge obtained through observation and logical reasoning and it is systematically structured. Principles and general laws are derived from science. It is possible to use science for prediction based on the deduced laws and principles.

Technoscience. These are theories and techniques that make the science practical. Christopher Alexander (1964) proposes that scientists work to identify and understand the parts of the world, while the designers/engineers try to shape the parts of new, practical structures in the world. What Alexander could not imagine in 1964 was how humans and the practical artefacts would integrate through a range of 'interfaces' to accomplish very complicated tasks (praxis).

Herbert Simon states that the disciplines of the natural sciences focus on discovering and describing how things are and how they work. Designers and engineers on the other hand focus on making artefacts that address specific issues. They are "*concerned with how things ought to be, with devising artifacts [sic] to attain goals.*"(Simon, 1996). Engineering knowledge comes mainly from Technoscience, and without a strong scientific basis, engineering is reduced to pure craftsmanship (Diaz and Bonilla, 2019).

Innovation. Innovation requires a grounded understanding of science and technoscience because the focus is on renewal and change to improve existing solutions. Innovation extends beyond technology. In fact, ten types of innovation can be identified and can be clustered into three groups (as shown in Figure 3, from (Keely et al., 2013)). The innovative *configuration* of enterprise includes profit models, networks of collaborators and supply chains, organisational structure, and processes. *Offerings* may be changed by considering product systems and/or their performance, and *user experience* may by impacted by innovative changes to service models, channels of delivery, brand management and customer engagement (Keely et al., 2013).

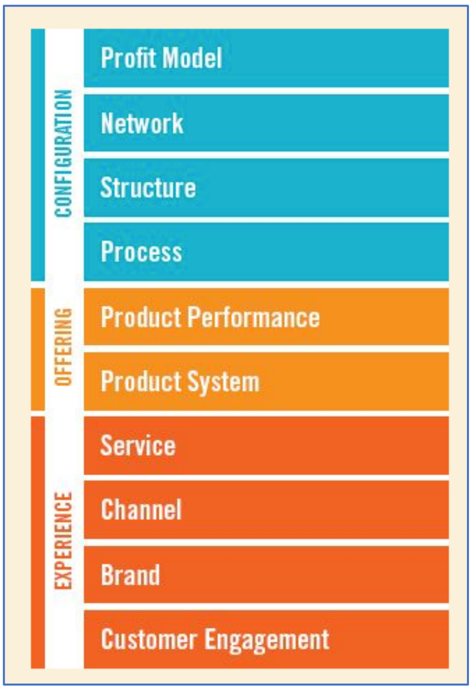

Figure 3. Ten Types of Innovation.

Society. Modern society finds it difficult to accept that problems are potentially open and evolving. There is no guarantee that science will find the answers, but society expects simple cause and effect solutions (Allen, 2017). There is a longing for an imagined world where significant problems are solved with primitive, easy to grasp approaches. Fisher (2006) calls this regression of the human psyche 'neo-primitivism'. He states that modern society has a predisposition to cults of the body, fundamentalism, extreme adventure tourism, violent combat sports and more. And complex interventions must be explained in terms that can be 'consumed' easily by many in society with little time and a limited appetite for complicated plans.

On the other hand, for the science, technoscience and innovation that are part of Industry 4.0, systems engineering people are required that have big picture skills, depth of knowledge of the process and the underlying principles and the ability to keep a strong focus on the issues at hand (Buede, 2016). Can societies, and by implication their systems engineering cohort, still locked into earlier phases of technology and development, transition into Industry 4.0? As Kim et al. (2019) puts it, "Supposing that the claims regarding technological advancements do take place in the developed world, this still leaves the question of how the developing world will be affected by these advancements, how they will function as a result of these advancements, and how they will affect the developed world given these advancements."

The Chasm Between the Developed and Developing World

One of the main differences between developed and developing countries is that developing countries have a low rate of industrialisation. Developed countries have the advantage of having adopted industrialisation early, thus creating a gap, or in some cases, a chasm between them and developing countries. However, while developed countries are developed and flourishing, they might still not be sustainable. Sustainable development is economic development conducted without depleting natural resources and is equally important in both developed and developing countries, but on different edges of the spectrum.

In 2015 the United Nations published a list of 17 sustainable development goals for countries to track their progress against as illustrated in Figure 3. The ideal is to obtain these goals by 2030. The goals were developed to uplift developing countries and to ensure that developed countries also become sustainable (UN General Assembly, 2015). Many of these developed countries, like Finland, have adopted strategies to minimise waste to the extent that no waste will be allowed to go to landfill by 2025 (Pantsar and Herlevi, 2016). New Zealand passed a Zero Carbon Bill to bring that country to a zero emissions status by 2050 (Shaw, 2019). One of the consequences of these strategies is the "re-mining" of industrial products like display screens, computers, etc. for resources and to re-use and repurpose every last bit of a product or material *at the source of repurposing* at end of utility and close to where the product or service is used, cutting back on carbon emissions in the logistics chain. It comes down to "re-shoring" of manufacturing to the developed countries (meaning that manufacturing is returning to developed countries, and away from developing countries with cheaper labour). This is driven by high taxes that are imposed on import of any raw materials that may compete with the materials recovered through these resource recovery practices, putting an economic strain on mostly developing countries that supply raw materials to the industrialised countries, or supply cheap manufacturing services.

Similarly, 'Millennium Development Goals' were set and progress was made, but the progress was very uneven in developing countries. This time round the UN wants to help the least developed countries and other countries in special situations that require special assistance.

Figure 4. United Nations Sustainability Development Goals[1].

The problem faced is that certain developing countries, especially the least developed countries, have skipped an industrial revolution in some respects, with almost 1.3 billion people not having access to electricity (Industry 2.0) and about 4 billion people still not having access, or very limited access, to the internet – a core element of Industry 3.0 (Schwab, 2017). Do we bridge that gap with intermediate technology or do we "catch up" in record time? If developing countries did in fact skip an industrial revolution at their own pace, how can we be sure that outside intervention would work to bring them to a more advanced level?

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[1] Adapted from https://www.un.org/sustainabledevelopment/sustainable-development-goals/

Factors Preventing Industry 4.0 Adoption in Developing Countries

In some developing countries there are people who have access to smartphones and internet, but not to running water and flushing toilets (Klynge, 2019). In other areas people in impoverished communities can do their schoolwork on digital tablets, but they do not have food to eat. Developing countries will not go through the fourth industrial revolution in the same way that developed countries do, as developing countries have a different economic outlook and might not have the same access to technological growth (Kim et al., 2019). They state: “The discrepancy between the readiness of the U.S.A. and Europe compared to the readiness of the developing world in general and the Philippines in particular shows that there is no uniformity with regard to the advance of technological innovation.”

There are numerous factors preventing developing countries from adopting Industry 4.0, the biggest being the “lack of a digital strategy alongside resource scarcity” (Raj et al., 2019). Most companies, and even most governments, do not have the strategic roadmaps in place or the necessary resources to get their people ready for Industry 4.0. They are, in a word, unprepared for Industry 4.0.

Most of the other factors are centred around the work force – the humans performing the jobs that might be automated by machines in future. The lack of a trained and experienced work force is a big hurdle for companies (Raj et al., 2019). Many jobs that are seen as repetitive or boring are now automated and performed by machines. This could save time and money for companies, but what about the people performing those tasks? One side of this coin is that these people risk losing their jobs as they will be replaced by machines. The other side of the coin is that these people can move to jobs where their skills and expertise can be utilised better than, say, in a repetitive and boring job. As simple processes are increasingly automated, the workspace becomes more complex and the level of skill and education needed from an employee increases (Hecklau et al., 2016). That being said, if an employee has limited capabilities or is close to retirement, would he or she be able to (or want to!) learn the new skills (so-called “upskilling”) necessary to perform this new task? The more people that are replaced by machines, the higher the unemployment rate, which will lead to further inequality between the social classes (Kim et al., 2019). The South African government is struggling to mitigate the already high unemployment rate (26% in 2018), even before possible automation owing to Industry 4.0 (Manda and Ben Dhaou, 2019).

This changing work environment could also cause conflict between co-workers and create social tension and it seems to be under-researched (Kurt, 2019). According to Schwab, “…technology will segregate the market into low skills/low pay and high skills/high pay categories, resulting in social tension”. Colleagues who used to do the same work are now divided where one is now the other’s manager. Or one person keeps his job while the other is made redundant.

In Raj et al. (2019) the authors state that in Hungary there is a lot of resistance from employees and middle management towards adopting Industry 4.0, but this rings true for several, if not most, countries. Humans by default resist change until it becomes inevitable. Another reason is that automation would decrease the chances for a developing country to offer low-cost labour (just think of China and India) which might be one of the ways in which they develop (Kim et al., 2019).

Another factor that prevents the adoption of Industry 4.0 is a shortage of financial resources. Upskilling employees, hiring employees that are more skilled, building Artificial Intelligence (AI) tools, buying AI tools, and building infrastructure will cost a company a lot of money. The cost of all of this needs to be weighed against the gains of automating and streamlining a business.

Data security and privacy is another adoption prevention factor (Manda and Ben Dhaou, 2019, Raj et al., 2019). The reader might think that this is only a problem in developed countries and that developing countries have more important problems to worry about, but this is untrue. Imagine for a moment a developing country that is told that it needs to secure its cyber space. A lack of education or knowledge about the subject (or even due to fear-mongering) could lead to a person in power making decisions that will negatively affect the security of his company's data. Poor or ineffective infrastructure, under-skilled staff, as well as poorly designed or implemented systems could lead to data breaches and comprised data security (Manda and Ben Dhaou, 2019, Raj et al., 2019). The authors call this a "lack of digital skills" and go on to state that, "…under-qualified employees are the second major barrier to realizing Industry 4.0, as businesses will become more data-driven and agile, requiring a more qualified workforce." In South Africa there is a low "e-readiness" level which is a big prevention factor (Manda and Ben Dhaou, 2019).

A lack of digital infrastructure is also a serious problem, even in developed countries. Reliable and fast broadband is needed to implement Industry 4.0. Even developed countries such as Germany are struggling with this for their Small and Medium-sized Enterprises (SMEs) (Raj et al., 2019).

As an example we can look at the Philippines as a developing country. According to (Kim et al., 2019), the Philippines IT-BPO (Information Technology and Business Processing Outsourcing) workers will have to move to "complex higher value services that still require human involvement." This move will result in reducing the chances of workers offering their often outdated skills and services, and employees will be in danger of being retired in a wave of automation. The Philippines have a lot of challenges to overcome in this regard ranging from a lack of Information and Communications Technology (ICT) infrastructure to restricted investments.

Recommendations

Industry 4.0 was established with developed countries in mind. Developing countries need to adapt Industry 4.0 to their own context and cannot use the blueprint for Industry 4.0 as is. This adds complexity as there is no blueprint or template for developing countries to follow, but it also gives them an opportunity to develop something that is tailored to their own situation and will enable a country to be globally competitive. As Kim et al. (2019) put it so eloquently, "The next logical step does not seem to be the world described by Schwab (2016), although such a world, if it presents itself to the Western world, will have a different set of implications for the developing world".

The aspects of Industry 4.0 that will best help a developing country are:

Increased throughput. Companies that adopt Industry 4.0 could have not only increased production, but also increased throughput owing to the increase in precision and productivity and the decrease in wastage and faults.

Increase in jobs. Increased production and throughput would put a company in a better financial position. Increasing production will warrant the employment of more workers, whether skilled or unskilled.

Global competitiveness. An increase in the above two aspects would enable the company to be globally competitive, and will elevate the country to be seen as a "big player" in the world of Industry 4.0.

Decentralised world. Industry 4.0 will help to create a decentralised world where individuals could have more power to influence significant events due to the internet, smartphones, and social media (Kim et al., 2019).

Enabled innovation. Companies and countries alike are forced to think of better solutions which could enable innovation. Developed countries have the resources and manpower to complete large tasks with large teams, whereas developing countries have to complete tasks with much smaller teams and much less resources at their disposal. Having to do more with less forces a team to innovate.

The aspects of Industry 4.0 that will least suit a developing country are:

Financial cost. The costs associated with digital infrastructure and education are high, especially if a critical industrial revolution was skipped.

Technological threat. New technologies (AI, robotics, automation, etcetera) are seen as a threat in developing countries where the biggest throughput is low-cost labour rather than technology (Kim et al., 2019).

The adoption of Industry 4.0 could be promoted if the governments of developing countries improved their regulations and standards (Raj et al., 2019). "Buy-in" from the government and political leaders would assure companies that they will receive the necessary support as well as enabling digital transformation and innovation (Manda and Ben Dhaou, 2019). But it is not just the political leaders that can cultivate innovation and transformation: the real innovation happens in the think tanks led by business leaders. On a third level is social leaders who can prepare societies for the changes that occur with the advent of Industry 4.0 (Manda and Ben Dhaou, 2019).

A Framework For Readiness Assessment

Motivation for the Framework

How might one go about establishing the readiness of an enterprise for the challenges of Industry 4.0? What dimensions of an operation may be used to map readiness?

According to Schwab (2017) the disruption introduced by Industry 4.0 will require new and radical ways to diffuse innovation and it will be almost impossible to manage it in a top-down manner, as Research In Motion (RIM) found out in 2011 (Molen). The backlash from teams against the inability of management to adapt to change escalated rapidly, and Blackberry effectively departed the technology landscape. Rodgers summarised the *change management* approaches into three broad categories (Rodgers, 2007) and added the concept of management by 'informal coalitions'. He notes that the first three types are often used in some combination, and almost never in isolation (Figure 5).

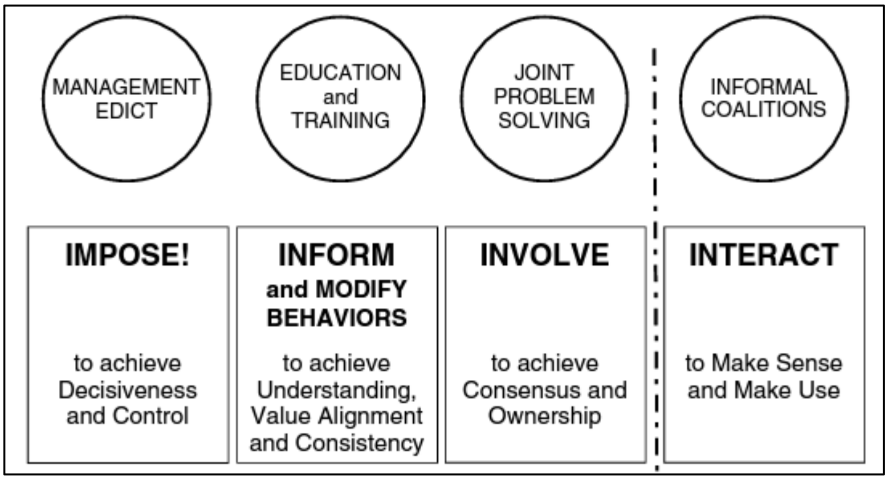

Figure 5. The Approaches to Continuous Change Management as Depicted by Rodgers (2007).

From the analysis in previous sections it is clear that Industry 4.0 introduces a raft of complex technological and societal complexities. In terms of *team dynamics* Wheatly (2005) makes a case for self-organisation as a key driver towards an enterprise that is more aligned with complexity principles. She listed three key principles for development of effective team work:

a. Clarity of identity and intent to enable sense-making in complex situations,

b. Sharing information to support ethical decisions and interaction,

c. Agility based on trusting relationships.

Mobilising teams in an enterprise to grow into the principles set out by Wheatly is not without challenges (Rowe and Hogarth, 2005).

Teams and individuals are part of the *corporate citizenry*. This collective has a responsibility to act in an ethical and accountable manner. Often management sets the tone by the priorities they publish and demonstrate and in times of change it dilutes quite easily to financial responsibility and many aspects are relegated to 'nice-to-have' status. Woermann (2016) argues for a diverse and empathetic workforce willing to expose and question issues. Context and contradictions are seen as valid sources of information about the situation that the corporate entity faces. This in contrast to the reluctant and often passive aggressive nature of corporate life where compliance is a result of fear and coercion.

Any enterprise operates in service of a perceived or stated need in society. The INCOSE Systems Engineering Handbook specifically considers product and services and in both cases focusses on aspects of *service and production maturity* (Walden et al., 2015). One of the hybrid Systems Engineering methods that can be utilised is Lean. Lean development is seen as a cross-cutting approach focussed on delivering the best life cycle value for complex deliverables while minimising waste. Process maturity in the Lean paradigm considers several principles according to (Schipper and Swets, 2012). These range from the basics of formally capturing procedures on the shop floor, to capturing knowledge as part of execution of process at a horizontal integration level over the life cycle of the offering in the organisation, implementation of cycles of continuous learning and improvement, and finally vertical integration of all aspects of the operation across the organisation (Figure 6).

Figure 6. Interconnected Integration of Lean Principles and Industry 4.0 (Gehrke et al., 2015).

Organisations also need to be aware of *technology change and innovation opportunities* and must be able to achieve "technology connectedness" aligned with stakeholder needs, according to Vlok et al. (2019). They continue to show that technology connectedness is an important aspect for successful organisations. It is fair to say that organisations that have large external networks, which can be leveraged to address technology requirements and user needs, are in a better position to be successful than an enterprise that focusses on adding new technologies in an *ad hoc* fashion.

The thesis is that by using at least the five dimensions discussed in this section (Leadership, Team Dynamics, Corporate Citizenship, Service and Production Maturity, and Awareness of Innovation opportunity under disruptive circumstances), it may be possible to develop a model to map enterprise readiness, and start a discussion for strategic change.

Development of the Framework

Based on insights of the initial review and by using the dimensions identified in the previous section, a prototype business readiness framework for use at an Industry 4.0 introductory workshop, was developed with financial support from a governmental innovation department in New Zealand. A single workshop was run to test the concepts with local businesses. The outcome was favourable (according to solicited feedback after the workshop) given that the participants saw value in being part of a larger development effort and by gaining insight into the integrated nature of the response required.

The initial framework (Figure 7) was developed using a multicriteria decision and conjoint analysis engine based on the work of Hansen and Ombler (2008). The inputs were solicited from half a dozen business and entrepreneurial individuals in Dunedin, New Zealand, and was used to derive the model shown below. The workshop was focussed on helping business understand their readiness, based on these agreed parameters that are seen as important for business success under the changes expected of Industry 4.0.

Using the framework it can be seen that an organisation that has a mature involving management style combined with self-directed teams will score 37% on those combined dimensions. A sensible adoption and use of the tools and technologies of Industry 4.0 in an interconnected manner will add almost 22% to the score. An enterprise that is mature at this level would expect to also score well on Corporate Citizenship and Production and Service Maturity, possibly adding another 26% for a total readiness indicator of about 85%.

The model does not accentuate Corporate Citizenship as much as was expected and this reflects on the small sample group of business leaders from a limited group of industries used to contribute to the prototype framework development. The group will be extended and the model will be updated in future. It is possible that different models may be developed for a range of industry sectors in future.

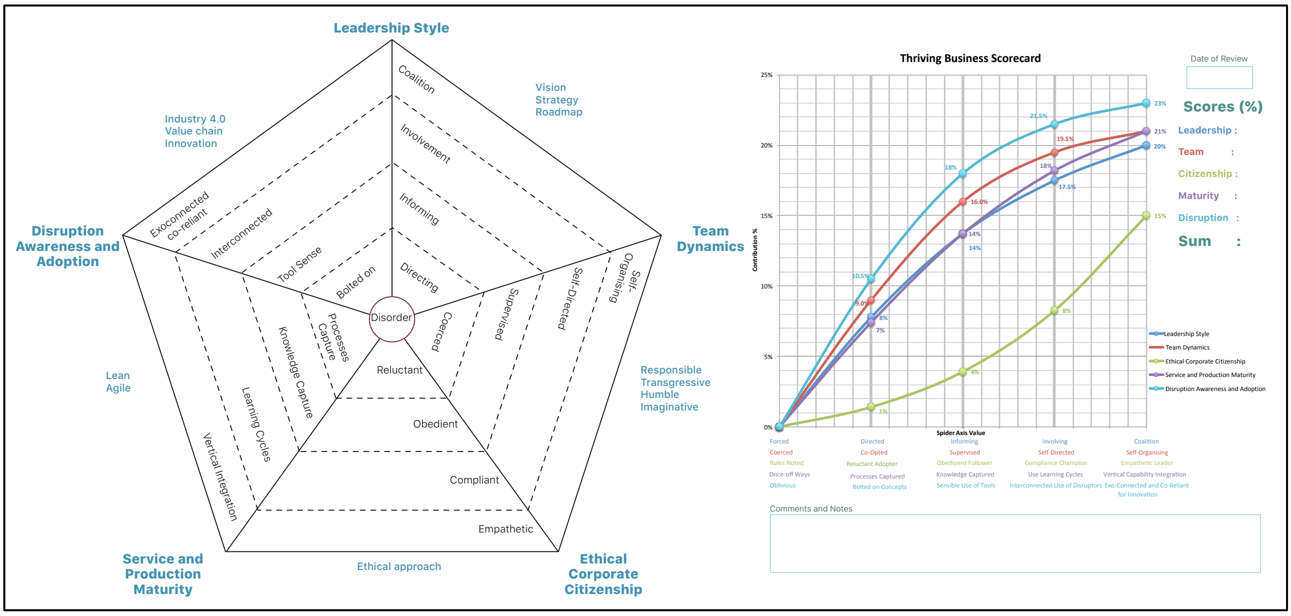

Figure 7. A Prototype Framework for Business Readiness for Industry 4.0.

The concept is a transferable artefact and could be used in any country using the same workflow to establish the important parameters.

The next set of similar frameworks (to be developed) will consider the relative readiness for aspects of Industry 4.0. The context is climate change and circular economy directives from governments and local councils. It will include an evaluation, using a similar conjoint analysis approach, to establish what the strengths and weaknesses of a region are in terms of being resilient to the changes of Industry 4.0 and environmental factors.

Conclusion

The economic and social world order is a system of systems. Economic refugee migration is a reality in many parts of the word. It is conceivable that Industry 4.0 will have social and economic implications for the world that go beyond nation states and regions. There is immense risk for governments in not being pro-active with tailor-made local and regional responses. In this paper we explored the surface of the possible barriers to adoption and immersion in the socio-technical shift of this massive change, especially for developing countries.

It is clear that every country will have to consider its own business and technology response and such a response will be contextualised by the region it is located in, its trade networks, human resources, natural resources, the effects of climate change responses in developed countries, and a host of societal dynamics internally and externally.

The courses of the development of the Circular Economy concept and Industry 4.0 are intertwined with the uncertainty of climate change. The work in this paper forms the basis of a planned strategic systemic response to these issues. Future work (in planning) will consider the qualitative evaluation of perceived barriers and opportunities under Industry 4.0 for countries like Finland, New Zealand and South Africa and the development of industry tools to evaluate readiness for Industry 4.0 based on leadership skills, organisational dynamics, ethics, agile and lean production and service methods, readiness for innovation, and appropriate Industry 4.0 technoscience immersion.

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Biography

Jan Hendrik Roodt is actively involved in the entrepreneurial space in New Zealand. His company launched a wine appreciation app for iOS recently. Commercial projects focus on Industry 4.0, the Circular Economy and environmental regenerative practice. Jan holds a PhD in Engineering Science and MSc in Physics. He leads transdisciplinary professional practice Master and Doctoral studies at several academic institutions in New Zealand and is an active member of the Institute of Information Technology Professionals of New Zealand, the IEEE (Systems Council), the International Council on Systems Engineering (INCOSE), and holds DARPA coin 1313.

Hildegarde Koen holds an MSc in Applied Mathematics and a PhD in Electronic Engineering. She has been permanently employed at the CSIR in South Africa since 2015 and currently holds the position of senior researcher. Her passions include Artificial Intelligence (AI), mathematics, and finding ways to use this for the good of the community. In 2019 she developed a workshop to educate colleagues and members of the defence force on AI. This has proved to be so popular that she has been invited to present this workshop in various forms at five different local information sharing events during 2019.