MBA Thesis

Industry 4.0

An empirical study to identify the critical challenges of implementing Industry 4.0 for manufacturing firms across Germany, Nordic, and Gulf region

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The author(s) declare(s) that they have completed the thesis work independently. All external sources are cited and listed under the References section. The thesis work has not been submitted in the same or similar form to any other institution(s) as part of another examination or degree.

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Abstract

Background: Industry 4.0 refer to the industrialization wave aiming to revolutionize current traditional firms, products, manufacturing environments by means of adoption ubiquitous information and communication technologies. The thesis presents an empirical study to examine challenges of I4.0 across countries that are currently strong in manufacturing and countries that are not considered manufacturing hubs nevertheless they are nominated for fast growth of industry 4.0 due to the superior infrastructure availability. The aim of this study is to understand the differences of challenges across countries in terms of investing in I4.0 through identifying the top critical challenges in studied countries.

Objectives: Identify the key barriers and critical challenges of implementing Industry4.0 and analyze the findings to identify the difference between the selected countries/regions. The findings should give support to manufacturing firms considering establishing firms in the selected countries.

Methodology: Empirical study **t**hrough conducting closed-ended question structure. The survey questions were validated in a pilot study through experts in the field. Following the survey, the findings were validated externally to ensure the findings are generalized.

Results: Empirical analysis showed a key common barrier of implementing industry 4.0 is the excessive reliance on big data. Labor resistance was identified as a key challenge in Germany, cost was the main challenge in the Nordic region while lack of necessary digital skills was the alarming concern in the gulf region.

Conclusions: An empirical framework has been developed showing how the different challenges interplay in Germany, Nordic region, and the Gulf region.

Keywords: Industry 4.0, smart manufacturing, and Digitalization.

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1. Introduction

In the manufacturing sector, the fourth industrial revolution which is presented in the term Industry 4.0, is just a creation of a new methodology to get things done in terms of transformation to digital manufacturing instead of what could be called machine-intensive manufacturing (Oztemel et al, 2020).

Industry 4.0 (I4.0) basically is new technologies that have been recently initiated in the last decade. During the last 10 years, implementation of I4.0 has made huge progress for several sectors among others the manufacturing sector. I4.0, which is the fourth industrial revolution, has been aiming to gain value creation in several sectors; manufacturing, medical, services…etc. Lasi et al. (2014) explained the outcomes of cyber-physical systems (I4.0 general-purpose technology) which could deliver several interactions such as human-human, human-object, and object-object based on the service that I4.0 is invested for.

I4.0 is originated first in Germany to increase the benefits of the global competition for German manufacturers thanks to its characteristics that could be seen in more automation and digital-physical World connection to achieve the goal of enabling decision-making process by monitoring the assets and the processes (i-SCOOP. 2022). In other words, German manufacturers have been one of the strongest competitors in the World thanks to the privileges of implementing I4.0 which in its turn could play a very important role in managing complicated processes such as tasks that should be processed by different partners located in different locations (Kagermann et al, 2013). After the success in Germany, USA has followed and launched Smart Factories parallel with the UK's project "Smart Advanced Manufacturing" (Sony et al., 2021). All was about intelligent corporations through implementation of I4.0 technologies such as cloud computing, internet of things and cyber-physical systems since I4.0 has been aiming for a prospective smart manufacturing where machines, devices and interfaces could be combined by what is called artificial intelligence to enable software to analyze, remote control, and develop automation (Kusiak et al, 2018).

The vision for the future of the I4.0 is to enable machines and electrical-driven components to collect data and information and thereby utilize them to gain self- development, improvements, and self-upgrading as well. Future more, since the World is facing a new stage of evolution in the manufacturing industry where digitalization is taking place rapidly, connecting people, machines, devices, and equipment in the manufacturing field is going to increase efficiency, productivity and to make workplaces safer, which is an important part of the I4.0 vision.

According to many studies, intelligent manufacturing is the future target for most manufacturers throughout the World. One of the most possible enablers to achieve this intelligent manufacturing has been Industry 4.0 (I4.0) technology applications in all manufacturing processes such as production, logistics, packaging, maintenance, safety, and quality (Duman et al, 2021).

Many companies have already recognized the benefits of I4.0. For example, predictive maintenance was provided by Siemens's MindSphere to maximize machines' optimization (Cao et al, 2019).

Not only progress in the economy for manufacturing corporations have been benefited from I4.0, but also social benefits have been brought up which can be a very important part for workers whereas social challenges such as a concern of machine-human replacement can be still a point to identify. (Muller et al, 2019).

For countries, smart manufacturing that has implemented I4.0 is also an added value as it's been considered one of the important sources for the Gross Domestic Product (GDP). In their study, Lucato et al., has presented that modern manufacturing corporations in European countries have contributed up to 17% of the GDP which also has been an important factor in decreasing the unemployment rate. They have also shown that the sophisticated manufacturing sector in European countries has been the milestone for these countries to be the leader for many industries all over the World. This also can be observed in other developed countries such as the USA, where 12,5% of GDP has been contributed by smart factories (Lucato et al., 2019).

1.1. Problem discussion

With fast changing economic climate and fast shifting global industrial hubs where several countries are growing up-fast and becoming a central hub for manufacturing, it is becoming essential for firms to understand the challenges in different countries with industry 4.0. This information will be an important pillar to make a conscious decision for investment and future expansion strategies. In this thesis, we question the challenges that manufacturing firms face country-wise in implementing I4.0.

There are a lot of benefits for both manufacturing firms and countries in implementing I4.0. However, these optimistic firms may also encounter a lot of different challenges that may depend on, among others, the country or the geographical region (Sony et al., 2021). Thus, it is vital to develop a deep understanding about how countries, in terms of policy, infrastructure, technology, culture…etc., would play an important role in either facilitating or obstructing manufacturing companies to implement I4.0 technologies.

What is important for manufacturers is competing in the market. This could be achieved through new technologies to reduce cost, differentiate their products, develop products, improve connections with suppliers and customers as well. To increase their competitive positions in the market. However, it is not all about benefits!! Indeed, new technology such as I4.0 technologies have also many challenges for the implementation phase which also could differ between countries (Sony et al. 2021). This is obvious when it comes for manufacturing corporations and directors to take crucial decisions, many meetings, discussions, data collecting and analyzing, surveys…etc. will be conducted to evaluate these decisions which basically could be about strategic projects that have pros and cons.

Directors and stakeholders are not always aligned for the same investment decisions, and this can be different according to the countries in which they are doing business. Canas et al. is one of others who also has emphasized that for implementing I4.0, manufacturing organizations aim to gain benefits in several domains, where a lot of challenges, limitations, and requirements these organizations must taking into consideration (Canas et al. 2021)

Several studies have investigated the possibility of implementation of I4.0 in organizations highlighting the challenges for realizing full adaptation such as costs, technology, time … etc. (Tseng et al 2021, Masood et al, 2020). Hizam-Hanafiah et al (2020) proposed the most important dimensions for corporations to survive in I4.0; Technology, People, Strategy, Leadership, Process, and Innovation. Furthermore, some articles have addressed the readiness of specific countries in adapting industry 4.0 given the profound economic value that industry 4.0 would bring increasing productivity, revenue growth, increase of employment rate and encouraging investment potential (Kuo et al 2019, Rußmann et al 2019, Duman et al 2021).

Sony et al., has identified a gap in the literature which is the need for international manufacturing corporations to understand the different challenges of implementing I4.0 across countries in order to gain fundamentals for their strategic decisions.

1.2. Problem formulation and purpose

Our study deals with the topic of I4.0 for the manufacturing sector in the globe, and thus, it is going to be on the interplay of industry dynamics and technology. I4.0 applications basically are technologies that include artificial intelligence, cloud computing, 3D printing (digital fabrications), digital platforms, and big data. The implementation of I4.0 augments enormous benefits to organizations, thanks to the wide possibilities this latest industry revolution has enabled based on data gathering, communications, integrations, and analytics (Duman et al 2021). I4.0 technology today is the most important opportunity for industry dynamics, thanks to its results in cost saving, revenue gain, and safer and more convenient workplaces for employees. Together all these results will play a great role in upgrowing for organizations and in return huge benefits in economic growth for countries which in its turn may change today's concentration and competitiveness in the global industry field (Geissbauer et al, 2016).

The thesis is about to carry an empirical study to examine challenges of I4.0 across countries that are currently strong in manufacturing and countries that are not considered manufacturing hubs nevertheless they are nominated for fast growth of industry 4.0 due to the superior infrastructure availability. The aim of this study is to understand the differences of challenges across countries in terms of investing in I4.0 through identifying the top critical challenges in different countries. Thereby, helping directors and organizations to plan accordingly and take into consideration all risks and challenges they are going to counter before implementing I4.0. The different rankings of challenges would allow us to understand 1- which countries are more eligible to implement I4.0; 2- identify the strengths and weakness of each country/region.

The study is going to contribute to researchers, I4.0 technology users, technology developers, directors, and countries' planning strategies.

In this context, we could formulate the following research questions that could guide our study:

RQ1: What are the challenges for manufacturing organizations in implementing I4.0 in different countries/region?

RQ2: How do these challenges differ across countries/region?

RQ3: What are the critical challenges for each studied country/region?

RQ4: Why would different countries/region may have different critical challenges?

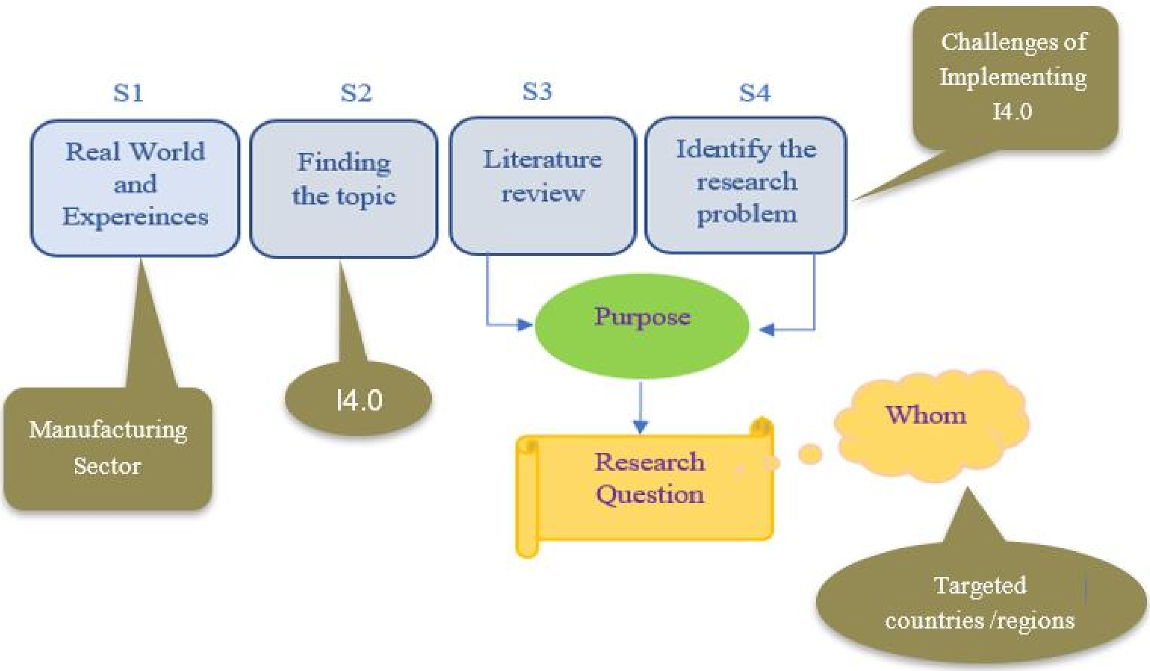


Figure 1 Problem Formulation

1.3. Delimitations

These research questions can be analyzed and approached from many perspectives:

1. Level/unit: It can be investigated on region, sector, organization, process, industry, manufacturing.
2. Empirical context/setting: Many countries/regions (Germany, Nordic, and Arabian Gulf Region), medium and large firms (more than 100 employees), all sorts of industry, private and public sectors.
3. Theoretical perspective/focus: Technology, infrastructure, culture, policy, leadership, management, skills, competitive market.

The research questions are going to be answered by an empirical study for many cases (large firms) in different countries, however the study will not take into consideration other sectors since the in-scope of this study is the manufacturing sector. Not even the differences of challenges among sectors will be answered in this study due to no gap in the literature for such a problem. The study is going to identify both benefits and challenges for both manufacturing organizations and countries, yet the answer will be only for the question of differences in challenges country-wise.

1.4. Thesis structure

After a short introduction of the thesis topic, research questions, research methodology and limitations. In chapter 2, The industry 4.0 is reviewed with fundamentally explaining industry 4.0 concept and the technology main drivers enabling the transformation of manufacturing to the new era. through the benefits of Industry 4.0 compared to conventional manufacturing for the firms and to the countries. Subsequently, challenges and barriers are reviewed to build our survey questionaries. In chapter 3, we present the method to perform an empirical study and the validation methods applied to prior of the study and the after the study to ensure the generalization of the findings. Chapter 4, the results are presented, empirically analyzed, and explaining the differences of challenges across countries. Finally, in chapter 5 we conclude the thesis and present an empirical framework.

2. Literature review

2.1. Fundamentals of Industry 4.0

Industry 4.0 is an accepted global term for the current industrialization wave that aim to revolutionize current traditional firms, products, manufacturing environments, and cities to smart ones. The smart-digital transformation is by means of adoption ubiquitous information and communication technologies. Industry 4.0 is an anticipated wave permitted by the matured 3rd industrial revolution enabled by the programmable logic control systems facilitating manufacturing automation through the application of electronics and IT (Oztemel et al, 2020). Roblek et al (2016) identified the concepts that are recognized under the fundamentals of Industry 4.0 to be:

Intelligent factories with autonomous systems, and sensors integrated in the equipment and machine, the equipment can take autonomous decisions and self-optimize to achieve a robust, intelligent, dynamic, and agile smart factory (Osterrieder et al, 2020).

Smart products with integration of microchips and sensors in the products, a communication can be established via Internet of things for products and each other and with consumers.

Cyber physical systems*(CPS*), CPS is considered to be the core of industry4.0, it lies at the cross section of digital and physical worlds, they are defined as systems with embedded software able: to connect to global network wirelessly and use global available data and services, to evaluate recorded data and interact with both digital and physical world, to record physical data and change the physical process autonomously to adapt to new conditions, to have a series of dedicated multi-modal machine-human interface (Oztemel et al, 2020).

Product and services development, Gaiaredlli et al (2021) addressed industry 4.0 impact on product and service value offering to increase level of quality and customer satisfaction. With the emerging technologies like additive manufacturing and robotics, technological advancement can permit rapid and customized prototyping for products.

Self-organization, moving toward decentralized self-organization processes change in the entire supply and manufacturing chains (Mrugalska et al, 2017).

Intelligent distribution and procurement systems, with the IOT, big data and artificial intelligence, manufacturing and retail models can evolve to adapt to human needs, instead of traditional forecasting models (Oztemel et al, 2020).

Smart City, a new model for urbanization, defined as cities that comprise several factors in the development policy such as smart environment, smart infrastructure, smart governance, smart economy, and smart mobility (Serrano et al 2018).

2.2. Industry 4.0 Technology Drivers

Implementation of Industry 4.0 systems is done through implementation of nine main drivers (Jain et al., 2020):

System integration: The main goal is to integrate all systems in operation starting from the supply chain to provide raw materials of the manufacturing process up to and including the sales to the end users. Such integration guarantees quick responses to stimuli in any division to avoid delays (Roblek et al., 2016).

The Internet of Things (IOT): Is a system of computing devices connected together digitally and physically through internet to assist in data collection and transfer with minimum interference of humans to assist in decision making regarding a specific process or even in full business models (Haddud et al., 2017).

Cybersecurity: with conventional manufacturing systems that operate offline, protecting data for an organization is practically easy. With implementation of Industry 4.0 techniques where manufacturing is directly integrated online and various means and channels of communication are continuously open, it is critical to ensure Cybersecurity measure are fully applied to protect business data (Deloite, 2019).

Cloud Computing: with access to vast computing servers, processes that were relatively expensive (either due to cost of privately owned computing or due to time required to finalize vast calculations on average computers) are now done at a much lower cost. Cloud computing does not only reduce cost of computing, but it also facilitates implementation of sophisticated process that were previously considered impractical with conventional computing capabilities (Tsohou et al., 2014).

Big Data Analytics: with improvements in sensors and data collection techniques, vast amounts of data could now be collected from the manufacturing process. Conventional processing of such big data would introduce delays and inefficiencies to the process of decision making based on the data collected. Therefore, it is necessary to utilize big data analytics techniques that could process such data quickly and efficiently (Reis et al., 2017).

Simulation: even though for current manufacturing systems, simulations are utilized to confirm the proposed system would fulfill its requirements, all these simulations are considered incomplete since it does not detect manufacturing issues. Simulation in Industry 4.0 techniques analyzes the manufacturing process virtually before physically commencing manufacturing to predict any expected issues during the manufacturing (Guizzi et al., 2019).

Additive manufacturing: with introduction of additive manufacturing, manufacturing costs have dropped significantly. Prototypes are now cheaper to manufacture without the need to utilizing special molds or fixtures. Customization is also relatively easy and cheap which assists business to be more flexible regarding its range of products (Zanoni et al., 2019).

Augmented reality (AR): although augmented reality is still in its early stage to be fully employed in Industry 4.0 manufacturing systems, it is expected that it would reduce the defects detected while manufacturing. AR is expected to provide a full virtual walk-thru of the manufacturing process starting the with raw materials provided through supply chain up to the completion of the final product. Through such virtual walk-thru, optimization of the manufacturing process and prediction of defects is expected to reduce the total cost of manufacturing and improve the quality of the final products (Mourtzis et al., 2019).

Autonomous robots: recently robots have been utilized in various manufacturing processes, however, these robots are not considered autonomous. Industry 4.0 manufacturing systems utilize autonomous robots to facilitate manufacturing. Autonomous robots are expected interact together without human interference and interact with humans if required. Autonomous robots are expected to reduce the lead time required for manufacturing and improve the quality of the final product (Cherubini et al., 2016).

2.3. Industry 4.0 Implementation Benefits

Despite the challenges, entities/governments are interested in implementing Industry 4.0 techniques in manufacturing due to the gains and benefits expected. Below is a list of gains and benefits identified through literature that encourage implementation of implementation of Industry 4.0 techniques in manufacturing (Schroeder et al., 2019):

Cost reduction: even though implementing Industry 4.0 systems requires a relatively high initial investment, on the long run many firms reached a reduction of their costs. Industry 4.0 systems ensures less lead times in many processes due to the improved communication systems and inventory management systems (Schlaepfer et al., 2015). (Zadi-Maad et al., 2018) indicates that also with improved manufacturing systems such as the adaptive manufacturing techniques, less time is required for manufacturing processes (machining and assembling). Zadi-Maad pinpoints that with additive manufacturing, less raw material is consumed since the actual part is manufactured directly without any material removal processes. Another source of cost reduction is that due to the improved manufacturing processes, quality of the manufactured products is improved and therefore, less parts are being rejected through quality control (Schroeder et al., 2019).

Regarding governments, even though cost reduction of manufactured does not have a direct impact on the country as a macro-entity, it does have some benefits. One of these benefits is that due to the reduced prices, products export is favored (Schroeder et al., 2019). Due to exporting products, currency is being pumped into the economy. Also, with the reduced prices, inflation is reduced, which is an important indicator of a healthy economy (Schroeder et al., 2019).

Quality improvement: with the advanced Industry 4.0 techniques implemented, quality of the manufactured products is expected to be improved due to various reasons. (Zanoni et al., 2019) suggests that with the advanced manufacturing techniques such as additive manufacturing, less errors are expected which yields more products conforming to standards and specifications. Even with manufacturing systems that utilize older technologies, sensors and control systems introduced assist in ensuring that quality is highly maintained (Oesterreich et al., 2016). Maintaining quality is important for firms due to different reasons. Maintaining quality ensures less rejection rates, which, on the long term, saves money to the firm (Ulewicz et al., 2019).

Ulewicz indicates that maintaining quality of products attracts customers to the product since it is considered issue free.

Like firms, governments are also interested in maintaining quality products. Maintaining quality of products influences export of products which as mentioned earlier has a direct positive impact on the economy (Schroeder et al., 2019).

Flexibility: Industry 4.0 systems ensure firms can easily maneuver through different obstacles easily. Arguments that Industry 4.0 system is expected to increase unemployment since machines/robots would replace labor is argued with the fact that due to the flexibility of the proposed system, excess labor could be trained to fulfill other tasks within the organization (Schroeder et al., 2019). Also, since manufacturing is facilitated under Industry 4.0 systems, an organization could easily utilize its manufacturing resources for different products in situations where demand for a new product increase. (Javeed et al., 2020) indicates that due to the impacts of Covid-19 pandemic, demand for hygienic masks boomed suddenly. Organizations that operated in the fabrics and clothing systems utilizing advanced technologies as per Industry 4.0 easily maneuvered their resources to penetrate the market of masks that they have never been familiar with previously.

In many countries, different incentives were provided to try to fill the gaps that have occurred when Covid-19 pandemic occurred. Governments were seeking flexible organizations to halt their operations and practice different activities. UK had listed different initiatives for organizations to design and manufacture ventilators and different life support systems (Davies et al., 2020). The pandemic clearly showed that utilizing Industry 4.0 techniques to increase flexibility of an organization is crucial.

Productivity: As mentioned earlier, utilizing Industry 4.0 mechanisms is expected to reduce overall costs and rejected products due to quality issues. With utilization of manufacturing robots and systems that require minimal human interference, manufacturing time per product is expected to drop. This yields an overall improvement in productivity (Schroeder et al., 2019). Also, Schroerder suggested that with utilization of efficient communication systems, time for resolving issues that interrupt manufacturing are expected to be resolved quicker. Another source of reduction of time necessary for manufacturing is through improved management of the supply chain. Industry 4.0 systems try to maintain stocks of raw material to avoid any delays in the manufacturing process. For these reasons, firms are interested in embracing Industry 4.0 since these would improve productivity and therefore, increase profits.

Regarding governments, improved productivity of entities operating under its legislation ensures higher export rates and ensures that no shortages of these products are expected. Both factors are favored by countries as mentioned earlier (Schroeder et al., 2019).

Quick conscious decision making with improved computational capabilities introduced by Industry 4.0, better data collection techniques are available and better data analysis. Such data analytics applied to customer data provides more information regarding customer needs and behaviors that could be utilized to improve performance of a specific product. Amazon fresh and whole foods for example are using data analytics to provide guidance of the products that require innovation and development to meet customers' expectations (Kopanakis, 2020). Another example, Pepsico, utilize data analytics for supply chain management (Tableau, 2021). Data collected from retailers and their sales is analyzed to ensure the correct amounts of inventory are being distributed to the retailers in a timely manner.

Governments tend to push firms to utilize data analytics to encourage efficient and conscious utilization of resources (Schroeder et al., 2019).

Increased Knowledge sharing and collaborative working: with the improved communication, both between humans and between machines, different manufacturing processes are no more segregated. With utilization of such advanced communication systems, firms could easily mobilize part of its facility to other locations with better business conditions. Such an example could be depicted with the fact that Apple, an American entity that previously had its manufacturing facilities located locally in the US had located its manufacturing facilities to China (Research, 2021). Due to different economic and social factors, it was found out that the cost of manufacturing Apple products offshore in China is cheaper than manufacturing it locally in the US. Therefore, Apple officials, with the help of Industry 4.0 mechanisms, could set their main manufacturing centers in China.

To improve communication, governments are investing in improving their communication infrastructure. India, for example, had large investments to improve their communication systems. Due to these investments and improvements, as of 2012, India had more than 350,000 call centers (Mattingly, 2012). Different companies found that locating their call centers remotely in India utilizing the advanced communication systems is cheaper than local call centers. This has created thousands of jobs in India and attracted foreign investments into the country.

With all the above listed benefits, it is clear why individual organizations are interested in implementing Industry 4.0 techniques. However, there are furthermore benefits that effect the economy and society. For example, to cope with technologies of Industry 4.0, new education systems are proposed that aim to prepare individuals to be able to interact with the new systems proposed. Egypt for example is providing a free scholarship, Egypt Future Work is Digital (EGFWD) to introduce different data analytics concepts to individuals. The initiative focuses on data analytics techniques before teaching individuals how to do freelancing work remotely. Personally, the initiative is supposed to provide income, but from the government's perspective, it reduces unemployment and attracts foreign currency into the country.

There have been different incentives from different governments recently that aim to encourage entities to convert to smart factories under Industry 4.0 systems (KPMG, 2019). Hungary provided $46 million incentives to Mercedes Benz Cars for building a full flex car manufacturing plant there (Group, 2018). These incentives were provided based on an investment by Mercedes of almost one billion euros. The facility is expected to create at least 2500 jobs. Another similar case occurred in 2017 when New York attracted United Technologies Corp, a global aerospace and defense company, to erect a $300 million digital research and development center against $10 million employment tax credits (Singer, 2018). Besides the funds invested, the center is expected to hire around 250 software engineers reducing unemployment in New York.

2.4. Industry 4.0 Implementation Challenges

Many challenges are identified by different entities/governments to implement Industry 4.0 techniques in manufacturing. Below is a list of challenges identified through literature that have caused issues while implementation of Industry 4.0 techniques in manufacturing (Raj et al., 4):

High initial costs for investment in Industry 4.0 systems, (Geissbaurer et al., 2014) indicates that to implement Industry 4.0 techniques, firms are expected to increase their investment capital by at least 50 % in the next 5 years to cover the costs of implementation. This is considered a large budget that many firms would not easily tolerate (Breunig et al. 2016) Also confirms through statistics that some firms prefer not to invest in implementation of Industry 4.0 techniques due to the very high initial investment required.

For governments, this has also been the case as suggested by (Dalenogare et al., 2018) in Brazil and by (Jain et al., 2020) in India. In both cases, the authors indicate that despite the fact of identifying the benefits of Industry 4.0 techniques, both countries lack the necessary resources to invest in the necessary infrastructure required to implement industry 4.0 techniques.

Cybersecurity breaches, (Deloitte, 2017) states that any device connected to the internet is considered a potential risk. A system that is highly secured utilizing up to date cybersecurity software is still vulnerable through its weakest points identified by attackers. With advancements introduced by Industry 4.0, manufacturing centers are connected to the network to facilitate communication and control of the manufacturing process. Such connectivity could introduce severe risks to the manufacturing cycle. (Zetter et al., 2014) recalls the incident known as Stuxnet malware that manipulated the speed of the centrifuges in a nuclear enrichment plant in 2009. Despite the cybersecurity systems utilized, the malware was introduced into the network through flash drives in standalones. The malware then autonomously spread itself across the system.

As for governments, in the United States, huge investments are being done to secure the country and entities from cybersecurity attacks. (US Department of Homeland Security, 2015) continuously provide updates and strategies to protect entities from cybersecurity attacks. Another cybersecurity attack in Finland had severe effect on many individuals as well as the Finnish government. Records of 25000 patient were leaked through Vastammo Psychotherapy center and used to blackmail the patients (Vastammo et al., 2020). This eventually led to bankruptcy of the center and the government had paid large amounts of money trying to capture the attackers and contain the incident.

Under-developed techniques, despite the technological advances reached in different fields, still some technological challenges exist that have not been solved yet. For example, in the field of additive manufacturing, (Zadi-Maad et al., 2017) indicates that utilization of advanced additive manufacturing for steel is still limited in size and in the type of steel utilized. Some grades of steel can't be processed using additive manufacturing since the mechanical properties of the resulting product would be slightly different from the actual raw material; this is an issue not encountered with conventional manufacturing. Another issue mentioned is that the cost of utilizing additive manufacturing for steels is relatively high when compared to other manufacturing techniques, therefore, for steels, additive manufacturing is still not economically rational. It is however expected that future technological advances are expected to resolve the issues mentioned by (Zadi-Maad et al., 2017).

Governments also face issues with under-developed technologies. (Aly et al., 2019) provides an example for such issue in Egypt with new communication technologies such as 5G systems. 5G has not been yet implemented in Egypt since this requires update of the currently installed network infrastructures. Such modifications require large investments that are not currently available to implement. Therefore, according to (Aly, 2019), Egypt is losing many different foreign investment opportunities interested in applying Industry 4.0 standards that are considered impractical in Egypt due to lack of 5G systems.

Labor resistance, with introduction of advanced technologies, reliance on robots and machines is expected to increase. According to (Schwab et al., 2017), Industry 4.0 is not expected to replace the current work force, however, it is expected to segregate the job market. It is expected that there would be only two types of jobs: low skill / low pay and high skill / high pay. (Haddud et al., 2017) however argues that the reliance on machines is expected to displace current workforce and that this is being opposed by labor to protect their source of incomes. (Ryan et al., 2017) proposes different techniques that could preserve jobs of workers, however, change of expertise is required. For that, different training must be conducted for the current workforce to introduce them to their new job requirements. This does not only introduce extra investment; it is also not favored by labor since it requires them to change their field of expertise after long years of service.

Some governments also tend to oppose full application of Industry 4.0 systems since they believe this is going to disrupt the society due to increasing unemployment rates. (Zemstov et al., 2020) states that in Russia, due to introduction of machines in the agricultural sector, less labor is being utilized. This led to internal migration from rural areas to larger cities in search for suitable jobs.

Lack of standards and/or certifications, for medium and small business, it is hard to follow the new technological trends without necessary standards and certifications to ensure the quality of the products provided as suggested by (Schroder et al., 2017). This decreases the tendency of such small or medium sized entities to update their systems to follow Industry 4.0 systems. It is preferred to continue their operations following a certified well-established methodology rather than following vague techniques that, according to them, might not be fruitful as the current methodology implemented. Also, such entities argue that they are worried of implementing some of the standards issued to impose Industry 4.0 techniques but then, due to fast technological advancements, a new standard would be issued deeming them outdated, therefore, imposing further investments to try to update their system to keep up to date with the new standards.

Ulewicz et al., (2019) implemented a study to analyze the readiness of implementing Industry 4.0 techniques in Poland and Slovakia for SMEs in the metal industry. The study reveals issues that prevent these entities to indulge in Industry 4.0 systems including lack of necessary standards and specialists to appropriately implement the necessary modifications to the current systems.

Lack of necessary infrastructure, implementation of Industry 4.0 systems requires modifications of different systems currently employed. The main modification lies within the communication layer to improve the quality and efficiency of data transfer. As stated by (Schroder et al., 2016), such modifications and updates are capital intensive. Firms could not implement industry 4.0 techniques without governments updating the necessary communication infrastructure. Also, with the new communication updates, improved cybersecurity gates have to be utilized to protect firms utilizing these systems from attacks and loss of data. (Buntz et al., 2016) conducted a survey to assess reasons why entities are not utilizing IOT systems; the results indicate that 33% believe that the current infrastructure acts as a barrier for introduction of the necessary systems for Industry 4.0.

Other studies reveal that due to the high investment cost, governments such as India (Jain et al., 2020), Poland (Ulewicz et al., 2019), Egypt (Aly et al., 2019) and Brazil (Dalenogare et al., 2018) are reluctant to implement updated 5G communication systems. This negatively affects foreign investments expected to be pumped into the countries ecosystem and it affects local entities willing to expanding their system to embrace Industry 4.0 methodologies.

Lack of necessary digital skills, to try to minimize the resistance from the current workforce, firms and entities propose providing necessary digital trainings to prepare them to accept the new change. (Muller et al., 2019) indicates some of the issues regarding digital skills training from both employers and employees' sides. Employers prefer to higher skilled workers than providing trainings to the current workforce since this is relatively cheaper and more efficient. Employers are not always confident that training would provide the necessary expertise required to fulfill the job requirements efficiently. From the other side, employees are reluctant to change their area of expertise after accruing long years of experience. Also, usually such training is provided after normal working hours, it is perceived as longer working hours for no extra payments. Also, even though they are being trained to be maintained within the entity, workers usually tend to feel unsecure regarding their jobs and salaries which causes tensions and competition between labor which negatively affects the entity.

Oesterreich et al., (2016), indicated that it is important to provide the necessary trainings to gain the fruits of the new systems implemented. An example in the construction industry in the USA, UK and Scandinavian region have introduced BIM concepts and software. The governments started teaching utilization of such systems in universities and providing necessary trainings to ensure efficient utilization of the concepts imposed.

Excessive reliance on big data, big data is currently employed to be analyzed to be able to provide necessary statistics to guide decision making. (Khan et al., 2014) indicates that despite that big data analysis is helping different entities conduct rational decisions in timely manner, there exists a group of issues regarding big data that might cause problems to entities relying on big data analysis. The main issue relies on the storage and processing of big data. Conventional computing could not provide the necessary resources for storage and processing. Entities are obliged to either invest in vast computing hardware that require large investments or utilize cloud computing systems. With cloud computing, cybersecurity issues arise which induces extra investment to secure communication systems. Another critical issue is the method of collecting the data and its reliability. Data collected might be irrelevant to the decision aimed and therefore, the data analyzed would guide decision takers to conduct an irrational decision harming their business rather than improving it.

From governmental point of view, big data also has its own issues. Governments are obliged to maintain citizens privacy while entities are trying to extract data from customers to assist in their marketing. (Perera et al., 2015) indicate concern of users of systems that invade their privacy and extract their personal information. Governments, therefore, are obliged to impose restrictions on entities harvesting such data which eventually affects the quality of decisions conducted by these entities.

Vague digital transformation strategies, with the rapid advancements in technology, firms intending to implement Industry 4.0 systems are required to continuously update and manage their transformation strategies. As suggested by (Schroder et al., 2016), despite the fact that SMEs are smaller in size and therefore, supposed to be more flexible to change, they face larger resource scarcity that eventually encounters them with larger challenges implementing frequent changes. The author indicates that senior management in SMEs are cautious regarding digital transformation and implementation of Industry 4.0 techniques which eventually slows down its effective implementation.

Geissbauer et al., (2015) indicates that in Germany, an innovative Readiness Index (IRI) has been developed by Pierro Audo Consultants (PAC). Statistics indicate most SMEs reject utilization of cloud computing techniques for various reasons including running cost and maintaining security of their systems. Through statistics, Geissbauer indicates that one of the main reasons for not embracing the digital transformation is reservations by the top management regarding Industry 4.0 methods.

Lack of coherence with other divisions or external entities, for efficient utilization of Industry 4.0, processes must be divided into smaller functions to be implemented by separate departments or even outsourced to external entities. For successful implementation of such division, effective communication and coordination is crucial as suggested by (Breuning et al., 2016). This is not always achieved due to various reasons, including, but not limited to, competitive barriers within individuals within the same entity as suggested by (Geissbauer et al., 2014), ineffective integration mechanisms between entities as suggested by (Dalenogare et al., 2018) or ineffective communication systems employed as suggested by (Majeed et al., 2017).

Based on the literature review, figure 2 is developed as a schematic summary to explain what the I4.0 technologies are, and what are the benefits and challenges of implementing Industry 4.0.

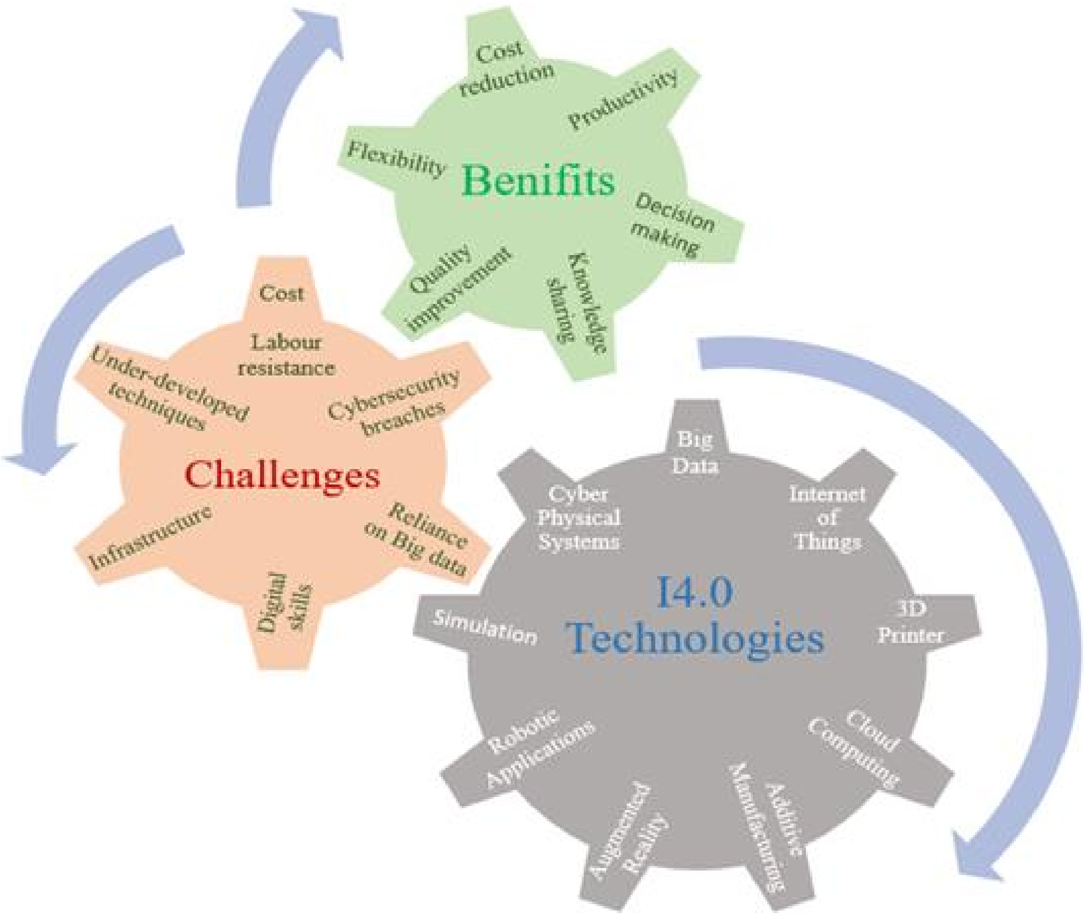


Figure 2 Benefits & Challenges of Industry 4.0 technologies

3. Methodology

3.1. Data collection

To be able to answer the research questions, we have decided to collect data through an online survey. The data will enable a quantitative analysis based on the normalized mean values of collected scores to identify the differences in critical challenges between the targeted countries/regions. Sony et al (2021) have adopted this methodology in their I4.0 research.

Since the most prevalent topic is cost efficiency to improve organizations key process indicators; the study targets engineers, managers, and directors in the manufacturing sector located in Europe and Arab Gulf region. In this context, we are expecting to gain good quality data from participants and thus be able to identify the different critical challenges between different countries.

Ball (2019) in her study "conducting online surveys", as well as Evans and Mathur (2018) in their study "the value of online surveys" have outlined a set of advantages for research that intend to conduct online surveys:

- Speed, timeless, and global reach: An online survey is conceived as a rapid method for both directions: sending the questions globally and getting them answered by participants in short period.
- Ease: Researchers can easily get in contact with participants via social media and email.
- Cost and Automation: Since the whole process (delivering and submitting) is automated, the cost then lays at the minimal level especially comparing with face-to-face interviews.
- Flexibility: This kind of survey is preferable thanks for the convenient given to participants when answering the questions, which in its turn could enable collecting large size of data.
- Low degree of social bias since respondents are free to answer the questions without any assumption that could be felt if there existed an interviewer.

There have also been some disadvantages in conducting online survey. Ball (2019) has considered lack of interviewer as a disadvantage for open-ended questions. Andrews et al

(2003) has also mentioned non-representative responses as another disadvantage in online survey where, for instance, those who for some reasons lack access to the internet. Though social media and email have been classified as advantages (Ball et al., 2019), however Alessi and Martin et al. (2010) have observed a sample bias of these communities, whereas some participants may think that sharing survey with their closest colleagues would give some help to students, but on the contrary, this could result in duplication of a specific response.

In their previous study in 2005 Evans and Mathur have developed a framework to outline both strengths and weaknesses of online surveys, see *figure 3*.

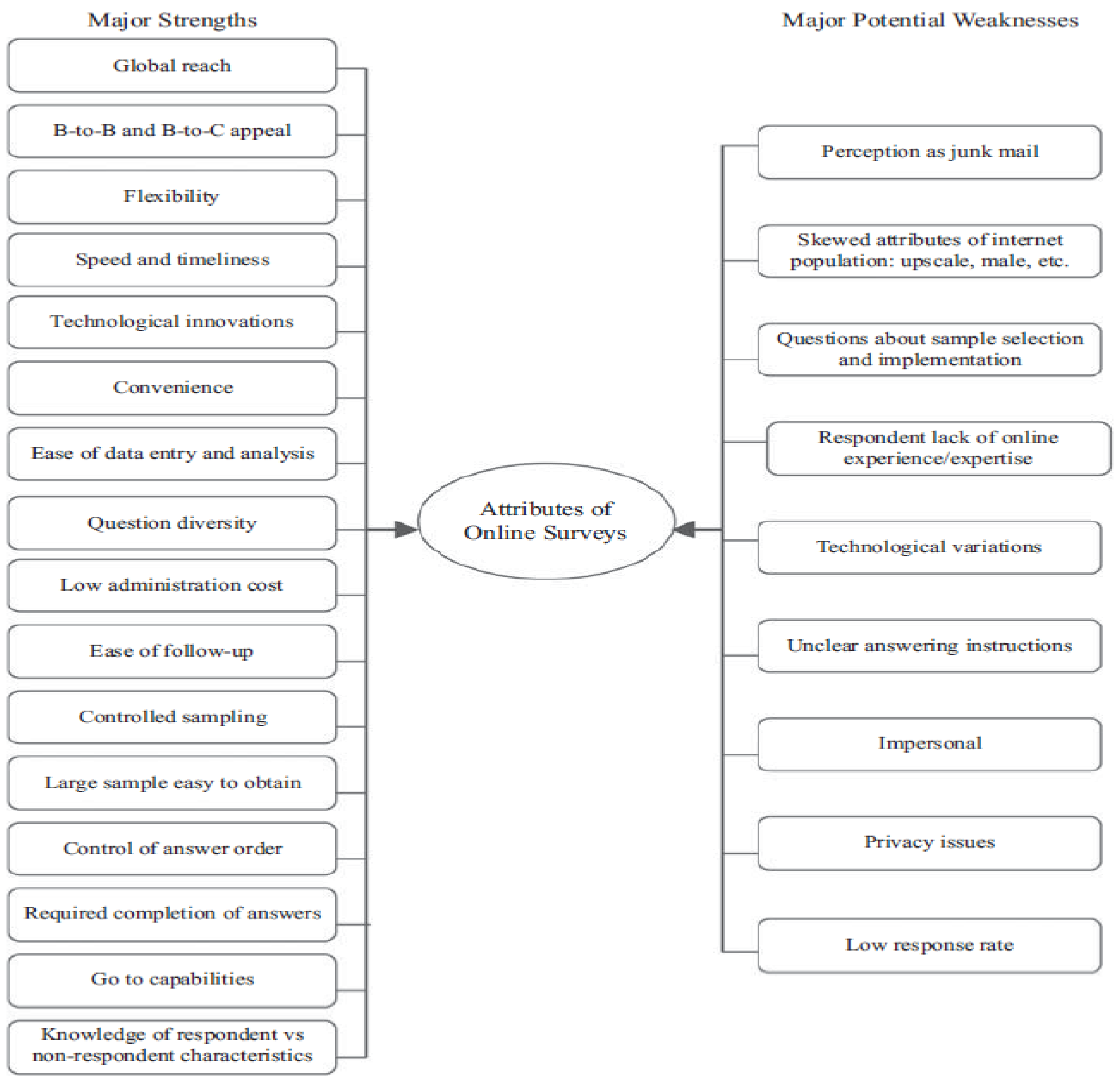


Figure 3 The strength and potential weaknesses of online surveys (Evans and Mathur, 2005)

In this context and related to the questions and the purpose of our study, as well as taking into consideration some of the recommendations presented in the study of Evans and Mathur (2018), we have:

- Established the purpose and the objectives of the survey in order to give a clear guidance.
- Clarified the type of the survey and the question format. According to Mathur (2018), scale format is one of the best for such a study.
- Been very careful about the length of the survey, otherwise there will be a risk for either bad quality data or low rate of responses.
- Decided to conduct an online survey with analyzed and compiled questions in order to gain useful inputs for this quantitative study.
- Made sure that the survey will have clear instructions.
- Insured those unnecessary questions don't exist.
- Decided to conduct a pilot survey first to help discovering any weaknesses that might be corrected.
- Taken into consideration that the estimated time for completion will be informed.

3.2. Design and Validation

Since the study aims to identify critical factors which will give an aspect of a quantitative study, so conducting closed-ended question structured survey is appropriate and could serve the purpose of the study (Sony et al., 2021). The method designed and chosen for this type of survey is five-point Likert scale which is well-known, beneficial as it is faster, easier to answer and to measure as well, and efficient since the respondents most likely to be managers don't have much free time (Leung et al., 2011). All these advantages will contribute to get a higher rate of responses that could match our expectations.

In this study, and referred to Ghauri et al., (2020), we have followed the structure in *figure 4,* which could explain the research process and design.

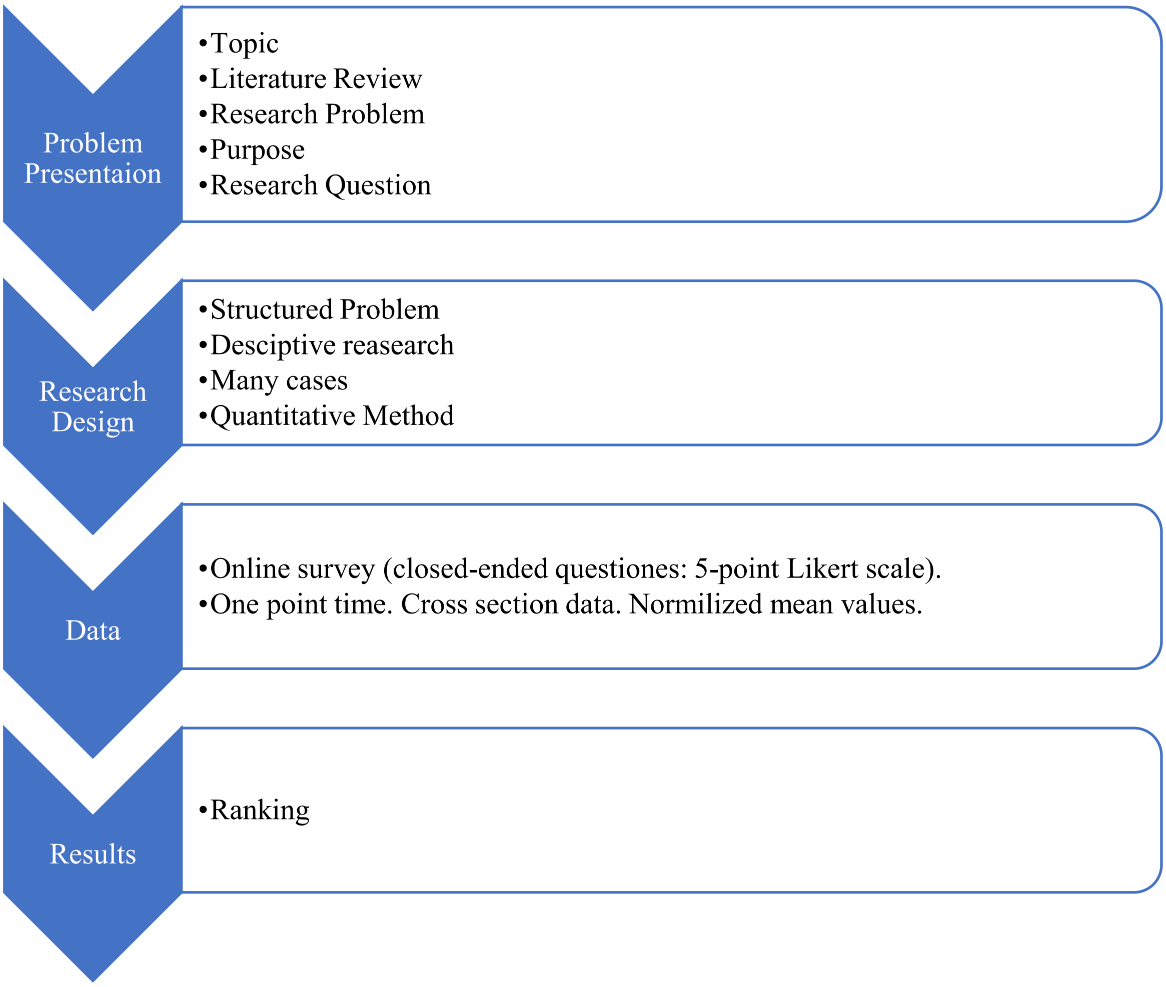


Figure 4 Research Process & Design

MS Forms, which is part of office 365, was utilized for creating the survey. It is easy to use, and it is an agile software to deliver the questions and for participants to submit the answers. However, limitation to 100 questions can be considered as a disadvantage of using MS Forms. Besides, for users there is no option to save a copy of their answers that could be useful for further investigations (Technostore360, 2021).

Wu (2007), through an empirical study supported using Likert scale instrument as a convenient approach to transform the qualitative collected data, such as opinions, into numerical scores that could serve a quantitative analysis.

Boynton and Greenhalgh (2004), assert that questionnaires may not achieve the purpose due to either low rate of responses or by collecting bad quality data. And for students to prevent such pitfalls, a validated questionnaire can be used previously.

Ball (2019), has outlined four types of validity:

1- Face validity: Questions' appearance.

2- Content validity: Are all questions and the purpose aligned.

3- Internal validity: Are the questions going to achieve the goal of the study.

4- External validity: Would generalize answers be caught?

In this context, and to make sure the data will be valid at this stage of the study (the first three types of validation), a pilot survey was conducted in the beginning and before going ahead with the final approved questionnaire. Twenty participants were targeted and selected based on their interests and their previous studies in the field of either I4.0 or research in online-survey methodology. These experts were asked to review the survey and to provide feedback and recommendations to improve the structure and questions.

The challenges are tabulated in the questionnaire and given to respondents for initial assessment. Table1, illustrates some of the most important recommendations and suggestions we have received form the participants of the pilot survey.

Referee	**Considerations, Recommendations, and Suggestions**
Referee 1: *Assistant Professor* *National University of Ireland, Galway*	1- If I were you, I would delete the comments questions. 2- Regarding the comments sections: Please do not make them compulsory as I feel it will be harder to get people to complete the survey.
Referee 2: *Assistant Professor* *Malatya Turgut Ozal University, Turkey*	1- For the questions of Cybersecurity breaches: The questions are very sharp, they can be softened a little more. 2- Questions about cyber-physical systems and internet of things technologies can be added to the questions
Referee 3: *PhD, Department of Anthropology,* *Durham University,*	1. You are asking personal information. Many people may be concerned and may not provide that information. 2. You are not asking any demographic questions. Is it relevant for your study?

Referee 4: *Senior Lecturer in Industrial Engineering, Namibia University of Science and Technology, Windhoek, Namibia.*	You use the term Industry 4.0" or i4.0. It may be a good idea to define what you mean by I4.0. your survey participants may not know what is I4.0 or may have different interpretation of the same.
Referee 5: *Prof. Dr* *University of Applied Sciences, Kufstein. Austria*	The first part of the survey should also serve as informed consent. You have to inform your participants about what to expect, what is the cost (risk, time) and what are potential benefits. To them.
Referee 6: *Professor of Business* *Hofstra University, New York*	1. The data you collect must be the one you plan to use. You are asking for comments about almost all questions. These are open ended questions and the response you get will be open ended. How do you plan to use this information? 2. Your survey should be designed so that it is specifically related to the research question you may have or the hypotheses you wish to test. I could not figure out your hypotheses or research questions from the survey. At least you should be clear in your mind about your research questions.
Referee 7: *Assistant Professor* *Blekinge Institute of Technology, Sweden*	1. The research is very ambitious 2. I am concerned about the sample of your study. It would be better off if you categorise the countries. Otherwise, how can you compare countries at different levels of development or progress.

Table 1 Recommendations from the pilot survey

3.3. Sampling and Distribution

External validity is the validity type based at which the sampling approach is selected in order to ensure the collected data would represent the entire population and thus minimizing the error (Ball et al., 2019).

Kelly et al., (2003) have identified two techniques: random sampling and non-random sampling. Non-random technique or systematic sampling is when choosing a certain set of targeted participants. Random sampling could benefit a large population with generalized results. However, it is little bit tuff with online surveys unless identifying a specific population of interest (Pol-Pons et al., 2016).

The approved valid interview was sent indirectly via the social media (random sampling with an identified population) as well as directly via direct contact such as emails or direct messages to 180 participants in the following regions:

1. Gulf countries represented in KSA, UAE, and Qatar.
2. Nordic countries represented in Sweden, Norway, Denmark, and Finland.
3. Germany.

The targeted participants have different titles such as directors, IT manager, senior manager, senior consultant, president, vice president, and CEO. To ensure good quality data would be obtained from the survey, some requirements of specific qualifications of the participants are preferred such as number of years of experience in manufacturing field, experience in I4.0, and at least a position as top managers (Antony et al., 2020).

To be efficient in gaining a high rate of responses, we have shared the survey in two ways:

1- Social media: Facebook and LinkedIn. Social media is costless; besides it is a very important source in speeding up the process of data collecting through an online survey (Ball et al., 2019).

2- Direct contact: Via emails, to get in touch with some of the targeted participants was an efficient process with good taste of incentives to gain more responses in short time, as we could better explain more about the purpose of the study and what could this study contribute to.

The survey was opened in 8 weeks. One of the challenges we faced was the war in Ukraine. The war has generated a big concern in over all the World and especially in the manufacturing sector. That has a negative impact on collecting data due to difficulties to reach managers in the manufacturing sector. Besides, I4.0 is new and not known for many which could make it difficult to receive large size of responses. However, we have received 82 responses based on which the response rate exceeded 40% which is sufficient (Saldivar et al., 2016). Besides, the sample size can be perceived as acceptable according to some previous study that had similar sample size (Sony et al., 2021) (Duman et al., 2021). Sample size and characteristics can be found in appendix A.

3.4. Data Analysis

The survey focused on Germany, Arab Gulf region (Saudi Arabia, Qatar, and United Arab Emirates) and Nordic Region (Denmark, Sweden, and Finland). The analysis method has been selected based on the goal of the study, which is identifying differences in challenges of implementing I4.0 between different countries/regions. All questionnaires have been sent at the same time to many manufacturing firms in different countries/regions, then we have intended to conduct a cross-sectional data analysis. The basic idea of the selected analysis approach is to rank the challenges based on the mean value. The critical challenges are going to be captured by using the methodology of normalizing the mean (Adabre et al., 2019). Normalizing the mean values of the different challenges will enable us to identify how critical challenges differ between among countries; when the normalized score of a challenge is above 0.5 then this challenge can be considered critical.

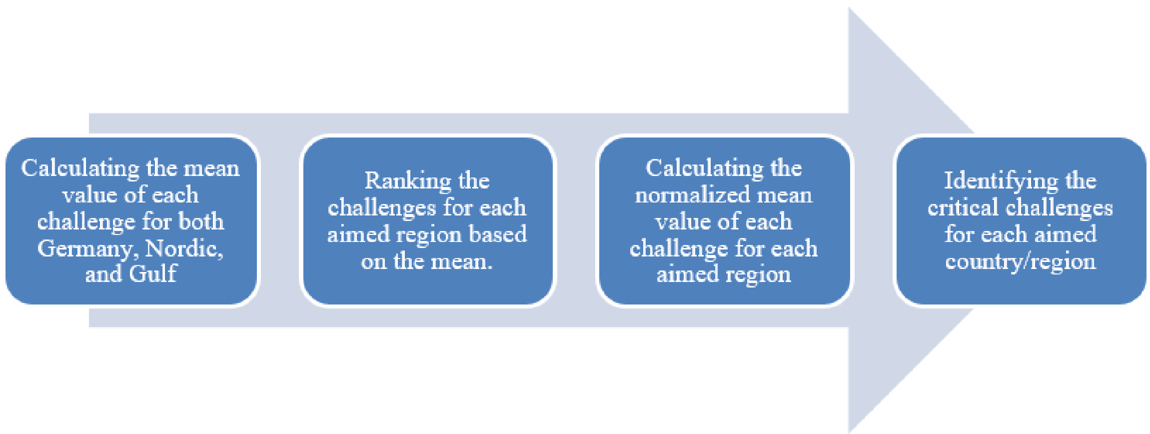


Figure 5 Analysis method implemented in our thesis

4. Findings

The aimed countries/regions in the thesis are:

Germany: Since Germany has been the leader in I4.0 over the World (Duman et al. 2021), this will enrich the study with some comparisons with other countries or regions in order to gain some understandings why these challenges either differ or are not equally critical between countries.

Nordic: Represented by Sweden, Denmark, Norway, and Finland. One of our interests of this study is to study cases from the region we are located in, in order to add value to companies we are working for.

Arabian Gulf Region or Gulf Cooperation Council Countries (GCC): Represented by KSA, UAE, and Qatar. Why GCC countries is interesting for this study? It is benefitable and valuable to gain more understanding to the companies in our original countries that we authors come from. In the Arabian region, gulf countries are the richest and most highlighted countries in terms of technologies, manufacturing, investments, and labor market.

Seven challenges have been investigated and based on the analysis of data provided by from the respondents, the challenges have been ranked based on the mean score for each studied area. To identify which challenges are critical for each studied area, normalization of mean scores was used (Alam et al., 2020). Normalization is a statistical methodology to rescale divers set of data to compare different features on a common scale (Ramzai et al., 2020). To compare challenges that have different characteristics to find the criticality levels of them for each studied country/region.

$$\text{Normalized } X = (\text{Mean} - \text{Min Mean}) / (\text{Max Mean} - \text{Min Mean}).$$

Challenge having normalized mean value above 0.5 is considered a critical challenge (Adabre et al., 2019). The normalized mean in tables 4, 5, and 6 present the ranking of challenges based on the mean score as well as criticality level of each challenge for each geographic area.

	Mean	Normalization	Rank
Cost	3,13	1,00	1
Excessive reliance on big data	2,73	0,71	2
Cybersecurity breaches	2,48	0,53	3
Lack of necessary digital skills	2,26	0,37	4
Under-developed techniques	1,99	0,17	5
Labour Resistance	1,86	0,08	6
Infrustructure required for Industry 4.0	1,75	0,00	7

Table 2 Ranking of challenges for implementing I4.0 in Nordic region

	Mean	Normalization	Rank
Excessive reliance on big data	4,21	1,00	1
Labour Resistance	3,54	0,67	2
Under-developed techniques	3,12	0,47	3
Cost	3,04	0,43	4
Cybersecurity breaches	2,75	0,29	7
Lack of necessary digital skills	2,63	0,23	6
Infrustructure required for Industry 4.0	2,15	0,00	5

Table 3 Ranking of challenges for implementing I4.0 in Germany

	Mean	Normalization	Rank
Excessive reliance on big data	3,51	1,00	1
Lack of necessary digital skills	2,73	0,50	2
Cost	2,59	0,41	3
Labor Resistance	2,32	0,24	4
Cybersecurity breaches	2,19	0,16	5
Under-developed techniques	2	0,04	6
Infrastructure required for Industry 4.0	1,94	0,00	7

Table 4 Ranking of challenges for implementing I4.0 in Gulf region

5. Validation

The collected data as mentioned above is primary data as it was collected through an online survey. The online survey has been published directly (direct contacts) as well as indirectly (social media). Ninety-four responses were received, twelve responses were excluded during the initial data filtration as the responses was outside the scope of this study, i.e., responders were not from the selected regions/countries, represent sectors other than manufacturing, as well as small firms. The remaining eighty-two responses is the target population that would represent the entire population to generalize the result of this study.

Ball (2019), has outlined four types of validity:

1- Face validity: Questions' appearance.

2- Content validity: Are all questions and the purpose aligned.

3- Internal validity: Are the questions going to achieve the goal of the study.

4- External validity: Would generalize answers be caught?

The first three types have been taking into consideration when we conducted the pilot survey. Now, in this stage of the study and after analyzing the data and getting the result, we have to move forward to the type four; External Validity, i.e., how the findings can be generalized!!

In surveys, it is impossible to catch the entire population and instead students study a sample that called the target population. To generalize the result of the study, the target population must be sufficient and can represent the entire population (Acharya et al., 2013). Two types of sampling method:

1- Nonprobability sampling: Subjective method or non-random method.
2- Probability sampling: Random selection method. To ensure that the study could be generalized. Simple random sampling is one of the classifications of probability sampling which in its turn enhancing the generalizability of our sturdy, i.e., the external validity (Acharya et al., 2013).

One of the threats of external validity is sampling bias which can be eliminated by random sampling (McEwan, 2020).

Ensuring the external validity of the study:

A- Unbiased target population:

From the survey result (see Appendix B), figures 6, 7, and 8 show that the sample has covered almost equally a wide range of industries in the manufacturing sector.

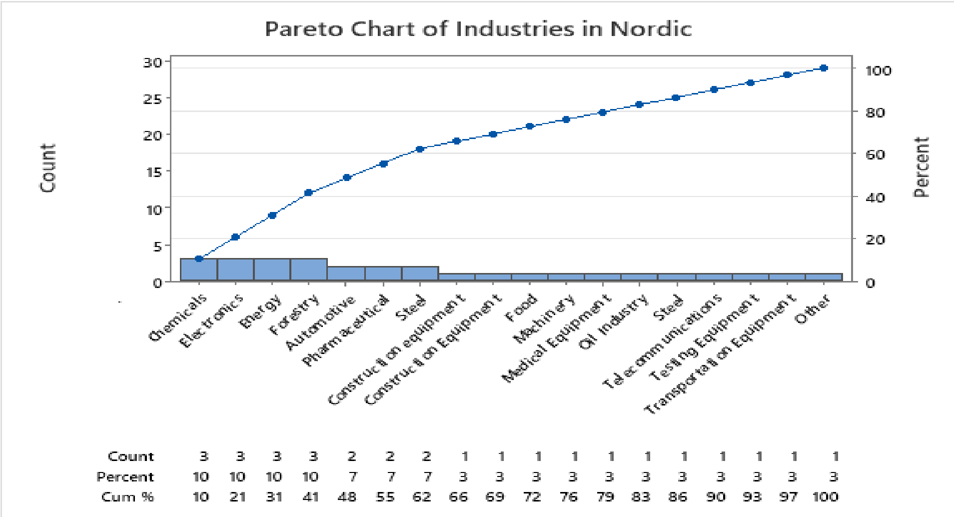


Figure 6 Industries in the Nordic

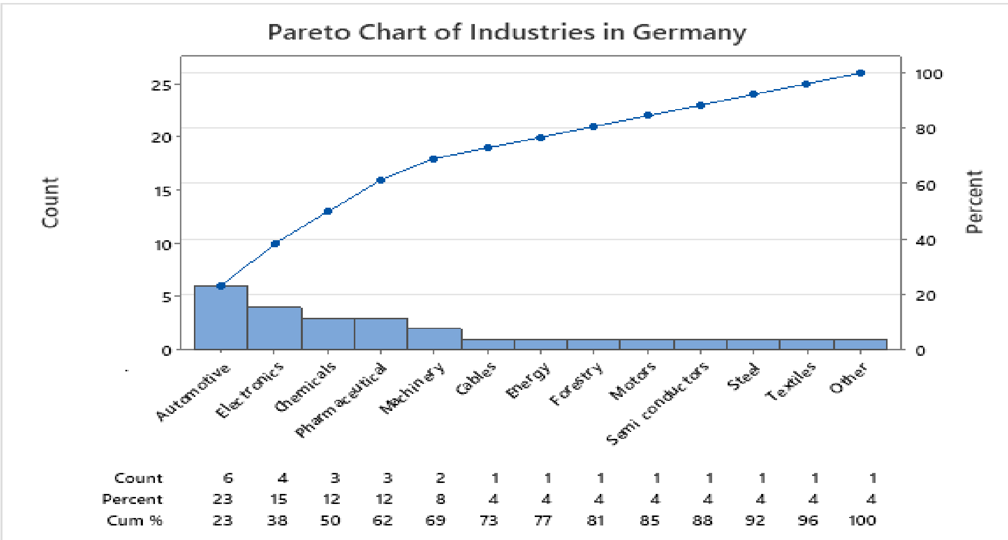


Figure 7 Industries in the Germany

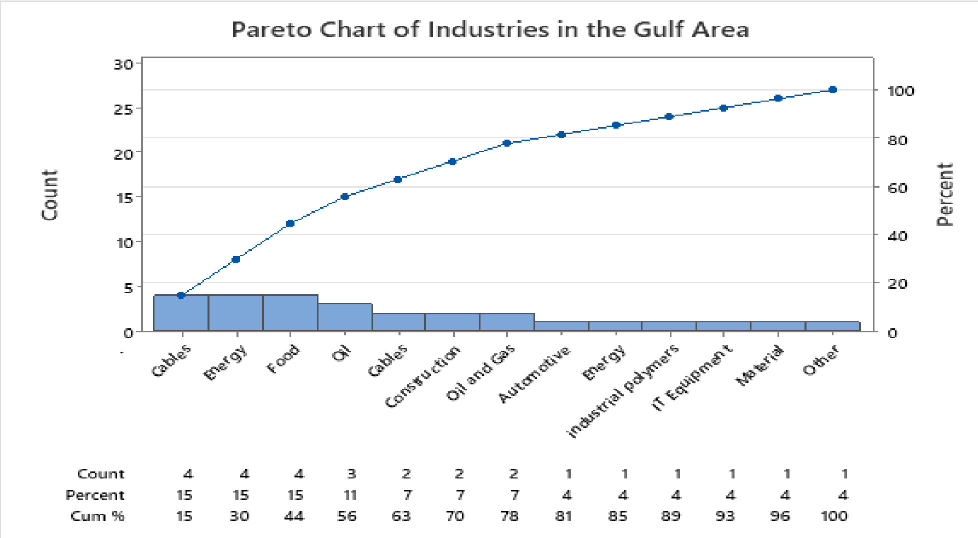


Figure 8 Industries in the Gulf Area

B- Randomness test: Runs Test is a statistical method used to determine the randomness of data sample such as data collected by an online survey and selected as a target population to represent the entire population (Bujang el at., 2018).

Hypothesis tests:

By using Runs Test in Minitab, we run hypothesis tests for data samples of the critical challenges in each region to check the randomness of the data.

Null Hypothesis	H_0: The order of the data is random
Alternative hypothesis	H_1: The order of the data is not random

When P value > 0.05 it means fail to reject H_0 i.e., the order of data is random and vice versa "when the P is low, the null must go" (McLeod et al., 2019)

Nordic

Cost, Excessive reliance on big data, and Cybersecurity breaches: The order of data collected for these three challenges has been found random.

Feeding the survey result (Appendix B) and running Runs Test in Minitab for the three critical challenges in Nordic, figures 9, 10, and 11 show P values greater than 0.05.

Runs Test: Cybersecurity in Nordic

Descriptive Statistics

		Number of Observations	
N	K	≤ K	> K
29	2,48391	14	15

K = sample mean

Test

Null hypothesis H₀: The order of the data is random
Alternative hypothesis H₁: The order of the data is not random

Number of Runs		
Observed	Expected	P-Value
13	15,48	0,347

Figure9. Runs Test for Cybersecurity in Nordic

Runs Test: big data in Nordic

Descriptive Statistics

		Number of Observations	
N	K	≤ K	> K
29	2,73276	12	17

K = sample mean

Test

Null hypothesis H₀: The order of the data is random
Alternative hypothesis H₁: The order of the data is not random

Number of Runs		
Observed	Expected	P-Value
12	15,07	0,231

Figure11. Runs Test for big data in Nordic

Runs Test: Cost in Nordic

Descriptive Statistics

		Number of Observations	
N	K	≤ K	> K
29	3,13448	15	14

K = sample mean

Test

Null hypothesis H₀: The order of the data is random
Alternative hypothesis H₁: The order of the data is not random

Number of Runs		
Observed	Expected	P-Value
18	15,48	0,340

Figure10. Runs Test for Cost in Nordic

Germany

Excessive reliance on big data and Labor resistance: The order of data collected for these two challenges has been found random.

Feeding the survey result (Appendix B) and running Runs Test in Minitab for the two critical challenges in Germany, figures 12 and 13 show P values greater than 0.05.

Runs Test: Labor resistance in Germany

Descriptive Statistics

		Number of Observations	
N	K	≤ K	> K
26	3,54359	14	12

K = sample mean

Test

Null hypothesis H₀: The order of the data is random
Alternative hypothesis H₁: The order of the data is not random

Number of Runs		
Observed	Expected	P-Value
16	13,92	0,403

Figure13. Runs Test for Labor resistance in Germany

Runs Test: big data in Germany

Descriptive Statistics

		Number of Observations	
N	K	≤ K	> K
26	4,20385	11	15

K = sample mean

Test

Null hypothesis H₀: The order of the data is random
Alternative hypothesis H₁: The order of the data is not random

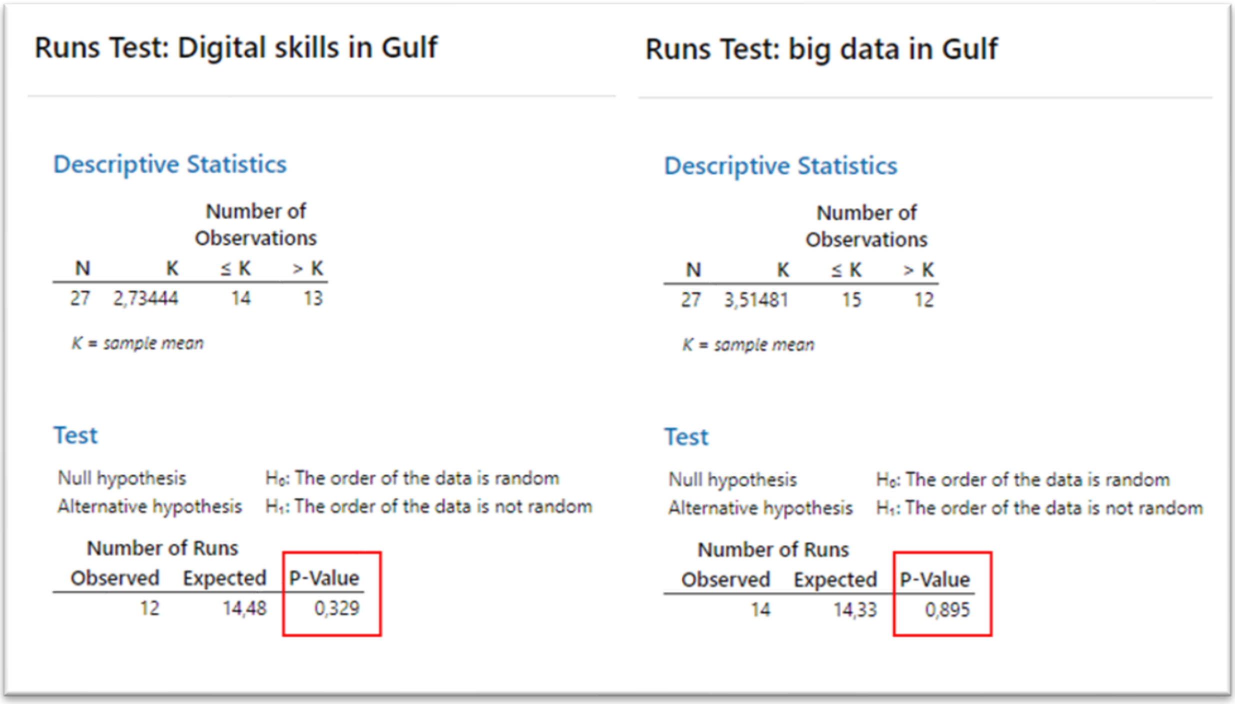
Number of Runs		
Observed	Expected	P-Value
15	13,69	0,591

Figure12. Runs Test for big data in Germany

Gulf

Excessive reliance on big data and Lack of necessary digital skills: The order of data collected for these two challenges has been found random.

Feeding the survey result (Appendix B) and running Runs Test in Minitab for the two critical challenges in the Gulf Area, figures 14 and 15 show P values greater than 0.05.



Runs Test: Digital skills in Gulf

Descriptive Statistics

		Number of Observations	
N	K	≤ K	> K
27	2,73444	14	13

K = sample mean

Test

Null hypothesis H₀: The order of the data is random
Alternative hypothesis H₁: The order of the data is not random

Number of Runs		
Observed	Expected	P-Value
12	14,48	0,329

Runs Test: big data in Gulf

Descriptive Statistics

		Number of Observations	
N	K	≤ K	> K
27	3,51481	15	12

K = sample mean

Test

Null hypothesis H₀: The order of the data is random
Alternative hypothesis H₁: The order of the data is not random

Number of Runs		
Observed	Expected	P-Value
14	14,33	0,895

Figure15. Runs Test for Digital Skills in the Gulf Area

Figure14. Runs Test for big data in the Gulf Area

6. Discussion

6.1. Critical Challenges

6.1.1. Excessive reliance on big data

Excessive reliance on big data is identified as a major challenge for Nordic, Germany, and Gulf area as demonstrated in table 4,5 and 6. Industry 4.0 is a digital evolution of manufacturing. It is the utmost importance to be able to manage efficiently and analyze the huge amount of data gathered from the emerged technologies targeted to enable industrial operation in an efficient and flexible way. The amount of information collected from Internet of things, cloud computing, cyber physical systems and artificial intelligence need to be translated into data used to draw conclusions and thus help improve companies.

The consistent availability and flow of data vertically and horizontally in and across the organization have been reported to a key challenge for SME's as they face resource constraints compared to larger firms (Schröder et al. 2016). Ahlers et al, (2015) showed that according to Innovation readiness index most medium sized firms reject to use cloud computing arising from the strategic direction decided by the senior management as they are extra cautious about adapting industry 4.0 technologies. Our findings are aligned with those reports and show that the firms are concerned with the consistency of the data processing and how that would impact the quality across different manufacturing sites. This was also identified a critical challenge by Buer et al. (2018) and khan et al. (2014).

The lack of certification standards, regulations on quality was identified as a challenge in industry 4.0 implementation. With large volume of generated data aggregated from the horizontal and vertical integration in the firm, it is becoming vital that quality management is becoming a central issue to the corporate (Zaidin et al. 2018).

Another factor that contributed to the importance of excessive reliance on big data in our findings is the role of governments need to create a solid foundation of cognitive and interactive environment for big data and governmental polices toward the enhancement of dynamic ecosystem. The European union have taken several steps in legislation and supporting industry 4.0 transformation (Jan et al. 2016). In gulf region, I4.0 is at an early phase and no government institutes have addressed the topic efficiently (Aichouni et al. 2021).

6.1.2. Cost

From tables 4, 5 and 6, the cost of implementing I4.0 in Nordic countries seems to be a critical challenge but not in Gulf area nor in Germany. Though the literature lacks information and studies regarding this topic, the respondents participated in the survey from Nordic have demonstrated a need for justifying the cost when investing in I4.0. This might be attributed to the low Gross Domestic Product (GDP).

Statistics from The World Bank show that the Gross Domestic Product in Germany in 2020 was almost twice as much as in four of the Nordic countries (Sweden, Norway, Finland, and Denmark). Even GDP in Saudi Arabia is relatively low comparing with Germany, but it is still greater than in Nordic countries separately, see figure 16 and 17. This could explain the higher ranking of the challenge "cost" in Gulf than in Germany, see tables 5 and 6.

It also might be attributed to the wage rate; Implementing I4.0 is an investment like other investments that require budget which includes labor expenses. GCC Countries have in average a lower wage rate comparing with European countries. For example, in 2018 monthly average wage in Saudi Arabia is 10238 SAR, i.e., 2457 Euro (General Authority of Statistic, 2022), while in Sweden for instance it was 34600 SEK, i.e., 3460 Euro, see figure 18 (Statista.com 2022).

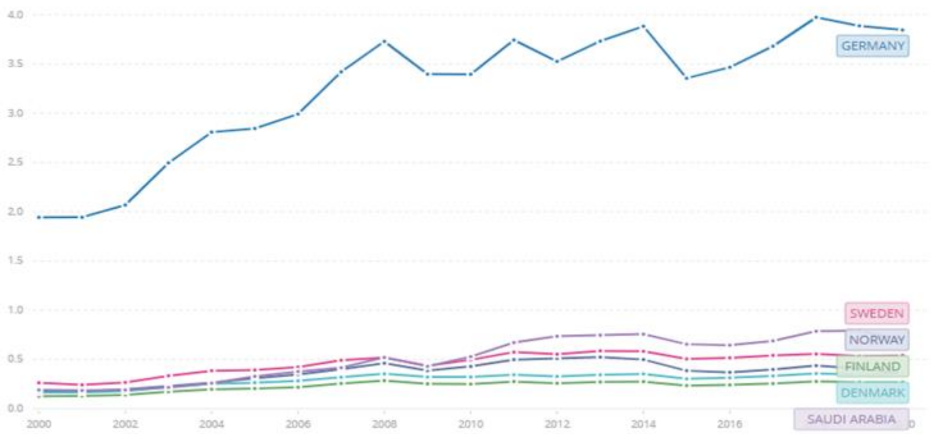


Figure 16 GDP (US$) Germany, KSA, Sweden, Norway, Finland, and Denmark. (Source The world Bank)

Country	Most Recent Year	Most Recent Value (Millions)
Denmark	2020	356,084.87
Finland	2020	269,594.83
Germany	2020	3,846,413.93
Norway	2020	362,198.32
Saudi Arabia	2020	700,117.87
Sweden	2020	541,220.06

Figure 17 GDP (US$) Year 2020 for Germany, KSA, Sweden, Norway, Finland, and Denmark (Source The world Bank)

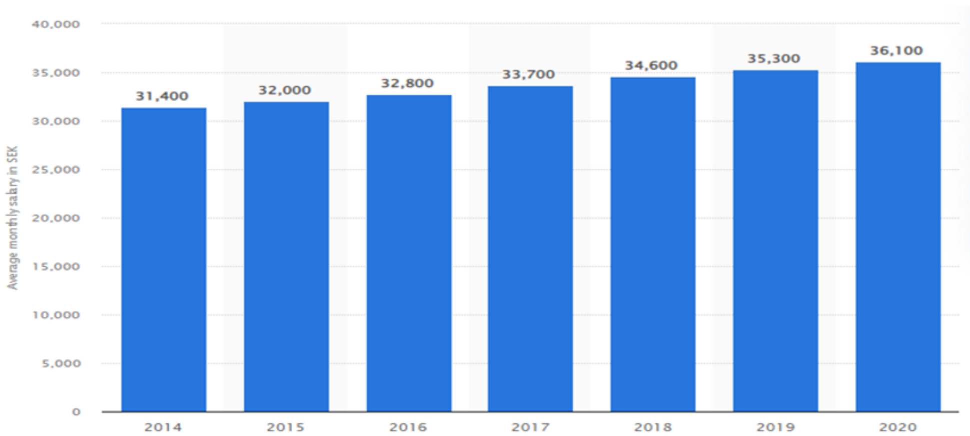


Figure 18 Average monthly salary in Sweden 2014 to 2020 in SEK (Statista.com 2022)

6.1.3. Labor resistance

According to the result of the survey, labor resistance is a critical challenge only in Germany. The survey result shows that the labor resistance in Germany can be generated from a high concern regarding three main concepts:

- Field of experience: Labors in Germany are not satisfied with changing their field of experience.
- Unemployment: There is a fear in the German society that automation will replace current labor. Thus, I4.0 applications may disrupt the society due to increasing rate of unemployment.

- Migration: I4.0 applications will lead to internal migration of workforces.
- In his study that targeted the German industry, Hirsch-Kreinsen has concluded the concern of job losses because of the fourth industrial revolution when progressive rely on digital applications takes place in the manufacturing sector (Hirsch-Kreinsen et al., 2016).

Why it is not a critical in GCC countries nor Nordic region? It could be probably attributed to the Population: Large population may generate a feeling of fear for being unemployed. The population comparing with the volume of manufacturing sector in Nordic region is relatively low which in its turn might reduce the fear of job losses due to digital technologies. However, a future study is recommended to examine cause-effect relationship between population and unemployment rate for countries that support I4.0 technologies. Figures 19 and 20 demonstrate the population in both Nordic countries and Germany. In 2020 the population in Germany was 83,16 million while it was only 27,1 million in four Nordic countries: Sweden, Denmark, Norway, and Finland. The difference in growth rate is obvious as well (Statista.com 2022).

Another factor can be workforce, migrant workers can be easily replaced and thus its resistance against new technologies such as I4.0 might be less comparing with local workforce. According to the International Labor Organization, with almost 70% proportion of migrant labor in the workforce population in the GCC countries, these countries are the largest consumer of the migrant labor market in the world (ILO et al, 2017).

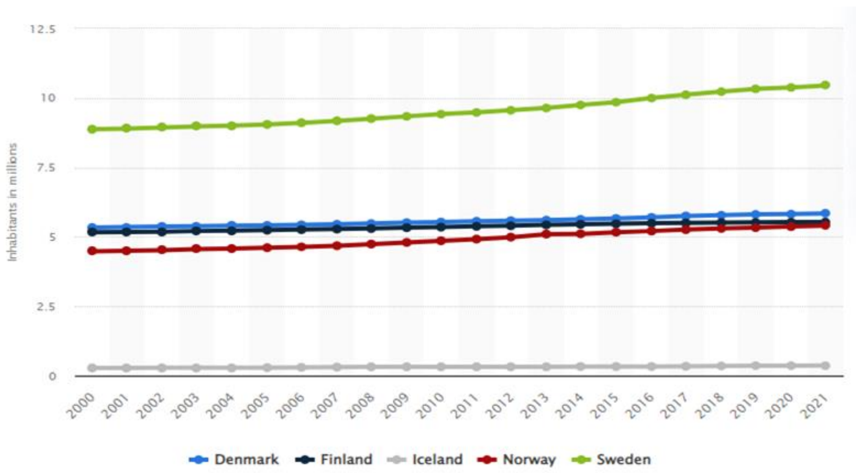


Figure 19 Population in Nordic 2000 to 2021 (Statista.com 2022)

Figure 20 Population in Germany 1990 to 2020 (Statista.com 2022)

6.1.4. Lack of necessary digital skills

The lack of digital culture and teams training on big data handling is also identified and linked to data quality as a key challenge. With excessive reliance on big data, employees need to be obtained industrial training to upgrade their skills and culture need to embrace the new way of working. Hung et al (2016) and Breunig et all (2016) reported that firm cultures are crucial and to succeed with the transformation to industry 4.0, the digital skill gap need to be filled and closed to ensure the success of the transformation.

Nico et all, (2018) have identified the emerging need for three main digital skill to be able to advance industry 4.0. Those are 1- Programming, 2- Additive manufacturing and 3- digital diagnosis. The digital analysis arises from the digital augmentation in many industries and therefore it is vital that employees need to be able to examine and respond to data provided by the machines. Additive manufacturing is revolutionizing the manufacturing landscape. The current design, engineering and management related to conventional manufacturing methods is not effective to develop 3D printing technologies (Despeisse et al, 2017). Digital coding/programing was identified in most of the industries as a pivotal skill to support the transformation. Nico et all (2018), have mapped the skill requirement for different roles and the mapping demonstrate that digital skills will be essential job requirement for operators, technicians, engineers, plant managers and all management.

In Germany and Nordic region lack digital Skills was less evident as a challenge compared to Gulf region. This can be explained due to the fact that Nordic and the German government have implemented an educational digital strategy program since 2016 aiming to enhance the Nordic and Germany digitalization process and securing a leading position in technology, quality and needed skills. (Wittmann 2020). Lack of digital skills was ranked a key challenge in the gulf area, this can be contributed to the deficient educational system and the mismatch between supply and demand and to meet critical skills needs (Muysken 2006; Nour 2013). In a recent report by McKinney, it showed that across the gulf region only 1.7% of the work force is digitally talented although the gulf countries are argued to be the most advanced in terms of digital transformation. With digital human capital shortage in gulf area, this might be a hindering challenge to advance in industry 4.0 with the current labor force.

6.1.5. Cybersecurity breaches

With an increased adoption rate for Industry 4.0 in manufacturing. A challenge of security arises making Cybersecurity become a key enabler for the transformation. Smart factories are subject to cyber terrorism through device hacking, Denial of services, malware, and vulnerability exploitation (Mullet 2021). Recently there have been several attacks targeting industrial systems, in 2017 malware targeted Schneider electronics industrial fail-safe system intended as emergency safeguard in the event of equipment malfunction (Lee et al., 2017). With industry 4.0 interconnected nature of digital systems and networks (equipment, IT system infrastructure, data, and Human), the risk of collateral sabotage and unplanned consequence is a serious concern. WannaCry cyberattack incident is a noted example of how a ransomware cyberattack cribbed the UK health system candling over 20000 medical appointments including surgeries (Ghafur et al., 2019). If firms and governments want to apply industry 4.0 infrastructure and new technologies, it is obligatory to be prepared to battle new cyber threats. Only 16% of companies are ready to face cybersecurity (Lezzi et al., 2018) identifying lack of guidelines, standard, technical, and managerial skills to implement them.

In our findings, cybersecurity breaches were identified as a major challenge in Nordic region, while it had a lower significance in Germany and gulf region. This can be explained by the findings of Gjesvik (2019) in which he shows that cybersecurity infrastructure protection in Nordic region have a low level of state involvement and less collaboration between public authorities, private companies, and civil sector. The feebleness of the Nordic defense against cyber-attack is also obvious by the frequency of cyber-attacks on the Nordic companies that occurred in 2021 compared to Germany and gulf region (Gerard et al., 2021).

In contract to Germany and the gulf region where there is an intelligence led centralized approach. In the gulf region have taken initiatives to create cyber awareness, establish technical standards to combat cybercrime through a national framework a centralized mechanism.

6.2. Non-Critical Challenges

6.2.1. Under-developed techniques

The technologies aim to transform the manufacturing business models facilitating smart factories concept, productivity, flexibility, efficiency (Ibara et al., 2018). Underdeveloped techniques were found to be a non-critical challenge in the three studied geographic areas. This finding can be explained due to the nature of the developed countries like Germany and Nordic regions where they are considered pioneers and world leaders in the different needed technologies covering Additive manufacturing, Artificial intelligence, augmented reality, cloud, global positioning systems, etc. according to the German federal statistical office, during 2021 Germany has 106 billion Euros for expenditure on research and development equivalent to 3.14% of the German GDP. The Nordic regions also assigned 18 billion Euros as funds for research and development equivalent to 3% of the Nordic region GDP. With such a huge expenditure budget, Germany has been granted 877 351 patents by the European patent office in 2021. Both Germany and some of the Nordic countries are listed in the top 10 countries that filed for international patent application in 2021 (Szmigiera et al., 2022). It is evident that Germany and Nordic regions have accessibility to the latest technologies as they develop the techniques and secure its availability through patent filing.

The gulf Arab states are a fabulously oil rich countries bringing them a lot of prosperity. In 2022, Saudi Arabia announced 6.4 billion USD investment in future tech not developing rather than purchasing and technology transfer. A noted example is the NOEM smart industrial city project that kicked off in Saudi Arabia which is the first city worldwide to be fully operated through integrated industry 4.0 technologies (Farag et al., 2019). With the economic power of the gulf state, they have the financial resource to obtain the technology from the original producers explaining why it is not a critical challenge for the gulf states.

6.2.2. Infrastructure required for Industry 4.0

According to the result of the survey, this challenge is not critical in any of the three studied geographic areas. It is even not strong challenge, see tables 4, 5, and 6.

Basically, infrastructure for I4.0 is digital infrastructure such as broadband, digital communication, networks, data center, cloud software, digital platform, and internet backbone. Digital infrastructure is fundamental and critical for implementing I4.0 since, as mentioned earlier, I4.0 is the fourth industrial revolution that mostly depend on digitalization, digital communication and transformation, and information technology (i-SCOOP. 2022).

Since the studied countries/regions are considered ones of the best countries in the World that having developed digital infrastructure, this could explain why this challenge is not critical and even very weak challenge that might not be considered as a challenge for implementing I4.0 in countries having well-developed digital infrastructure.

According to the report published in 2020 at U.S.News & world report website regarding the most developed digital infrastructure countries, the aimed countries in this study Germany, Sweden, Denmark, UAE, Norway, Finland, Qatar, and KSA occupy advanced places among 78 countries in the World and rank respectively 6, 10, 12, 14, 15, 20, 24, and 27 (U.S.News & world Report, 2020). This could explain why infrastructure required for I4.0 is not a critical challenge in these countries. Figure 21 is developed based on the report by U.S.News & world report to demonstrate the best 30 developed digital infrastructure countries in 2020.

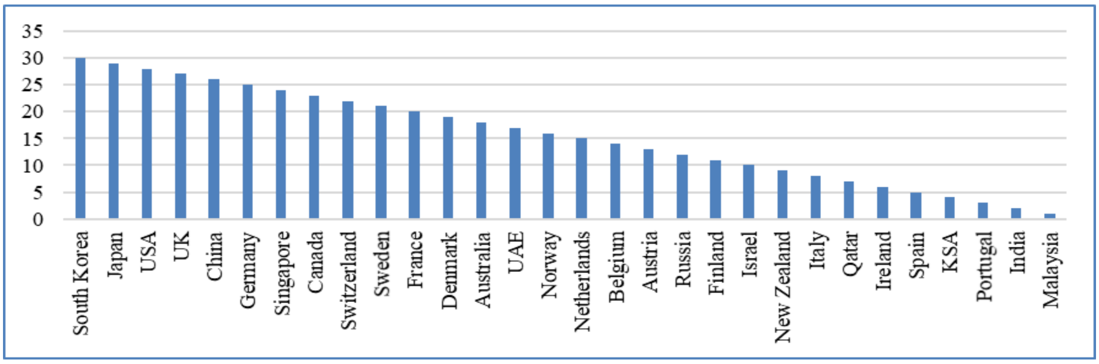


Figure 21 Ranking of Country-Level for developed digital infrastructure

7. Conclusion

From our interest point of view as well as the top relevant topics for the last decade particularly in manufacturing sector, I4.0 has been the studying topic for this thesis. Since I4.0 is an investment then it is a project that normally have risks to be considered. By reviewing the literature, lot of benefits have been approved that will be gained from implementing I4.0 no matter the geographic region. However, as risks for a project, challenges exist and can differ country-wise. Thus, identifying the problem was the first step in building the research study after specifying the topic of the study. Accordingly, we have defined four questions to be answered by this thesis:

RQ1: What are the challenges for manufacturing organizations in implementing I4.0 in different countries/region?

Answering this question has been done by reviewing the literature. Ten challenges identified by previous studies have been collected. However, seven of them were country-wise related.

RQ2: How do these challenges differ across countries/region?

Empirically, we have answered this question by conducting an online survey. the result has shown differences in ranking of the challenges among the targeted regions.

RQ3: What are the critical challenges for each studied country/region?

Through calculating the normalized mean values, we have been able to identify the critical challenges for each region; the challenge with a normalized mean value that exceeds 0,50 has been considered as a critical challenge.

RQ4: Why would different countries/region may have different critical challenges?

The result has proved differences in challenges as well as critical challenges among the studies regions. We have answered this question by first interpreting factors that could be related to each challenge and then by elaborating in the differences of these factors among the studied regions.

The goal of this study has been set to understand the differences in challenges across countries in terms of implementing I4.0 technologies in the manufacturing sector. Thus, this study will contribute helping directors and organizations to plan accordingly and take into consideration all challenges they are going to counter before implementing I4.0 in different geographic regions.

Since this study has been designed based on a cross-sectional data analysis, we suggest future works to look at the time impact on critical challenges region-wise. Besides, and since Germany has been the leader in I4.0, another suggested future study can be carried out for both benefits and challenges based on the size of the firm in Germany.

As a conclusion for the result of the study, an empirical framework has been developed. Figure 22 summarizes the result of this study; "Reliance on big data" is a common challenge for the three studied regions, while "Infrastructure required for I4.0" and "under-developed techniques" both are non-critical challenges for none of the studied regions.

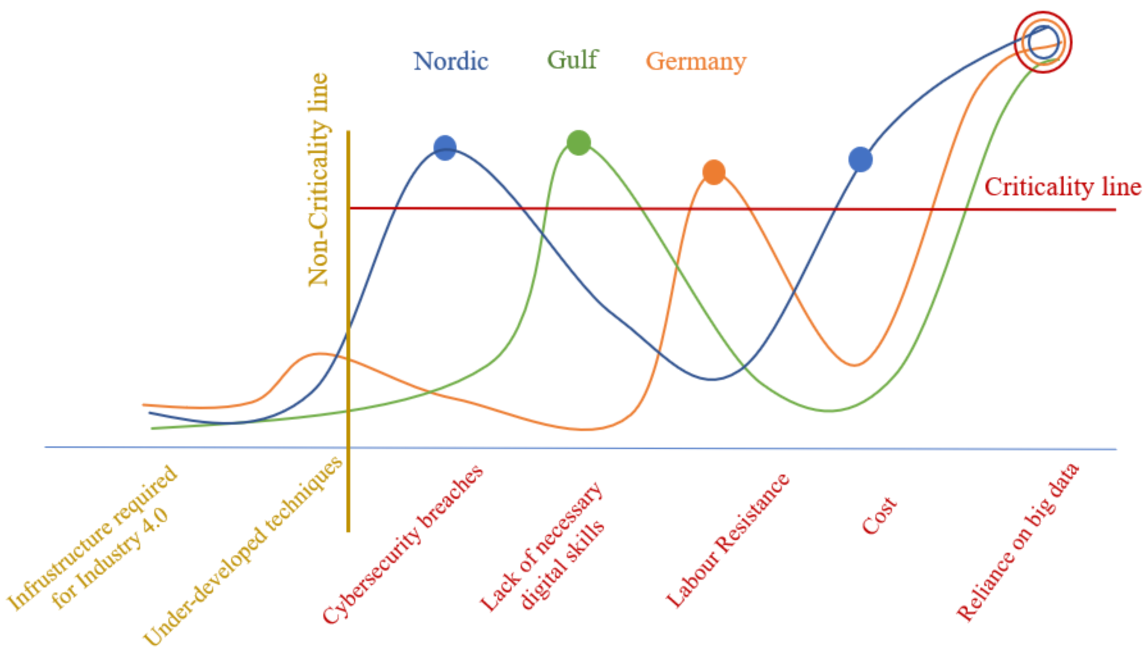


Figure 22 Empirical framework

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9. Appendix A

	Country	Type of manufacturing	Size of Organization	Level of Industry 4.0
1	Sweden	Electronics	Large	Low
2	Sweden	Steel	Medium	Low
3	Sweden	Forestry	Large	Low
4	Sweden	Construction Equipment	Large	High
5	Sweden	Automotive	Large	High
6	Sweden	Chemicals	Medium	Low
7	Sweden	Automotive	Large	Medium
8	Sweden	Pharmaceutical	Medium	Low
9	Sweden	Steel	Medium	Medium
10	Sweden	Energy	Large	Low
11	Sweden	Telecommunications	Large	High
12	Denmark	Wind turbins	Large	Low
13	Denmark	Construction Equipment	Medium	Medium
14	Denmark	Medical Equipment	Large	Medium
15	Denmark	Transportation Equipment	Large	Medium
16	Denmark	Pharmaceutical	Medium	High
17	Denmark	Electronics	Large	Medium
18	Finland	Steel	Large	Low
19	Finland	Chemicals	Medium	Low
20	Finland	Energy	Large	High
21	Finland	Machinery	Medium	Medium
22	Finland	Electronics	Large	Medium
23	Finland	Forestry	Large	Medium
24	Norway	Oil Industry	Large	Medium
25	Norway	Energy	Large	High
26	Norway	Testing Equipment	Medium	Medium
27	Norway	Food	Large	Medium
28	Norway	Forestry	Large	Medium
29	Norway	Chemicals	Large	Medium
30	Germany	Automotive	Large	High
31	Germany	Steel	Large	Medium
32	Germany	Automotive	Large	Medium
33	Germany	Semi conductors	Medium	Medium
34	Germany	Electronics	Large	High
35	Germany	Automotive	Large	High

36	Germany	Textiles	Large	High
37	Germany	Chemicals	Large	High
38	Germany	Tools	Medium	High
39	Germany	Motors	Medium	Medium
40	Germany	Pharmaceutical	Large	High
41	Germany	Automotive	Large	High
42	Germany	Forestry	Medium	Medium
43	Germany	Automotive	Large	High
44	Germany	Electronics	Medium	High
45	Germany	Chemicals	Large	Medium
46	Germany	Automotive	Large	High
47	Germany	Pharmaceutical	Large	High
48	Germany	Electronics	Large	High
49	Germany	Electronics	Large	High
50	Germany	Machinery	Large	High
51	Germany	Cables	Large	Medium
52	Germany	Chemicals	Large	High
53	Germany	Pharmaceutical	Large	High
54	Germany	Machinery		
55	Germany	Energy		
56	KSA	Cables	Medium	Medium
57	KSA	Cables	Medium	Medium
58	KSA	Food	Medium	High
59	KSA	Energy	Medium	Medium
60	KSA	Energy	Medium	Medium
61	KSA	Food	Large	Low
62	KSA	Cables	Large	Medium
63	KSA	Oil	Medium	Medium
64	KSA	Oil	Large	High
65	KSA	industrial polymers	Large	Medium
66	KSA	IT Equipment	Large	High
67	Qatar	Cables	Medium	High
68	Qatar	Energy	Large	High
69	Qatar	Food	Medium	Medium
70	Qatar	Energy	Large	Medium
71	Qatar	Construction	Large	Low
72	Qatar	Oil and Gas	Large	Medium
73	Qatar	Construction	Medium	Low
74	Qatar	Oil and Gas	Large	Low
75	Qatar	Material	Large	Medium
76	UAE	Automotive	Large	Low

77	UAE	Cables	Medium	Low
78	UAE	Cables	Large	Medium
79	UAE	Energy	Large	Medium
80	UAE	Food	Medium	Medium
81	UAE	Oil	Large	Medium
82	UAE	Oil	Large	Medium

Responses' Description

Country/Region	Responses	Average Size	Average Level of I4.0
Nordic	29	Large	Medium
Germany	26	Large	High
Gulf Area	27	Large	Medium

Respondents' sample region-wise

10. Appendix B

The survey results.

Nordic

Respondent	Cost	Cybersecurity breaches	Under-developed techniques	Labor Resistance	Infrastructure	Digital skills	Excessive reliance on big data
1	4,00	2,00	1,80	3,00	1,67	2,60	4,00
2	3,00	3,00	1,99	1,86	1,75	2,20	2,75
3	3,40	4,00	2,40	1,50	2,33	2,80	2,50
4	2,60	3,17	2,20	1,83	2,17	2,40	2,75
5	3,20	2,67	2,00	2,17	1,83	1,60	3,00
6	3,40	2,83	2,00	2,50	2,33	1,60	2,50
7	2,60	2,17	3,00	1,80	0,00	0,20	1,00
8	3,40	2,33	1,80	2,33	3,00	1,60	3,50
9	3,60	2,67	2,60	2,83	2,00	2,20	3,00
10	3,00	2,50	2,60	2,83	2,00	3,80	3,00
11	2,00	1,33	1,80	2,00	2,17	1,80	3,00
12	3,40	2,17	2,00	3,00	3,00	3,60	3,50
13	3,00	1,67	1,80	1,00	1,00	1,60	3,50
14	3,00	2,83	1,80	0,83	2,80	3,00	2,00
15	2,20	1,80	0,20	1,90	0,00	0,20	2,10
16	3,00	2,50	2,60	1,50	0,83	2,80	2,50
17	2,60	2,17	1,40	2,33	2,33	2,20	3,50
18	4,20	3,67	3,20	3,50	3,50	3,60	3,50
19	3,40	3,50	1,60	2,33	1,00	3,00	4,00
20	3,60	3,33	1,99	1,20	0,00	2,20	3,50
21	2,60	2,33	1,00	1,60	1,00	2,60	2,00
22	3,80	2,50	2,00	1,40	1,83	2,20	3,00
23	3,00	2,50	2,00	1,83	1,83	2,20	2,75
24	3,80	2,90	1,70	2,20	0,80	3,00	1,80
25	3,20	2,20	2,90	1,70	3,00	1,00	3,70
26	2,70	2,40	1,60	0,60	2,50	2,10	1,90
27	4,10	1,80	1,30	0,80	1,60	1,80	2,00
28	2,80	2,10	1,90	1,40	1,40	2,00	1,00
29	2,30	1,00	2,50	0,20	1,20	3,50	2,00

Germany

Respondent	Cost	Cybersecurity breaches	Under-developed techniques	Labor Resistance	Infrastructure	Digital skills	Excessive reliance on big data
1	3,20	4,17	3,40	3,00	3,30	2,00	5,00
2	3,20	2,50	2,60	3,00	2,50	2,40	3,25
3	2,60	3,00	2,20	3,67	3,15	3,20	3,50
4	2,80	2,00	4,00	3,83	2,50	3,20	4,70
5	4,20	3,00	3,40	3,80	2,00	3,20	5,00
6	2,20	2,50	1,75	3,17	1,67	2,60	4,10
7	3,60	2,50	3,40	3,50	1,33	2,80	3,20
8	1,60	2,00	3,40	3,50	1,50	2,80	4,80
9	3,20	2,17	3,10	3,83	1,90	2,60	4,60
10	3,00	3,70	3,20	3,33	2,10	2,00	4,50
11	2,80	3,10	2,70	3,67	1,20	2,80	3,75
12	3,20	2,50	3,00	3,50	1,80	2,00	4,50
13	2,60	3,00	3,20	3,83	2,20	2,80	4,40
14	3,00	2,10	3,40	3,50	1,80	2,40	4,20
15	3,10	2,70	3,20	3,50	1,70	2,40	4,80
16	3,60	2,20	3,00	4,00	2,30	2,20	4,50
17	2,80	2,83	3,40	3,83	1,50	2,80	4,30
18	4,00	3,30	3,20	3,50	1,60	2,80	4,20
19	3,00	2,40	3,00	3,50	1,80	2,80	5,00
20	2,50	3,60	3,10	3,67	3,60	2,20	4,50
21	3,00	3,00	2,80	3,33	3,10	2,60	3,70
22	2,80	2,37	3,30	3,67	2,60	2,80	4,60
23	3,90	2,83	3,90	2,90	2,60	3,00	3,80
24	2,40	2,60	3,80	3,20	2,90	2,90	3,00
25	3,70	2,80	2,80	3,90	1,40	2,50	2,70
26	3,10	2,70	2,90	4,00	1,80	2,70	4,70

The Gulf Area

Respondent	Cost	Cybersecurity breaches	Under-developed techniques	Labor resistance	Infrastructure	Digital skills	Excessive reliance on big data
1	2,00	2,00	1,80	1,67	2,33	3,00	4,00
2	2,60	1,67	2,00	3,00	1,33	2,00	3,00
3	1,00	3,33	1,60	2,83	2,50	2,00	5,00
4	3,20	2,83	2,20	2,00	2,83	2,20	2,75
5	1,60	1,50	1,80	2,32	1,95	2,73	3,60
6	1,80	1,50	2,00	3,00	2,00	3,00	3,00
7	3,20	2,67	1,20	1,67	1,83	2,00	3,25
8	3,00	2,50	1,60	1,50	1,50	2,40	3,00
9	2,60	2,00	1,80	2,67	1,17	2,50	3,50
10	3,80	2,83	2,20	2,00	1,83	1,80	2,50
11	2,80	2,50	1,60	1,00	1,67	1,80	2,25
12	3,20	3,83	3,80	5,00	2,50	4,00	2,50
13	2,00	2,50	1,80	3,83	1,17	3,20	3,75
14	2,20	2,00	0,80	2,00	0,67	2,40	3,00
15	3,00	2,17	1,60	1,00	2,33	1,00	4,50
16	3,40	1,00	1,80	2,50	1,67	4,00	5,00
17	3,20	1,50	1,40	2,33	1,50	1,60	3,25
18	2,20	3,17	3,60	3,67	3,50	3,60	3,75
19	2,60	2,00	3,40	1,50	1,83	4,00	3,50
20	2,20	2,33	1,80	1,50	1,67	3,20	4,50
21	1,40	1,33	1,40	1,50	2,00	2,60	4,25
22	2,20	1,83	2,60	3,00	1,83	3,40	4,25
23	3,60	1,67	2,40	3,67	2,17	3,20	3,75
24	2,60	1,50	2,00	1,67	2,00	3,40	3,75
25	3,10	2,40	2,50	2,60	2,40	3,80	2,60
26	1,70	1,20	3,00	3,10	1,80	2,80	3,40
27	3,60	3,30	0,20	0,20	2,50	2,20	3,30