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Impacts of adopting industry 4.0 technology by SMEs

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Introduction

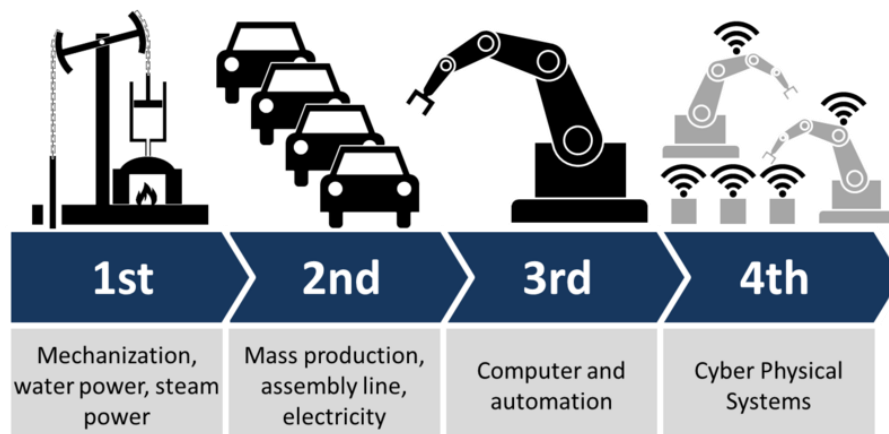
This paper explores what Industry 4.0 is and how it impacts businesses. We look at the characteristics of Industry 4.0 in terms of vertical and horizontal integration. Organisational changes and their effects and impacts are discussed, as well as the many aspects of benefits and challenges to adopting industry 4.0 technology

What is Industry 4.0

Industry 4.0, to many people, is seen as the fourth industrial revolution because, like the three previous revolutions, it has the ability to transform and improve industrial processes.

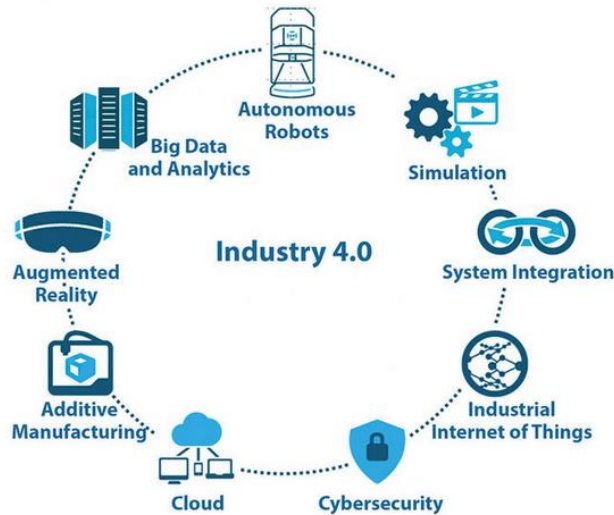
The earlier industrial revolutions, were:

1. Use of water and steam for mechanization, leading to advancements in the textile and iron industries.
2. Use of electricity and assembly line for mass production. Here we also saw the creation of the telephone, light bulbs, and combustion engine.
3. Adoption of computers, through creation of transistors, microprocessors, and the world wide web, enabling the beginning of automation.



(Marr, 2016)

This fourth industrial revolution, also referred to as Industry 4.0, is the combination of multiple systems and new technology that are connected, creating "cyber-physical systems". It is a complex network that is constructing a new industrial paradigm that includes this cyber-physical system, as well as Big Data, Autonomous Robots, Internet of Things, Augmented Reality, Additive Manufacturing, amongst others, as depicted below by (Ciukaj, 2019)



Ciukaj further explains that Industry 4.0 is more than just technology, but it also applies to “new ways of working and the role of people in the industry.”

For the manufacturing industry, it is the enhanced interaction between labour process, management systems, and technology innovations.

Industry 4.0 is enabling the improvement of efficiency, productivity, and sustainability whilst opening up new opportunities for businesses.

(Abdelmajied, 2022) supports this by stating “When these enablers are combined, Industry 4.0 has the potential to offer some amazing improvements in manufacturing environments. Machines that can foresee faults and initiate maintenance operations on their own, for example, or self-organized logistics that adapt to unexpected changes in production are examples”

Characteristics of Industry 4.0

Industry 4.0 has distinct characteristics: vertical integration & horizontal integration (Abdelmajied, 2022).



(Gehrke, et al., 2015)

Vertical

Within the scope of Industry 4.0, vertical integration is the connections between the different corporate levels within a business. Starting on the shop or manufacturing floor, moving up through organisation and planning, and on to standards and business segments.

These connections, established via cyber-physical systems and the Internet of Things, provide an efficient data flow to enable effective planning, development, and quick response to unexpected changes. It is reliant on communication between systems such as production monitoring and control, product management, quality management, and sales forecasts and insights.

Once established, the information automatically gathered at each level will enable the business to quickly identify where resources or personnel need to be moved to address shortages, equipment failures, anomalies, quality variations, and other such problems. This results in increased efficiency and reduced waste.

Horizontal

Horizontal integration differs from vertical integration because it involves connecting all parts of the supply chain – internally and externally. Vertical integration is high level co-ordination within the business, whereas horizontal integration of Industry 4.0, as depicted, refers to the consolidation of the network of processes that then make up the whole value chain.

As explained by Abdelmajied, each system or machine that is connected to the network become a node which “continuously communicate their status to respond autonomously to dynamic production requirements cost-effectively and reduce system downtime through predictive maintenance.”

For a business with several sites or one that collaborates with business partners, horizontal integration allows this data and information to be shared to create a highly automated and transparent value chain which updates instantaneously.

What this provides to all of the businesses or sites included, is a further increased flexibility to respond to changes; whether they be supply problems or fluctuations in demand.

Organisation changes and effects of Industry 4.0

Organisational changes, as highlighted by (Serumaga-Zake & Andrew van der Poll, 2021), are necessary for the implementation of Industry 4.0 technologies. These changes can be split into three distinct categories:

1. **Process:** the modification of processes used in production, in methods of service and supply, communications, operations, and other processes that support internal activities
2. **Structure:** this covers introduction of new management systems or methods, as well as significant changes to company strategy. An example of this would be changing from a linear product cycle to circular.
3. **Boundaries:** reforms in the way in which a company interacts with external contacts, be they business partners, suppliers, customers or competitors.

As such, the impacts and effects of implementing Industry 4.0 are far reaching into every aspect of a business.

(Abdelmajied, 2022), breaks the impacts down into six categories:

1. Industrial sector:

The new industrial paradigm is set to create a manufacturing industry that, in many cases, could “autonomously govern themselves, trigger operations, and adapt to changes in their surroundings”. With this companies would need to fully integrate all of their products, services, and processes into the Industry 4.0 technologies that they adopt, so that they can get real-time data sharing. This adds considerable complexity, but offers opportunities for more efficient use of resources, increased productivity, and greater flexibility.

2. Products and services:

As the market adapts to the enhanced developments of Industry 4.0, it is suggested that there will be market demand for more intelligent products and services. This will require products to become more modular and easily configurable, enabling high levels for customisation to meet the specific requirements of each individual customer. To achieve this, manufactures will need to produce products that are interactive, can be remotely managed, and provide real-time status information throughout the products lifetime.

3. Business models and market:

Industry 4.0 technologies will significantly disrupt the way businesses sell their products and services, this means they will have to adapt and introduce new business models that are more responsive. Through the increased digital connection between the manufacturer and the end customer, businesses will be able to have insights into the market demands. Which as Abdelmajied states: “will result in the establishment of increasingly sophisticated and digital market models, boosting competitiveness by removing barriers between information and physical structures”.

4. Work environment:

The technology advancements brought about by Industry 4.0 will redefine job scope and the required competencies of the employees. Increased human-machine interaction, such as use of robots and virtual environments, will affect the types of work carried out exclusively by employees. It is expected that the increase communication, aided by cyber-physical systems and the Internet of Things, will make work more productive and efficient. However, through use of these technologies it is necessary to consider the reframing and adapting of present jobs to avoid technological unemployment.

5. Skill development:

Following on from work environment, skills development is a fundamental factor for the effective implementation and acceptance of any new Industry 4.0 technology or process. New competencies will be essential, therefore upskilling of current employees with high-quality training will need to be factored into the planning of implementation. The employees must be given the opportunity to acquire new skills to prevent job losses, but they must also be willing to take on new responsibilities.

6. Economy:

This is the most complex category to summarise due to the vast array of factors that influence an economy. Focusing on just two of those factors, as discussed by Abdelmajied, we look at social dimension and sustainability.

Employee satisfaction, within social dimension, could be increased through the use of human-machine interfaces. These will ideally enable easier processing of arduous, repetitive, or dangerous tasks, which will free up the employee to focus on other more interesting work. However, there is

the risk that this could also lead to the replacement of “easy jobs” by automated technology/processes, thereby reducing staff requirements for that particular task. In addition to this, companies may face resistance from their employees to the changes due to absence of confidence and fear of the complexity of using something new.

On the other hand, Industry 4.0 does increase the requirement for different roles that include monitoring, training and collaborations. Due to this, and as previously stated, the business has a social responsibility to ensure that they factor in upskilling and training of their staff on the technologies that are to be introduced.

In terms of sustainability, now more than ever, businesses must take action to make sure not only are their day-to-day practices more sustainable and environmentally friendly but also the products and services they provide. Industry 4.0 offers many opportunities here; real-time feedback on processes can highlight areas for greater efficiency. This will allow the business to identify areas for reduced resource consumption, increase product lifecycle, and reduced waste.

An additional category to consider is the supply chain. Digitalisation and communication of the different software used in the entire supply chain, such as material resource planning (MRP), customer relationship management (CRM), quoting and ordering systems, and other business management software; provides real-time, consistent and accurate data. This accurate data enables more informed decision making and permits the manufacturing business to efficiently plan and control whilst still being flexible to response to changes.

The example provided by Abdelmajied states, “by faster reacting to changes in demand, supply, and prices, companies can reduce planning cycles and frozen periods. Future events and trends, such as consumer behaviour, delivery time, and industrial output, can be predicted using business analytics techniques.”

Benefits of adopting Industry 4.0

As briefly mentioned earlier, Industry 4.0 is enabling the improvement of efficiency, productivity, and sustainability whilst opening up new opportunities for businesses.

Efficiency

Digitalisation, system integration and the communication between these systems is what is driving the increased and improved efficiency. This does not have to be limited to the manufacturing floor, it can also be adopted for innovation and product management. Connecting software packages that provide real-time data on aspects like production costs, service cases, customer feedback, and sales opportunities will enable a product team to more efficiently manage their roadmaps and development plans. They will be able to track ROI, identify risks, and get insights into what their customers want/need next, which in turn informs on what developments to prioritise.

Productivity

In terms of productivity, (Firican, n.d.), explain that higher productivity coincides with each industrial revolution, and that each “era goes up 50 times over the preceding age.” This is due to the enhancements from increased automation.

Quality of life

Another benefit is that smart technology that is connected and can be used remotely is improving our quality of life. Firican includes a quote from Bernard Ford that exemplifies this: *“ordering a cab, booking a flight, buying a product, making a payment, listening to music, watching a film, playing a game and even controlling the lights and temperature in our homes can be done remotely.”*

New opportunities

Industry 4.0 is creating and opening up new market and growth opportunities, as it combines the improvements from multiple fields to create new products or services. As an example, introducing the Internet of Things and deploying sensors into products can allow a business to monitor the uptime of their products in real-time. This will enable them to predict for planned maintenance, which they can offer as a service. Offering of this service before a product stops working will ensure the least amount of disruption to the customer, and increase the customers satisfaction.

Lowering barriers

An additional benefit described by Firican is the lowering of barriers to entrepreneurship. They provide the example of the 3D printing (additive manufacturing) for prototyping. Entrepreneurs, as well as intrapreneurs, can now test various products with lower costs and “without the traditional time and cost restraints often encountered with traditional prototyping methods.” The speed from invention to market is therefore also reduced.

Additional benefits

Serumaga-Zake supports these benefits, where they also have the following listed:

“increased revenues, enhanced product quality, supporting innovation across many applications, energy efficient and environmentally sustainable production, waste reduction, increased flexibility, and enhanced safety in the workplace.”

Additional evidence in support of these benefits are supplied by the interview between Alex Otanez (Shockoe) and Mike Upchurch (Chief Strategy Officer at Notch). Mike focuses on the uses and benefits of machine learning:

“Using machine learning for predictive maintenance has proven to reduce downtime, in some cases as much as 50% and increase machine life by 20% to 40% ...

Improving yield/throughput/capacity and quality ... In some industries, the increase can be in the 10% range, but in others, like semiconductor manufacturing, where they are already good at yield, the results can 1%. However, in that business, a 1% improvement in yield is worth \$100M. This is accomplished by looking at the end-to-end process and understanding not only how each machine contributes to defects, but also the interdependencies of each machine to each other as well as environmental factors; such a factory temperature fluctuations.

As for systems optimization, think of looking at the entire process from sales through manufacturing and delivery. An example would be using 1,000 variables and 10,000 constraints to figure out how to optimize system performance. The company that did it raised earnings 50%. ... An example would be that large oil and gas companies have simulations of their entire plant so they can do things like see how changes in maintenance schedules affect the entire system using software and then optimize the schedule before doing any physical changes.”

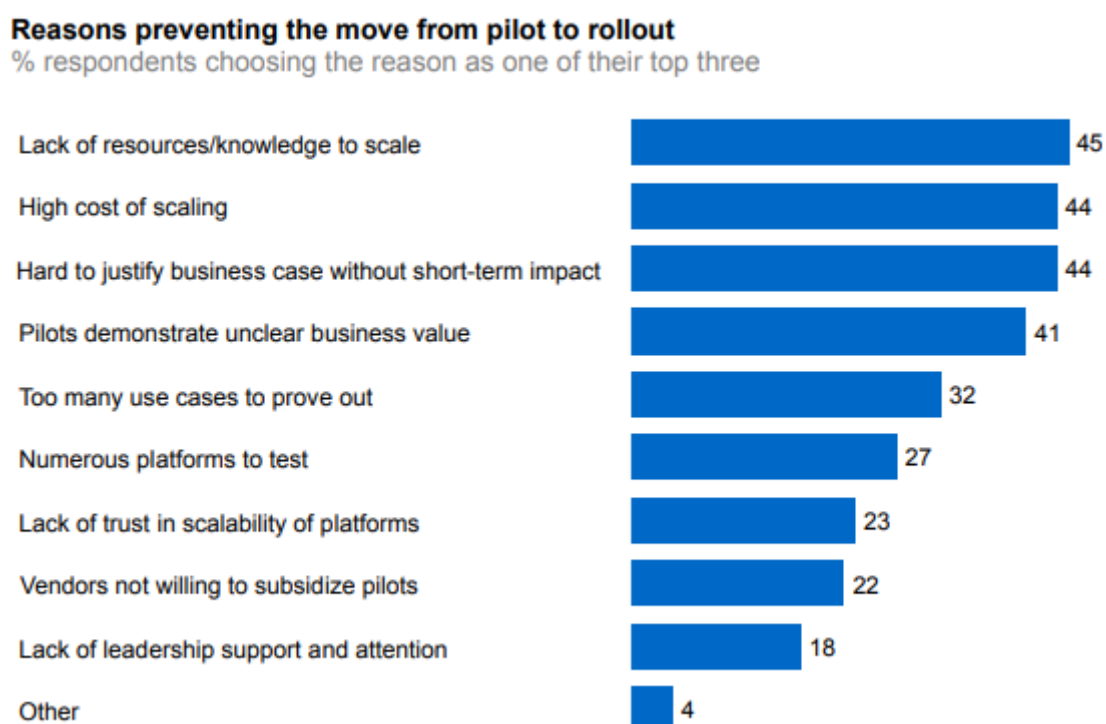
(Otanez, 2017)

The benefit of increased efficiency also leads to increased sustainability. Adopting Industry 4.0 technology such as smart lighting and systems that will optimise the businesses energy consumption will save a company money, which can then be better invested into their staff, products, and future scheduling.

Challenges

Although there are benefits, as discussed, any significant change brings about challenges, many of which are real however some may be self-imposed.

KcKinsey, as cited in the white paper from World Economic Forum (Leurent & de Boer, 2018) provides the following list of objections from a survey carried out with manufacturing leaders:



However, (Cronin, et al., 2019) argue that some of these objections are in fact myths. These are self-imposed roadblocks.

High cost:

On the challenge that Industry 4.0 technology incurs high costs, this may be true for aspects like large scale introduction of robotics into an SME that does not yet have the capacity requirements, but for connecting software packages and the Internet of Things this can be added relatively inexpensively.

This will require significant work in the beginning to implement and provide training, however, typically this type of technology makes processes more efficient, can increase quality, reduce waste and in the longer term save money. A simple business case and financial audit will be able to highlight the time required for return on investment.

Once an SME has grown large enough to require advanced robotics, the cost vs benefits can again be assessed. One factor of this is that the price of technology is continually decreasing (compared to early iterations) whilst their capabilities are increasing, and labour costs are increasing.

It is worth noting however, that a businesses cash flow must also be taken into account. There is a very real issue right now with severe supply chain shortages and longer lead times, which is causing delays to incoming cash because products cannot be shipped. This is being compounded by the increased labour costs and energy costs. Each of these are in part due to uncontrollable external factors – global pandemic and war in Ukraine. This lack of cash flow will disrupt and reduce the amount of funding that can be assigned to adopting Industry 4.0 technology.

Other authors bring to the forefront further challenges; (Firican, n.d.), for example focuses on the areas of inequality, cybersecurity risks, core industry disruptions, and ethical issues.

Inequality:

Here they state that “the largest beneficiaries tend to be the providers of intellectual and physical capital (shareholders, investors, and innovators).” They then go on to explain that there has been an increase in demand for highly skilled workers, which in turn has reduced the requirement for workers with lower skills and less education.

This has the potential to increase the gap between these types of people within a society. Especially for developing countries where there are additional technological and infrastructure challenges as well as skill challenges to try to overcome.

This challenge is echoed by Serumaga-Zake & Andrew van der Poll, who emphasise the disparity between the developed countries and those still developing, like areas of Africa. These “economies may not have the human capital, neither the financial means to investigate the opportunities of the 4IR [4th industrial revolution].” They later go on to include the risk of re-shoring of global supply chains:

“Low-cost labour is no longer an effective strategy for attracting manufacturing investment from foreign investors. The cost of automation is expected to drop through the introduction of automation, mainly owing to the resources in developed economies. They might export their assembly operations back to developed economies, thereby creating less opportunity for employment in developing African economies”

Within the inequality challenge we also have skill shortages. This has been mentioned several times, but it is a very important challenge faced by all companies wanting to expand and adapt to Industry 4.0. Companies must plan for the cost and time taken to upskill their workers. However, governments and local authorities also have a social responsibility to ensure the next generation of workers have access to the most up to date teaching within a school and higher education setting.

Here, Cronin again argues that this challenge is a myth. It is understood and accepted that robots and software will undoubtedly take on some of the roles of repetitive tasks, however it has been reported that adoption of Industry 4.0 will generate more jobs in new areas.

In the World Economic Forum report “The Future of Jobs” (World Economic Forum, 2020), Cronin summarises that although 75 million jobs could disappear across all industries and geographies, they will be replaced by 133 million new jobs that will be more attractive. These jobs will offer people

more challenging and diverse tasks, with requirements for increased creativity, communication and problem-solving skills.

However, the challenge still remains to upskill the existing work force so that those on the front line, such as factory workers and material handlers, are not left behind.

Cybersecurity risks:

A fundamental element of Industry 4.0 is the networking and connecting of multiple software and devices, this significantly increases the risk of tampering and hacking of data. One of the most recent hacks being Uber (Winder, 2022)

The increased use of big data, data analytics, and machine learning as part of Industry 4.0 mean that this challenge could be faced by all types of industry, not just the giant firms.

Core industry disruptions:

The emergence of new types of services that utilise elements for Industry 4.0 have already caused significant disruptions within different industries, which has negatively affected jobs associated with the traditional service/product. New competitors are challenging the traditional services; examples provided by Firican include Taxis vs Uber, TV & Cinema vs Netflix & Amazon Prime, as well as Hotels vs AirBnB. Traditional businesses will need to adapt and adopt Industry 4.0 technology in order to remain competitive and profitable.

Ethical issues:

Questions of morality and ethical concerns are increasing with the development of artificial intelligence, increased automation, and access to big data. Specifically on the data that companies hold of individuals, groups, or competitors, is the concern of that the data is being used for manipulation or personal gain. GDPR has gone a long way to helping relieve some of this concern, however it has not eradicated it. Firican brings up the case of Cambridge Analytica where personal data had been used for political advertising without the consent of the person.

(Cetrulo & Nuvolari, 2019) provide an additional ethical concern of micro-managing workers through constant tracking of their activities. Data collected from these individual "can potentially be used to discriminate employees according to the speed in performing a task".

Abdelmajied expands on this list to add financial constraints, and organisational nature including; "insufficient research and development procedures, a lack of infrastructure, poor data quality, a lack of digital culture, and a lack of trust among partners ... lack of management support and resistance to change".

Conclusion

In conclusion, Industry 4.0 is more than just adopting new "smart" technology, it is a new industrial paradigm that will cause significant disruptions but will ultimately provide positive transformation.

The enhanced interaction and communication between labour processes, management systems, and technology innovations will increase efficiency, productivity, create business growth, and support the necessary transition to more sustainable practices.

Businesses can look internally at vertical integration to enable effective planning, development, reduction of waste, and quick response to unexpected changes. Whilst also implementing horizontal integration with the whole value chain, to further increase flexibility and efficiency with insights from external collaborative partners or other sites.

Executing the adoption will require considerable organisational changes to their processes, structure, and boundaries. This will have impacts on the products and services they supply, their current business models, the markets they sell into, as well as their employees work environments, skill developments, and the overall economy.

The execution of adding Industry 4.0 will bring up several challenges, including costs, disruption to current operations, increased cybersecurity risks, and potential inequality. Specifically on inequality, there is the risk of losing staff through replacement of their tasks with automated systems or robotics.

However, with a well thought out business plan that includes the upskilling of current work force, the benefits can be substantial. Not only will the business see improvement of efficiency, productivity, and sustainability, but they will also open new opportunities, lower barriers, increase quality, and increase revenues.

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