



VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

FACULTY OF BUSINESS MANAGEMENT

DEPARTMENT OF BUSINESS TECHNOLOGIES AND ENTREPRENEURSHIP

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PRAMONĖS 4.0 POVEIKIO INOVACIJOMS VERTINIMAS
THE EVALUATION OF THE IMPACT OF INDUSTRY 4.0 ON
INNOVATION

Master's degree Thesis

Business Management study programme, state code 6211LX058

International Business specialisation

Business study field

Vilnius, 2022

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THE OBJECTIVES:

1. Analysis of the literature review associated with Industry 4.0, innovation, and evaluation models of countries and businesses regarding Industry 4.0;
2. Building up-to-date Industry 4.0 Index involving developed, developing and least developed countries, and finding a correlation between Industry 4.0 Index and Global Innovation Index;
3. Group and individual country evaluations to assess the impact of Industry 4.0 on innovation;
4. Development of the decision tree for governments to use while creating plans for integrated industry and innovation strategies at the government level.

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<p>This master thesis evaluates the impact of Industry 4.0 on innovation. The aim of the research is to evaluate the impact of Industry 4.0 on innovation and create a decision tree as a framework for the governments while prioritizing the directions in the policy/strategic documents. The tasks are as follows:</p> <ol style="list-style-type: none"> 1. Analysis of the literature review associated with Industry 4.0, innovation, and evaluation models of countries and businesses regarding Industry 4.0; 2. Building up-to-date Industry 4.0 Index involving developed, developing and least developed countries, and finding a correlation between Industry 4.0 Index and Global Innovation Index; 3. Group and individual country evaluations to assess the impact of Industry 4.0 on innovation; 4. Development of the decision tree for governments to use while creating plans for integrated industry and innovation strategies at the government level. <p>In general, the research consists of introduction, literature review, methodology, results and conclusions. As a result, final framework and conclusions are presented at the end of the thesis. The master thesis is 66 pages, including 17 tables, 7 figures, 76 bibliographical sources.</p>		
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**DECLARATION OF AUTHORSHIP IN
THE FINAL DEGREE PAPER**

December 21, 2021

I declare that my Final Degree Paper entitled „The Evaluation of the Impact of Industry 4.0 on Innovation“ is entirely my own work. The title was confirmed on November 12, 2020 by Faculty Dean's order No. 186vv. I have clearly signalled the presence of quoted or paraphrased material and referenced all sources.

I have acknowledged appropriately any assistance I have received by the following professionals/advisers: Doctor Eigirdas Žemaitis.

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No contribution of any other person was obtained, nor did I buy my Final Degree Paper.

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INTRODUCTION

Industry 4.0 is an actual concept that refers to the vital innovation engine bringing the next wave of innovation in a global age. It targets the acceleration of the development of machines and tools, and innovations to address the modern century's challenges thereby using the power of advanced information technologies. (Ortiz *et al.*, 2019) The goal of Industry 4.0 is to achieve better operational work efficiency, as well as a higher level of automation. It is undeniable that Industry 4.0 and its technologies have an impact on a wide range of business sectors in the changing world. The interconnection of real objects and virtual processes has grown in importance, which means that machines and manufacturing systems can run autonomously without the need for human intervention. Production in this period is based on Cyber-Physical Systems (CPS), which focus mainly on the development of intelligent machines along the value chain. It was expected that Industry 4.0 will lower the cost of logistics by 10-30%, the cost of manufacturing by 10-30%, and the cost of quality control by 10-20%. (Xu *et al.*, 2018a; Carvalho, Cazarini 2019; Özüdoğru *et al.*, 2018; Ortiz, *et al.*, 2019) IR4.0 offers big opportunities and creates conditions to inspire innovation on products and services that may need a new set of approaches. When companies transform their business models through the implementation of those emerging technologies, it generates innovations and increases competitiveness. (Deloitte 2018) In today's world, governments, businesses, and industry associations are now focusing and investing in Industry 4.0 in order to achieve industrial performance. (Rocha *et al.*, 2019). The companies which are the last ones to implement the concept of Industry 4.0 for the digital transformation will be the first to lose and leave the market (Ilic *et al.*, 2017).

Society 5.0 is a society in which developed IT technologies, artificial intelligence, robots, and augmented reality, the Internet of Things are actively used in daily life. Industry, healthcare, and other areas of activity, primarily for the benefit and convenience of each citizen, as well as for economic gain. Industry 4.0 mainly focused on developing technology to increase efficiency and productivity, but Industry 5.0 is led by growing social shifts and realities. Industry 5.0 emphasizes technology and innovation as critical components for the transition to a new industrial paradigm, production is required to respect the boundaries of our planet, and worker welfare is located at the center of the production process. (Breque *et al.*, 2021) Thus, countries will be more adaptable to changes in the economy if the core components of competitiveness are strengthened. To accomplish their goals for sustainable development and prosperity, countries are required innovative and forward-thinking leadership.

When the appropriate social, institutional, and technological elements are in place, the transition to the next step occurs. (Bal, Erkan 2019; Alekseev et al., 2019)

Problem.

Industry 4.0 implies a set of disruptive innovations in manufacturing and advances in industrial processes that result in dramatically increased productivity. These technological changes force businesses to reevaluate the innovation processes. (Carvalho, Cazarini 2019) Thus, the advanced technologies of Industry 4.0 present unlimited possibilities for the next wave of innovation, have an impact on companies' innovation processes, and bring new methods to innovation. (Leurent, Abbosh, 2019; European Union 2016) The research problem is to identify the key indicators of Industry 4.0 which have an impact on innovation.

Research object.

The object of the thesis is to assess the impact of the Fourth Industrial Revolution on innovation.

Aim of the thesis.

The aim of the research is to evaluate the underlying impact of Industry 4.0 on innovation and create a decision tree as a framework for the governments while prioritizing the directions in the policy/strategic documents. The framework will show how to migrate to Innovation 4.0 which will help us to reach Society 5.0. So that time to reach "Information Society"- Society 5.0 and Innovation 4.0 depends on the level of implementation of Industry 4.0.

Tasks:

1. Literature review associated with Industry 4.0, innovation, innovation methods/tools, innovation processes in the Industry 4.0 environment and evaluation models of countries and businesses regarding Industry 4.0;
2. Building up-to-date Industry 4.0 Index involving developed, developing and least developed countries;
3. Finding a correlation between Industry 4.0 Index and GII;
4. Group and individual country evaluations to assess the impact of Industry 4.0 on innovation;
5. Creation of the decision tree for governments to use while setting up integrated industry and innovation strategy documents.

Methods of the Research.

As a Multi Criteria Decision Making method, TOPSIS Method has been chosen to build the Industry 4.0 Index. Additionally, the correlation will be used in order to find the

strength of the relationship between Industry 4.0 and GII. Group and individual country evaluations will be done to evaluate the impact at the end.

The Structure of the Thesis.

This study is organized into four parts which include Scientific Literature, Methodology, Results, and Conclusion parts. In scientific literature, theoretical aspects of Industry 4.0 and the nature of innovation, innovation system and its elements, government support to innovation, Innovation Transformation Map, new innovation methods and tools, innovation processes in the Industry 4.0 environment, and finally evaluation models of countries and businesses regarding Industry 4.0 will be analyzed. In the methodology part, the TOPSIS method, methodology of Industry 4.0 Index including weights and measurement scales, correlation and assessment criteria for the group and individual country evaluations will be explained. The results part will demonstrate the final Industry 4.0 index, a correlation between Industry 4.0 and Innovation Indexes, and present a deep dive into the group and individual country evaluations of the impact of Industry 4.0 on innovation system and final decision tree. The last part-conclusion will show the key findings from decision tree for developed, developing and least developed countries to make the decision for strategic documents at the governmental level which suggests practical ideas and solutions.

Implementation of the research.

Governments, that are interested in automatization and improvements of processes, technological innovations, finding new approaches to innovation system and also other processes along the value chain, could implement the main findings of this research which will be investigated in the incoming part of the study.

1. Literature Review

1.1. Theoretical aspects of Industry 4.0

There are four historical stages in the Industrial Revolution. The First Industrial Revolution began with the mechanization of production facilities with the help of water and steam power in 1784. Small industrial firms and traditional family businesses have been displaced by large manufacturers. As energy resources and raw materials, the usage of steam, steel, and iron has also sped railway construction. If the First Industrial Revolution is being characterized by power generation, the Second Industrial Revolution is characterized by industrialization and called the age of electricity. It is also symbolized by mass production through electrification in the manufacturing systems along with various industries in 1870. In Cincinnati, USA, in the 1870s this era witnessed the first introduction of the assembly lines in slaughterhouses. Monorail trolleys were being utilized for the cut meat parts during the processes. The Third Industrial Revolution is considered as the automatization of production thereby usage of the electronics and ICT systems. The first programmable logic controller (PLC) has been developed in 1969. Consequently, it caused the development of international trade and industry worldwide. This third revolution introduced a new style of economic management, emphasizing a more horizontal, more adaptable negotiation in which businesses work together to accomplish a more accurate and concentrated economic activity. This revolution was well recognized for the technology used in Japan in the mid-1970s, including microelectronics, biotechnology, computer science, etc. (Ortiz, et al., 2019; Carvalho, Cazarini 2019; Özüdoğru et al., 2018)

The foundations of the previous industrial revolution are being used in Industry 4.0 and it undergoes the highest rate of digitization, virtualization, integration between production and internet, and advanced technological innovation with machines using sensors and AI. Smart manufacturing is staying the core of the new industrial revolution and aims to customize the products for customers. (Carvalho, Cazarini 2019)

In this era, our devices will be able to listen, define our needs in advance, help us in time. Another key point to remember is that we can be sure that all these significant technological changes will reach and benefit all. The new technological revolution creates a condition that will drastically shape and change the way we live, work, and interact with one another. It will be the biggest transformation and absolutely something new that human civilization did not experience before. Industry 4.0 does not only touch manufacturers, but also all of us (Schwab, 2016a; Deloitte 2017). Thus, Industry 4.0 is not only about technology-based

changes, but also it causes disruptive innovations which have an impact on main industries including health and education (Shwab 2016b; Xu et.al 2018b). According to M. Skilton and F. Hovsepian, there is some examples use of machine learning in different sectors as in Table 1:

Table 1. Examples of using Machine Learning in different sectors

The name of the area	Problem	Example implementation of Machine Learning
Call centers	Speech recognition	Automated call centers need an intelligent system to recognize a customer request and make every attempt to satisfy that request.
Financial sector	Stock trading	An intelligent agent forecasts the performance of a specific stock based on present and historical stock movement.
Retail banking	Using a cash machine	Banks seek to maintain their ATMs sufficiently loaded with cash while avoiding the two extremes (overfilled or empty).
Social Media	Face detection	This is becoming increasingly important in the world of social networking platforms and some financial organizations. This capability allows an intelligent agent to tag a person across a large number of digital pictures.
Retail	Product recommendation	Many individuals buy online every day, and businesses may save each shopper's purchase history and apply machine learning algorithms on this data to offer suggestions of things that may also be of interest to them. Amazon has had a lot of success with this type of feature on its website.
Patents Search	Patent Analytics	Documents are organized and prioritized using machine learning technologies.
Manufacturing	Identification of defect	Machine vision and ML algorithms can be used to detect manufacturing problems.
Utilities	Demand forecasting	Machine learning can assist utility companies in predicting energy consumption trends.
Education	Personalized learning	Within an eLearning environment, intelligent agent tutors can address more than 80% of a typical student's inquiries. They can explain things over and over again without losing patience with the pupil. They can also assess a student's performance and give suggestions.

Medicine	Expert diagnosis	Both IBM's Watson and Google's Deep Mind have been assisting radiologists in diagnosing potential cancer cases using x-rays, surpassing human radiologists in some situations.
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Source: Skilton & Hovsepian (2018)

Klaus Schwab has defined three clusters in order to categorize the megatrends in Industry 4.0 age. These spheres are physical, digital, and biological.

Physical- the most essential megatrends in this field are 3D printing, autonomous vehicles, robotics, and new materials. For example, 3D printing or Additive manufacturing is to build objects layer by layer from a digital master design file and allows on-demand production. (Schwab, 2016b)

3D printing technologies allow companies to co-design the products and produce customized products with increasing their value. (Dalenogare et al., 2018) Robotics means that automation is applied to more complex and diversified tasks. In terms of advanced robotics, robots had been programmed by autonomous units before, but now they are connected to clouds and have access to information remotely. (Interm report, 2016)

Digital- Nowadays, we are witnessing that there are billions of devices including smartphones, computers that are being connected to the internet. Their number is anticipated to increase to a trillion in the next years. This process will lay the foundation of changing the organization of the supply chain management that will lead to the transformation of all the industries. Some technology-based platforms enable people to create wealth through smartphones. These kinds of platform gather assets, people and data to offer new types of services. Sometimes, the question is raising that which one is more important, having a technology-enabled platform or the underlying asset placed in the core of services? According to Tom Goodwin, Uber does not have a taxi, Airbnb does not have a real estate, Facebook does not create the content itself, Alibaba does not have any inventory. However, each of them is one of the largest businesses in the world. (Schwab, 2016b)

Biological- innovations happening in the biological field are also playing an important role. Achievements in genetics are examples embodying the Fourth Industrial Revolution. During the last years, the ease of the process of gene sequencing or genome editing (gene editing) has been achieved with low cost and less time. Human Genome Project had taken 10 years and billions of dollars to complete the project however, the scientists can realize gene sequencing with less than 1000 \$ and within a few hours. Synthetic biology will allow us to modify the organisms thereby writing the DNA. These kinds of technological advancements will also be applied to the agriculture sector. Big data is playing an essential role to analyse the

histories of diseases and their treatments. For example, IBM Watson’s computers can offer personalized treatments for cancer patients through using Big Data. (Schwab, 2016b)

The fusion of the 4th Industrial Revolution

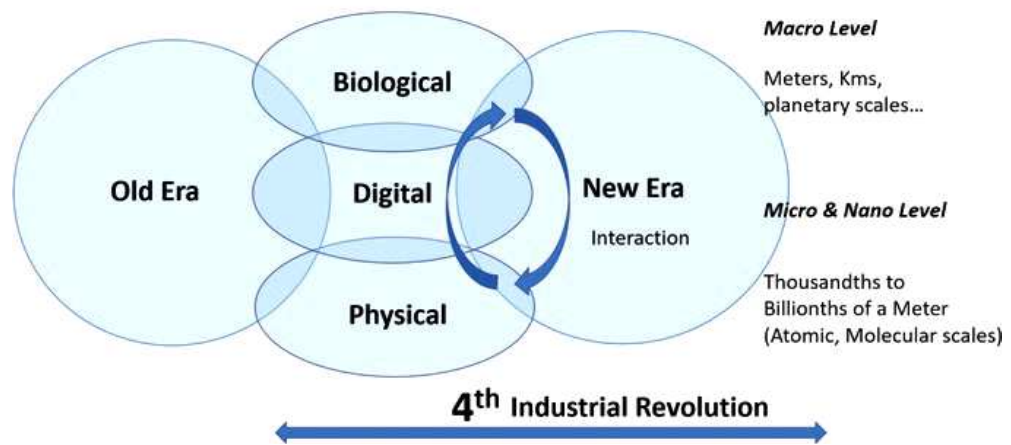


Fig. 1. The new fusion of the Industry 4.0

Source: Skilton & Hovsepian (2018)

Intelligent manufacturing systems are supposed to minimize waste, overproduction, and energy use. (H.Trollman, F. Trollman 2019) According to White Paper “Driving the Sustainability of Production Systems with Fourth Industrial Revolution Innovation” of World Economic Forum, 4IR technologies will enable to reduce Green House Gas emissions to air, improve the efficiency on water use and land use, reduce waste generations and increase the usage of renewable materials though holding circular economy principles. (Leuren, Abbosh, 2019)

Industry 4.0 has six design principles including virtualization, decentralization, interoperability, real-time capability, modularity, and service orientation. Industry 4.0 technologies are intrinsically tied to these Industry 4.0 design principles. They guarantee the innovative performance of today’s industry. (Carvalho, Cazarini 2019)

Virtualization- The capability via CPS to regulate physical processes. Physical objects are followed in a virtual environment by utilizing sensors. Simulation models are possible in this virtual environment. The concept of virtualization is that a virtual twin can be abstracted from the industry by utilizing machine-to-machine (M2M) monitoring and communication. Virtual plant models and simulation models are connected to the sensor data. It is therefore possible to build a virtual copy of the physical world. An employee can be informed in the case of a problem. People view the virtualization of Industry 4.0 as one of the most effective tools for assisting human work. By delivering, exchanging, and synthesizing information virtually, fast, and in real-time, this approach streamlines the time, analysis, and decision-making of staff

and established teams. In general, virtualization enables us to see and perform things that were previously impossible. (Carvalho, Cazarini 2019; Swisslog)

Decentralization- Devices have the ability to take a decision and complete tasks. This results in a decentralized control system, which is critical given the growing market demand for products. In industry 4.0, decentralization is defined as the increased capacity of local enterprises and particular activities, including those carried out by machines, to make the decisions independently. Rather than depending on central computers or making decisions in a hierarchical manner, allowing local operators to respond to changes and make adjustments, this concept allows for more flexibility and makes the expertise more accessible. This may be considered as a deconstruction of the traditional production hierarchy in preparation for the transformation of businesses into decentralized self-organizations. For example, the more we can decentralize intelligence in warehouse operations, the faster such systems can decide about how to best accomplish their jobs. (Carvalho, Cazarini 2019; Swisslog)

Interoperability- a crucial idea, particularly in relation to the CPS, Internet of Services and IoT concepts. Industry 4.0 cannot happen without it. It implies allowing people, machines, and devices to communicate easily with each other while exchanging data. In the industry 4.0 manufacturing environment, the idea of interoperability states that a cyber-physical system (CPS) consists of intelligent machines and intelligent storage systems and simplifies capable of automatically sharing information, starting actions, and managing each other independently. By linking software and programs, embedded manufacturing systems are vertically integrated with business processes internally to industries and horizontally with the value chain. For example, warehouse management software is playing a key role in this era and to meet the vision of Industry 4.0. Today's warehouse management systems must be adaptable, data-driven, and future-ready. (Carvalho, Cazarini 2019; Swisslog)

Real-time capability means real-time data collection and analysis in order to be able to act quickly. It claims that during the production process, intelligent machines with particular software will automatically adapt to the procedures and decision-making via CPS to the production demands, thereby monitoring product quality to make decisions at all times. This connectivity will reduce resource misuse, waste, and material waste while also increasing energy efficiency. One of the most notable elements of Industry 4.0 is the real-time capability concept, which ensures that the industry has the fastest possible response time to internal and external stimuli by exchanging, obtaining, and evaluating data and information in real-time. (Carvalho, Cazarini 2019)

Modularity means adaptability to the changing requirements and the ability to extend or alter modules. Modular systems are adaptable and advantageous, especially when product

requirements vary seasonally. Modular systems may easily adapt to changing requirements by replacing or extending specific production modules, making adding and deleting modules considerably easier. These modular systems may be easily modified in the event of seasonal variations or changes in product manufacturing demands. As a result, without mistakes, productivity loss, or customer dissatisfaction, production can always respond to environmental, systemic, and changing consumer needs. Material handling businesses must adapt to current changes while maintaining their ability to innovate and change in the future. Modular solutions give businesses the option to do so. Swisslog's AutoStore is an example of automated storage which helps to reduce the space to store inventory. If requirements change it can expand, or it can also move to a new place as well. (Carvalho, Cazarini 2019; Swisslog)

Service orientation- a result of the using internet of things to link CPS and people. Those services can be accessed through webs as service orientation can be internal or external. As a result, Industry 4.0 maintains its network performance in collaboration with all of its stakeholders, including consumers, partner industries, and suppliers, among others. Using virtual and digital platforms that are available at all times, anybody may have access to helpful services, goods, and information about the sector. (Carvalho and Cazarini, 2019)

The major features of the Fourth Industrial Revolution are characterized by vertical networking, horizontal integration, through-engineering and exponential technologies. Vertical networking is the network of the smart production systems, smart services with customized production operations. Horizontal integration is to create a new value creation network which include the integration of customers and suppliers. Through-engineering is considered for all the value chain from the production process to final product which simply means product life cycle. Sensor technologies is an example to speed up exponential technologies. (Koleva 2018; European Union 2016)

Based on the Teresa Taurino and Agostino Villa's studies, in order to involve small and medium-sized enterprises in the fourth industrial revolution, there was a special program designed in similar forms in fifteen European countries which covers three main fields as followings:

1. The availability of Big Data analytics and digital data, as well as cheap sensors and cloud computing;
 2. Robotics and advanced automation, together with human-machine interactions;
 3. Increased connection through the use of intelligent sensors (Internet of Things).
- (Taurino, Villa 2019)

Moreover, Industry 4.0 technologies and concepts are categorized into 3 groups. Group Smart factory includes Internet of Things (IoT), Internet of Services (IoS), Cyber-

Physical Systems (CPS), 3D Printing (Additive Manufacturing), automation, modularization, robotics, man-machine interaction. Group Simulation and modeling include simulation tools and models augmented reality, and virtual reality. Group digitalization and virtualization include social media, cloud computing, mobile computing, and Big Data. (Cordeiro et al., 2019)

In terms of the impact of Industry 4.0 on product development, there are three types of impact. To make existing products smarter is the first way. For example, adding new principles such as connectivity to mobile applications in order to improve its performance and user experience. Data-enabled products are the second way. For instance, businesses build digital platforms in order to manage the data. As a result, consumers are offered a product/service which gives access to data generated by smart technologies. Creating an entirely new product is the final way that embodies mass customization. (Ilic et al., 2017)

Intelligent products are also being considered as Cyber-Physical Systems (CPS) which allows businesses to extend services based on data through the integration of the internet, sensors, software. For example, as website downtimes affect business performances, sensors are warning of future errors which reduce those downtimes. It helps to improve service quality and also products. The data are being used for the optimization of the complete product lifecycle. Data coming from customers helps firms to shorten innovation cycles. (Müller & Däschle, 2018) It has also shortened product life cycles as market-demand variables and rapidly changing developments in the production system push manufacturing companies to work flexibly in order to respond to fluctuating customer needs quickly. So that only firms that can respond rapidly and cost-effectively to changing market requirements and customer choices will be able to compete in this climate. Moreover, from Industry 1.0 to Industry 4.0 production systems have changed from craft production, mass production, customization production and finally personalized production that the last one is a more reactive production system to have ability to perform in a dynamic market. (Rahman 2020)

The production of vast amounts of standardized items is known as mass production meaning that mass production is based on economies of scale. The aim is to deduct overheads in the production cost. Customization is different from personalization. Based on consumer needs, personalization is the unique identification of a product. If consumer makes a choice from a set of product options, it is a customization that is not unique. Mass customization is more efficient and gives more choices than mass production and aims to produce customized products based on individual needs. (H.Trollman, F. Trollman 2019; Akdogan, Vanli 2020)

With analyzing the wide range of product offerings accessible on today's worldwide market, it is feasible to design a product and market in such a manner that consumer

satisfaction reaches and stays at a high level for an extended period of time. (Rahman 2020; Saniuk et al, 2020) The phrase "Industry 4.0" refers to a new industrial revolution that focuses and incorporates the most recent technological advancements and assists in both fast and customized production. Mass customization is becoming more common since the arrival of Industry 4.0 meaning that mass customization refers to the capacity to offer individualized products or services in large quantities and at affordable prices using flexible procedures. Big data is large volume of data analysed in order to create new values. Big data applications should be used to identify customer preferences and upgrade current industrial settings. (H.Trollman, F. Trollman 2019; Carvalho, Cazarini 2019) Data resources and digital solutions are utilized with the goal of mass customization of products and services in order to respond to the individualized need of customers. The use of digital technologies makes it easier for businesses to operate and create new business models. (Dobrowolska, Knop 2020; H.Trollman, F. Trollman 2019; Ślusarczyk 2018)

Revenues of new smart, personalized products, and new business model innovations can lead to 25% revenue increases at the firm and industry level. (Man and Strandhagen, 2017) Increasing the production of personalized products leads to growth in sales and manufacturing. An increase in quality, elimination of loss, reduction in time and cost for maintenance regarding smart systems cause less importation and more exportation. (Bal, Erkan 2019)

The new industrial stage has the ability to totally change the way of interactions among consumers, employees, and market in order to be able to create a digital edge, where physical resources and digital information combine in new ways to produce value and money which contribute to the development of sustainable companies' performance. Another key point to remember is that digital transformation does not only mean product or process innovations but also it creates new digital business models and digital organizational and management forms and makes changes in a traditional view of entire supply chain management. (Herceg et al., 2020) In general, from a technological standpoint, the "Industry 4.0" technologies and concepts are predicted to have the greatest impact, particularly on procurement, manufacturing, and distribution operations in the supply chain. (Pfohl et al., 2015)

According to Klaus Schwab, there are four major impacts of Industry 4.0 on businesses across industries:

- consumer expectations are shifting
- products are being improved by using data, which improves productivity
- the importance of new forms of collaborations triggers forming the new types of partnership
- operating models are turning into new digital models.

The technologies including internet access, online customer services, e-commerce, e-banking, augmented reality, ERP, SCM, CRM, IoT, artificial intelligence, additive manufacturing-3D printing, and others are enabling and developing new business models and significant changes in the internal structure of organizations aiming for internationalization and performance improvement. (Garcia et al., 2020)

Additionally, Big Data is playing an important role for companies to make essential decisions for company growth. For example, these data enable a company to uncover the problems and fix them before they happen, or identify new business trends that can advance a company in the market. (Ortiz et al., 2019) Some manufacturers describe Industry 4.0 as “information to optimize products”, “providing better solutions to customers”, “using data to provide answers more quickly” and “communication and data analysis”. (Ślusarczyk 2018)

Consequently, customer needs, cost reduction, productivity, efficiency, business model innovation and competitiveness in the market are triggering to implement Industry 4.0 elements. However, it should be highlighted that if the organizational structure is supportive, business is able to benefit from Industry 4.0, if not it will lead to constraint results. (Haseeb et al., 2019) Financial issues, organizational coordination challenges and employment skills are the biggest barriers in Industry 4.0. (Herceg 2020) One of the key issues is that Industry 4.0 will accelerate the automation of tasks, which means that employees should be prepared to complete new tasks. Industry 4.0 will divide the job market into the segments “low skill/low pay” and “high skill-high pay”. Another key point to remember is that, managers should also adapt the management strategy of companies to the newly emerging market requirements. (Maresova et al., 2018; Schwab, 2016a)

Due to the increase in connected devices, the high connection required by Industry 4.0 creates a condition of more open and easily accessible systems, which has boosted the probability of new cyberattacks. (Ortiz et al., 2019) Therefore, the key challenges derived from Industry 4.0 are on the issues related to digital security and privacy. (Özüdoğru et al., 2018) Cybersecurity is to protect the information that is stored on a network or a device. The technology is capable of protecting information against attacks such as cyberattacks and even physical threats. It should be understood that no system in the world is completely safe and that there is always a risk that must be accepted. In addition to local security -cybersecurity, it is critical to discuss physical security (steel doors, safes), which is an incredibly important method that assists the user in preserving data in a data center. (Ortiz et al., 2019)

1.2. Innovation, innovation system and government support to innovation and Innovation Transformation Map

The term innovation implies a new way of doing or making things, it can occur through the use of new tangible and intangible input combinations. In general, innovation is an enhancement of existing goods or the development of entirely new goods or services, the translation of present circumstances into desired ones, to create new value for the people. The main reason why innovation is important is that innovation is the engine of rapid economic growth. There are 8 types and 3 grades of innovation. Grades of innovations are incremental, distinctive and disruptive innovations. Incremental innovation is that a few new features are included in the new product, missing in the previous one, without modifying the core feature. (Ghosh et al., 2017) The bulk of innovations falls into this group. Distinctive innovation is that while the new product has several features close to previous products, it integrates features referring to previously non-existent functions. Smartphones, modern TVs, iPods, or ATM machines can be an example of distinctive innovations. (J. Kasmire et al., 2012) Disruptive innovation is full break-up of current goods of the past. It can occur in response to the fulfillment of a certain need, or by generating a new need that has not occurred before, for instance, Internet or Facebook. (Zach, F. J et.al., 2020)

Industrial firms' radical innovation, linked with the integration of human-cobot technologies, is strongly linked with the need for stabilization in mutual collaboration. Cobots play a vital part in the performance, productivity, and efficiency of the manufacturing process. Many industrial business architects are focused on ethical workplace circumstances, with the goal of creating the "correct" collaboration atmosphere through the development of human-cobot structured workplaces. (Chromjakova 2020)

Types of innovations are product/service innovation, process innovation, organizational, marketing, pro-poor and inclusive, grassroots, frugal and social innovation. Product or service innovation is the innovation that new or dramatically enhanced goods and services in terms of their characteristics and usability are introduced to a market such as iPod. Process innovation is the implementation of new or considerably upgraded processes such as procedures in distribution, logistics or manufacturing. Organizational innovation happens where new organizational approaches are applied in foreign relations or business experience. (Polder, M. et al., 2010; United Nations, 2019).

The Fourth Industrial Revolution brings various innovations and has become vital in product and process innovation in order to produce significant productivity and competitiveness. Incremental innovations can accelerate this process in this era. It should be

noted that innovations are triggered by some factors from emerging technologies and manufacturing to new skills and leadership. (EBIT 2018)

Marketing innovation includes labels that inform consumers of their decisions and enhance supply chain performance (for instance, independently verified eco-labels, or labels that guarantee that human rights are protected in the manufacturing phase of products). Pro-poor and inclusive innovation is designed to satisfy, meet the demands or needs of the disadvantaged, injured people. Grassroots innovation attracts grassroots players such as NGOs or communities to the process of applying knowledge into sustainable development issues that are frequently identified at the local level. Frugal innovation means that products are designed or redesigned in order to cut costs with maintaining its core functions. The last type of innovation is the social innovation which aims to give social and environmental benefits. (United Nations, 2019)

According to future trends, Society 5.0 is considered more environmentally friendly; and also has a better also integration with the environment and people. In general, a more sustainable future is expected where the impact issues related to environmental, social, and economic are integrated and related to each other. (Ortiz et al., 2019)

Customer sophistication, rapidly changing market demands, modern technologies, globalization of the world, market competition, etc. trigger innovation in companies. As a result, businesses benefit from innovations, can diversify their products, can make their customer satisfied, get customer loyalty, and extend their market size in a market. Another key point to remember is that, companies should take into account that innovations have their own risks to be considered. For example, a product cannot be accepted in the market, paying much attention to the product prevent attention on marketing and quality of other existing products, the product can make the company dependent on it, and product can be unsuccessful and can result failure to enter the market. The reasons why a business fails can be originated from lack of financial resources, lack of experience in the process, lack of market understanding, etc. (IncoNet, 2014)

An innovation system is a network of organizations in the public and private sectors whose operations and relationships initiate, acquire, modify and disseminate emerging technologies. The concept of "innovation system," developed at the end of the 1980s. Over time, innovation systems are developing and co-evolving with their environment, society. Political, and economical contexts. There is no simple framework for the development and management of innovation systems that can be reproduced across countries. However, all innovation systems share common characteristics which can be divided into 3 categories: actors, connections, and framework conditions/enabling environment (United Nations, 2019).

Innovation is a process of finding smarter ways to organize productive resources to meet individual or social needs. This process is carried out by firms and other performers who communicate within knowledge networks, and through links that allow actors to learn through communication. Actors of the innovation system include firms and entrepreneurs, research and education system, intermediary organizations, consumers/users, civil society and citizens, and government. Firms and entrepreneurs have the capacity to learn, absorb, drive innovation and market and sell new knowledge and technologies via an innovative impact. They are at the center of the innovation system. They play a key role in bringing together different kinds of knowledge to introduce innovative technologies, products and services to the marketplace. They have to increase their capacity to define, accept, absorb and disseminate current knowledge and technologies. This process is not confined to research and development, interacting with suppliers, consumers are a critical process here. They need to be continually involved in learning and innovation networks and to invest in building ties with other companies and Science Technology Innovation (STI) stakeholders. Creating absorptive capacity and technical development always depends on openness to and integration of global knowledge and technology by local actors. The research and education system has the ability to study, consume and develop new applied expertise and to provide human capital to the innovation system. Researchers may provide a range of support facilities, from testing new technologies to fully realized R&D. Their ability to develop and adapt expertise to innovation processes is crucial to technology learning and the creation of a local knowledge base. Intermediate organizations have the capacity to network and collaborate and to define applicable knowledge, as well as to enhance information sharing and management capability. Consumers/users have the potential to learn, assess and adapt new technologies, change procedures and constrain structural change. Civil society and people have the potential to challenge non-inclusive and inefficient policies, shape partnerships and advocate for reform, organize and accelerate innovation and pioneer alternatives. Civil society, social enterprises, non-governmental organizations, and committed people are critical to the focus of STI policy on addressing the needs of society. Government has the ability to mediate innovation goals, guide public resources to focus areas, support capacity and linkages in the innovation system, eliminate barriers to innovation, influence the incentive system, establish and impose rules and requirements, and aim to strengthen framework conditions via government policies (United Nations, 2019).

Connections and partnerships between participants are critical element of every innovation system. Successful innovation systems provide strong and developing network links that allow companies to transfer new knowledge into innovation and improved productive

ability. Networking and Collaborative Power are the secret to encouraging technology adoption, learning and the advancement of emerging innovations. They also facilitate the flow of essential resources, including finance and human capital. Effective innovation systems stimulate national and international interactions through economic sectors, technology and research disciplines. Supply chain collaborations, including organizations that fund innovation and end users of new technologies, ensure that innovation address demand, is socially accepted and has a chance of success on the market. There are also knowledge and technology brokers and innovation intermediaries who are playing a key role in promoting sharing of information and innovation collaboration. (Lundvall et.al, 2009)

Framework conditions and an enabling environment- Successful innovation systems provide an enabling atmosphere and create favorable conditions for parties, especially companies, to participate in innovation activities. For the promotion of Industry 4.0 and innovation, a sustainable partnership model involving governmental bodies, private firms (Research and Development, Design and Testing centers), industry organizations, research and funding institutions (universities, banks) is required. (Roland Berger 2014) In general, entrepreneurs are at the center of the processes. The fundamental blocks of innovation systems include the regulatory and policy frameworks, human resources, governance and institutional setting, business environment and access to financial resources, technical and R&D infrastructure. Regulatory and policy framework should stimulate existing and new entrepreneurs to invest in knowledge and innovation and to take relevant risks. The policy framework should contain different Science Technology Innovation policy tools, which should be linked internally and externally with other essential policy spheres. Innovation policy should align with industrial, foreign direct investment (FDI), trade, education, and competition policies. Institutional setting and governance include the norms in society (including non-written social and cultural norms), legal rules and standards, as well as the organizational setting and governance mechanisms establish, regulate and execute it. Organizations established to provide assistance to companies are especially important in the development of knowledge and the accumulation of technical capacity. Business environment and access to financial resources are key factors to incentivize businesses to be innovative companies and continue in this way. Not only financing of innovative projects is enough, but also policy frameworks and organizational capacity are big deal. Firms and businesses have to improve their management competencies in order to establish reliable strategic plans and evaluate the risks of their programs. Organizations such as banks, government agencies, investors, which finance innovations for sustainable development, should align their tools and instruments to facilitate the processes regarding financing. Human capital allows adopting the most recent

technologies and to conduct innovation processes. The development of human resources depends on all levels of education, the skills such as technical and managerial skills involved in various innovation activities from research and development, engineering, design to networking. With new technologies adopting, some skills become important. Technical and R&D infrastructure means technical infrastructure such as Information Communication Technologies, energy, water, transport and urban, infrastructure for R&D and innovation processes namely laboratories, testing and etc., and existing technologies. (United Nations, 2019)

One of the essentials in an innovation system is how government supports the innovation in a country. There are regulatory frameworks, economic and fiscal instruments, education, innovation strategies, trade policy, etc. All these tools are explained in Table 2 below: (Miedzinski, et.al, 2017)

Table 2. Policy instruments of government support to innovation

POLICY INSTRUMENTS		THE FORM OF GOVERNMENT SUPPORT TO INNOVATION
REGULATORY FRAMEWORK	Regulations on environmental and health security	Government incentivizes companies to align processes to regulatory frameworks through innovation, for example substitution of dangerous chemical and define certain fines and penalties for free-riders.
	Standardization of the product and industrial operation	Government incentivizes companies to align processes to regulatory frameworks through innovation for social and environmental performance standards of products and processes.
	Customer protection, labeling and certification	Government provides information regarding social and environmental performance of products and services in order to promote innovative products and processes.
	Intellectual property rights	Government protects companies and firms regarding their knowledge and creates a condition to have an access to knowledge and technologies.
	Competition Law	Government prevents the creation of monopolies that can inhibits innovation and its benefits for customers or the environment
	Bankruptcy Law	Government enables by protecting business atmosphere, investors, companies and customers against some of the negative effects of failure.
ECONOMIC INSTRUMENT	Funding R&D	Government finances companies and institutions for research and development.
	Funding companies for innovation	Government supports companies by providing financial resources.
	Subsiding companies for tariffs and other similar reasons	Government ensures financing for companies in order to adopt specific technologies.

	Tradable permission schemes	Government sells emission rights causing the increase of costs for polluters in order to promote the reduction of emission for innovation.
	Removal of grants for unsustainable activities	Government removes some subsidies such as subsidies for fossil fuels.
FISCAL INSTRUMENT	Tax incentives for companies and technology adopters	Government supports innovations by applying tax incentives for R&D activities and adoption of innovations
	Removal of tax subsidies for unsustainable activities	Government can abolish tax subsidies for some issues as fossil fuels to promote the innovation.
EDUCATION & TRAINING	Staff mobility	Government supports sharing of knowledge, connections between participants of innovations system.
INNOVATION STRATEGIES	Tech and science parks	Government incentivizes smart specialization in innovation and technology.
	Networks and technology platforms	Government facilitates exchange of information and knowledge relates to innovation.
	Strategic roadmaps and technology insights	Government creates vision in investment and development of innovation environment in innovation system of a country.
TRADE POLICY	Trade tariffs	Government removes barriers for the sale of innovative goods and services.
DEVELOPMENT OF CAPACITY AND INFORMATION PROVISION	Business consultations	Government promotes relevant knowledge and skills.
	Promotion of local entrepreneurship	Government encourages local businesses and innovations.
	Technological transformation	Government helps adoption of specific technologies tackling some challenges.
	Capacity building for government	Government develop its capacity in order to be able to coordinate, implement, assess its relevant policies in the field of innovation.
	Market intelligence services	Government enables exchanging of knowledge, experience, information and data in innovation trends.
INFORMATION INSTRUMENTS	Raising awareness	Government conducts raising awareness campaigns to make stakeholders aware about science, technology and innovation trends to improve its relevant policy in future.
	Creation of networking	Government aids for knowledge sharing through an organization of Start-up weekends, etc.
	Events for innovation/virtual and material infrastructures	For example, transformation labs, online hackathons, etc.

Source: Miedzinski, et.al, (2017)

Basically, innovation enables most of the world's long-term productivity and economic development, and creative companies are dramatically outperforming non-innovators in terms of both job creation and revenues. Figure 2 demonstrates that the innovation transformation map has 5 key issues- innovation system, government innovation, business model innovation, technological innovation, innovation for a social benefit that are strategically important. These all key essentials have also their own sub-categories that there are unbreakable links between each other. (World Economic Forum, 2021)

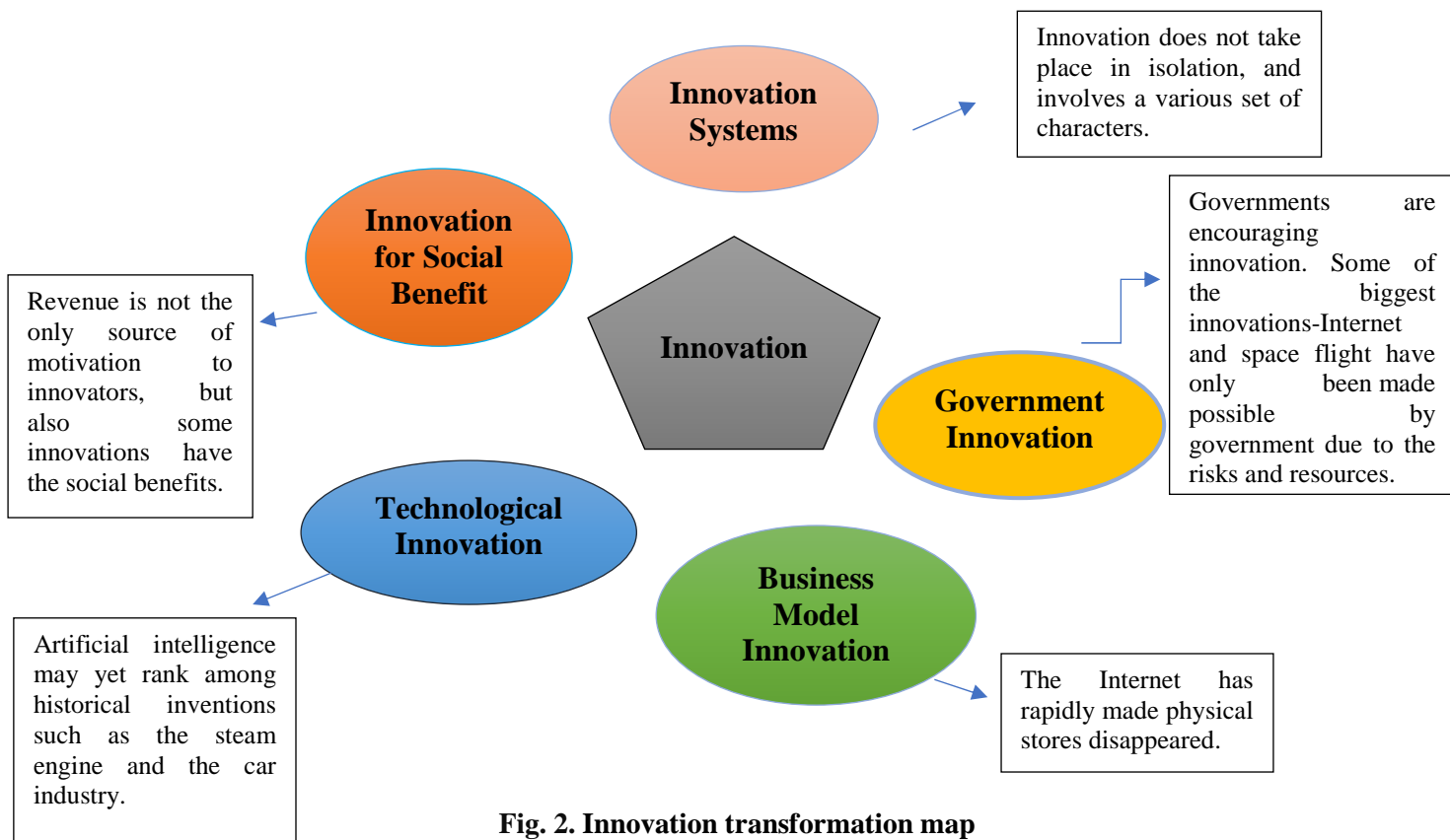


Fig. 2. Innovation transformation map

Source: World Economic Forum (2021)

The innovation system is tied to internet governance, science, private investors, agile governance, justice/law, entrepreneurship, Industry 4.0, sustainable development, education and skills. Government innovation has close relations with agile governance, urbanization, public finance and social protection, global governance, digital communication, etc. Innovation for social benefits has links from social innovation to Industry 4.0. Technological innovations are more likely linked to Industry 4.0 technologies. Business model innovation is connected to corporate governance, future of economic progress, consumer goods and lifestyle, future of computing, digital communications, entrepreneurship and Fourth Industrial Revolution. As researches show that all key issues of innovation, except for government innovation, have close relations with Industry 4.0. (World Economic Forum, 2021)

1.3. New innovation methods and tools

In addition to the contribution of Industry 4.0 on innovation and creation of new products and services, it also has an impact on new innovation methods and tools themselves. This part of the study discusses the new innovation tools that should be used by controllers who design digital business models (International Association of Controllers 2018).

The business model is a concept that represents a company's commercial activities in a simplified manner. Thus, a *business model* is an abstract depiction of how a firm essentially functions in order to achieve its set strategic objectives. The magic triangle of the St. Galler business model navigator to demonstrate how the advanced technologies affected the business model. The model is based on 4 important components: customers (who?), value proposition (what?), value chain (how?) and revenue mechanism (value). Customers, who are served by companies, are at the center of the business model. The value proposition covers the products and services offered by companies to customers. The value chain includes all the activities and resources needed. Revenue mechanism is the financial aspect of the business model. In case of changes in two components of the business model, it is called *business model innovation*. If these changes are derived from the usage of digital technologies, it is referred as *digital business model innovation*. (Gassmann, et al, 2013)

World digitization triggers the creation and application of new controlling tools. Given the changes in the economic environment, traditional methods are usually unable to fulfill the greater expectations. As a result, businesses are increasingly utilizing new innovation tools. Early on, start-ups used these techniques to adjust to the uncertainty in their environment, such as requirements deriving from technological improvements or consumers. Those new methods to support the innovation are Open Innovation, Design Thinking, Agile Approach, Lean Start-up (International Association of Controllers 2018).

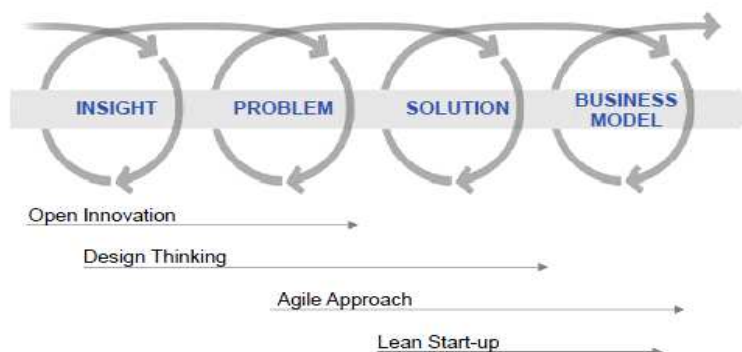


Fig. 3. Innovation tools along the end-to-end innovation process

Source: International Association of Controllers (2018)

Open Innovation - Companies that use the Open Innovation approach seek external ideas, solutions, and technologies rather than relying solely on internal innovations. There are three types of Open Innovation, which differ in the direction of their idea flows outside-in, inside-out, and coupled innovations. The first form of open innovation is outside in. The pioneer of Open Innovation opens their company's borders to the adoption of outside ideas and technology. The second form of open innovation is inside out that Open Innovation initiator makes their own resources available for usage by external parties. In this approach, previously unutilized innovations are made available to others. The third form of open innovation is coupled innovations which means a combination of both the first and second approaches where organizations give and take the ideas. (International Association of Controllers 2018)

In Japan's strategies for taking the lead in the Fourth Industrial Revolution, the third policy is the acceleration of innovation and technological improvements for Society 5.0 – Industry 5.0. It includes 3 stages: 1. Creation of an Open Innovation system; 2. Development of innovation bases which leads the world; 3. Strategic promotion of intellectual property management. The first stage has two basic directions which include increasing investments (triple) in R&D centers and universities for the next ten years within the academic-industry collaboration and supporting start-ups to connect from local to the global market. (Intern report, 2016)

Design Thinking – It is a collaborative approach for the creation of innovative problem solutions. This approach highlights the understanding and identification of consumers' needs and desires. When the prerequisites of "desirability," "viability," and "profitability" are fulfilled, innovation is born. In general, design thinking processes are presented in Figure 4. (International Association of Controllers 2018):



Fig. 4. Design thinking processes

Source: International Association of Controllers (2018)

Agile Approach – it is a method that emphasizes the quick response to changes in the marketplace. It is characterized by some advantages namely flexibility and adaptivity, time to market and customer satisfaction. (International Association of Controllers 2018)

Lean Start-up – the concept is originated from the term lean manufacturing which focuses on improving productivity and quality and decreasing lead times. So that it reduces product development time. The main concept in this approach is that by investing time in goods or services that are created iteratively to meet the demands of early consumers, start-up

enterprises may decrease market risks and prevent too expensive product launches and lost revenues. (International Association of Controllers 2018)

1.4. Innovation processes in the Industry 4.0 environment

Businesses that have a strong Industry 4.0 strategy are significantly more successful overall. They're innovating and developing more quickly, successfully embracing Industry 4.0 technology, and doing a better job of recruiting and training the staff they'll need tomorrow. According to Technology and Innovation for the Future of Production: Accelerating Value Creation Report of World Economic Forum, value dimensions from emerging technologies have been categorized based on value to the individual, society, industry, firm, and factory. The question for the value to the individual is that how those technologies will change the human's life? Value to society is characterized by economic growth, job creation. Values to the industry is considered connection, integration, access and enlarging market share. Value to the factory focuses on the impact of technologies on production operations such as safety, environment, increased quality, reduced time, simplification of operations. Finally, values driving from technologies to the firms are characterized by smart and customized products and services, innovative business models, risk reduction, additional business and smart innovation. It is predicted that revenues generated by connected, and personalized products, new smart, and new business model innovations, such as pay per performance, may deliver 25% revenue growth at the firm level and 25% revenue increases in neighboring industries. (Renjen 2019; Martin, Leurent 2017)

Industry 4.0 is the fastest period of innovation in history. In today's world, innovation is characterized by more complexity, multidisciplinary, collaboration, unplanned, unpredictable, and disruptive. It is growing exponentially rather than at a linear pace. Product life cycles are becoming increasingly shorter as innovation cycles accelerate. For example, Additive manufacturing allows rapid design prototyping which shortened time to market for new product launches and made also contributions to innovations. It should be noted that Industry 4.0 has the capacity to create innovations in response to global issues. (Leurent, Boer 2019; UNIDO 2019)

Artificial intelligence is self-learning machines that analyse cases and data more quickly and objectively than human labour. With companies using common platform technology, core industry technology and relevant data, new types of various products and services are created. It means that taking advantage of Artificial Intelligence technologies and data leads to discover

and acquire new demand, and create innovative goods and products. Relevant examples are given in the Table 3: (Interim Report, 2016)

Table 3. Innovation triggering by Industry 4.0 technologies

TECHNOLOGY +		RELEVANT DATA	= VARIOUS GOODS AND SERVICES
INDUSTRY 4.0 TECHNOLOGIES (AI, IOT, ROBOTICS)	FinTech	Data on financial markets/trade/distribution	Credit by data on trade, Robo Advisor (Asset management)
	Drug discovery technology	Health and medical data	Personalized medicines/cosmetic and beauty services
	Bioinformatics/ Genome editing	Biological data	New types of farm product, bioenergy, new drug discovery
	Production control technology	Accidents and near-miss data	Improvement of productivity with early detection of failure

Source: Interim Report (2016)

Smart production innovations- Cyber-physical systems (CPS) use wired or wireless data infrastructure to connect and communicate software and mechanical or electrical elements. It aims to establish value creation for industrial manufacturing. The CPS integrates smart machines, storage systems and production plants that exchange information permanently. This technology enables the monitoring and control of production systems with complicated processes at all levels of hierarchy and a wide range of product types. The predicted paradigm change in production to Industry 4.0 or smart factories and production systems will decentralize existing centralized applications. (H.Trollman, F. Trollman 2019) The IR4 innovations/technological advancements will allow this new paradigm are:

1. A cobot, also known as a collaborative robot, is a robot designed for direct human-robot interaction in a shared area. So that they will help workers to manage physical objects.
2. M2M means that machines communication with other machines in order to enhance the process flow, reduce time spent for processes. It will involve inspecting components for wear in order to avoid or decrease downtime.
3. NFC and RFID technologies allows wireless communication which are used in logistics, product tracking/security warehouse management, and sale points.
4. QR codes are being used to determine components or tools, or ensure more information about a product.

5. Augmented reality uses a technology based on smart glasses and allows the simulation of an environment with real objects, help in the improvement of production processes. Simulation modelling is a way of running a virtual or real a system or process to find out or estimate the output of the modelled system or process. Simulations are done by using real-time data to represent the real world in a simulation model, which include humans, products and machines. Simulations help quality control meaning that possible defects are identified in advance.
6. Mobile devices are used to give instructions to workers, applications that can track or control machines, machines that can be traced via QR codes, and photographs or videos that can be provided as part of support or service.
7. Predictive maintenance decreases unplanned machine shutdowns using electric motors to monitor and track data regarding mechanical stress and operating temperature, which is often transferred to the cloud for storage and analysis.
8. Pull principle in production system- Raw materials or intermediate goods are automatically requested on demand.
9. Localized part sourcing presents the benefit of creating employment and decreasing transportation costs, etc. (H.Trollman, F. Trollman 2019)

1.5. Evaluation models of countries and companies regarding Industry 4.0

Some digital maturity models or readiness indexes exist for the evaluation of digital preparedness for Industry 4.0. There are two approaches for readiness assessments: 1. Collection of a large quantity of data from entities to evaluate the countries in relation to digital readiness namely GCI (Global Competitiveness Index), GII (Global Innovation Index), NRI (Network Readiness Index); 2. individual evaluations of enterprises based on digital maturity models. So that those indexes are on macro-level (state-level evaluation), digital maturity models for enterprises are on micro-level (enterprise-level evaluation). The macro-level evaluations are being carried out through a large quantity of criteria which also include prerequisites for digitalization. NRI is introduced in 2002, not from the introduction of Industry 4.0. (Basl and Doucek 2019)

According to Alexander N. Alekseev *et al*, the formation process of Industry 4.0 is structured into three stages. The first stage is the preparation of a socio-economic system, the second stage is the formation of the fourth industrial revolution as an industrial area, and the third stage is the transition to Industry 4.0. All of these stages can be individually evaluated through some indicators to assess country performance. The first stage is evaluated through the

indicators related to the level of society’s digitization, the presence of legal documents for Industry 4.0 and total value of scientific research in the relevant field. The second stage is assessed through the indicators related to the number of companies in the area of Industry 4.0, the number of digital companies in the service sector, a ratio of profit to expenses of companies in the field of Industry 4.0, the share of Industry 4.0 on GDP. The third stage is evaluated by using the indicators related to level of automatization of non-cognitive business operations/ everyday non-cognitive processes, and the level of replacements of humans with artificial intelligence. (Alekseev et al., 2019)

Danish Institute has built DII 4.0 global analysis (Danish Institute of Industry 4.0). Global Industry 4.0 Readiness report 2016 covered 120 countries. In addition to the ranking of countries, the report also categorized countries into 9 groups and recommendations were given according to each group. As shown in Figure 5, the recommended strategy for Group 1 and 2 countries is “Foster manufacturing & strengthen position”, for Group 3 and 4 is “Further strengthen position”, for Group 5 and 6 is “Catch up to protect”, for Group 7 is “Foster manufacturing & Complete turnaround”, for Group 8 and 9 is “Complete turnaround”. (Faarup, J., & Faarup, A. 2017)

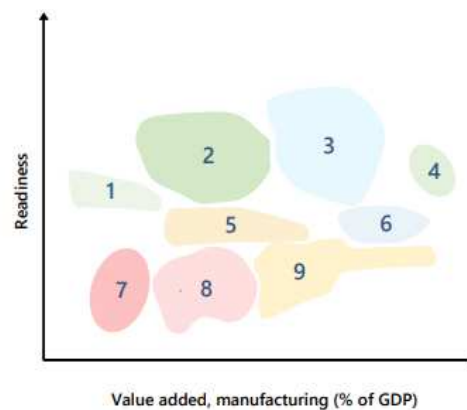


Fig. 5. Categorization of countries for the recommended strategies

Source: Faarup, J., & Faarup, A.(2017)

The Industry 4.0 Readiness Index of Roland Berger is also an example for direct evaluation of Industry 4.0. The number of countries evaluated in this index is only 24 economies from Europe. (Batchkova, et al., 2018)

Based on Hayriye Atika and Fatma Ünlü’s studies, the Industry 4.0 Index has been created for Turkey and European countries through using ten indicators and cluster analysis have also been done. Indicators were taken from Eurostat and TUIK database and measure enterprises having ERP software package, sharing supply chain management information, giving portable devices for a mobile connection to the internet, using Customer Relationship

Management (CRM), using the Cloud Computing applications, having received orders online, using software solutions like CRM, having ERP software package to share information between different functional areas, enterprises with broadband access, the using internet in communication with public institutions. (Atik, Ünlü 2019)

According to some researchers' studies, assessment of Industry 4.0 at meso-level has been done which aims to evaluate the technological prerequisites of adoption of Industry 4.0 in some production sectors in ten European Countries countries, by demonstrating which sectors and countries show the most advanced and effective progress in Industry 4.0 implementation. Data were taken from Eurostat and 12 indicators had been selected for assessment. (Demeter et al., 2018)

Some consulting companies namely McKinsey&Company, Accenture, KPMG etc., have developed their own digital maturity models. One of those companies is PWC. Its model will be explained in the following part. In general, these kinds of digital maturity models identify the level of digital maturity whether it is lower, median or higher digital maturity. Then, the gaps in the maturity level across identified dimensions of the model are analyzed.

The self-assessment test of PWC consulting firm introduced one of the best practices to evaluate the company regarding Industry 4.0. The self-assessment is aimed to offer an overview of the company's situation in relation to Industry 4.0 by assessing actual maturity against targeted maturity of a company along six dimensions, thereby finding areas that need improvement and classifying the current maturity level as in Figure 6. Those six dimensions include Business Models, Product & Service Portfolio, Market & Customer Access, Value Chains & Processes, IT Architecture, Compliance, Legal, Risk, Security & Tax, and Organization & Culture. For example, the first question is that "How would you rate the contribution of digital features, products & services to the overall value creation of your portfolio?" and the answer is based on a 5-scale level. 1 means no contribution (Value is generated solely with the sales of physical products and product-related services (e.g. traditional maintenance) and 5 means main contribution (Value is mainly generated by purely digital products and the licensing of Intellectual Property (e. g. cloud-based predictive maintenance solution, licenses for 3D-printing of products)). Thus, the digitalization-related issues such as value creation by digital products&services, digitized products, individualization of products, digitization and integration of product life cycle phases, data analytics and collaborative development of products are being evaluated in the first dimension- *Business Models, Product & Service Portfolio* in the self-assessment test. Secondly, *Market & Customer Access* is being evaluated with the question related to the integration of various digital and non-digital sales channels, usage of multiple digital channels to foster customer interaction, digital

sales approach, dynamic pricing, extensive data collection, and customer access approach. Thirdly, *Value Chains & Processes* are assessed with the questions regarding complete digitization, virtual factory, integrated end-to-end planning system, fully digitized factory, and digitization of horizontal value chain. In the fourth dimension, *IT Architecture* of a company is being evaluated with the issues related to real-time analytic capabilities, exploration and exploitation of new digital technologies, agility, and IT integration with customers, suppliers. The fifth, *Compliance, Legal, Risk, Security & Tax* covers the issues related to digital compliance policy, intellectual property protection, cybersecurity, etc. The last area - *Organization & Culture* is about new business models, capabilities and resources related to Industry 4.0, the capacity of senior management, and collaboration on the Industry 4.0 topics. In terms of selecting the key performance indicators (*KPIs*) for the Industry 4.0 Index, the experience of Industry 4.0 *self-assessment test of PWC* consulting firm has been used. (PWC 2021)

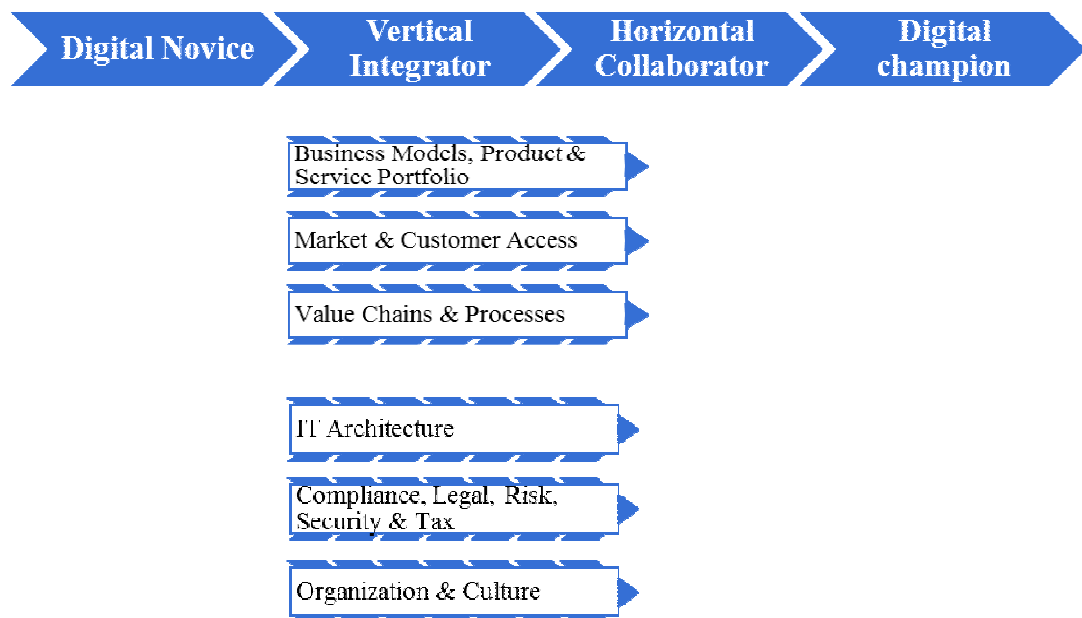


Fig. 6. Digital maturity model of PWC

Source: PWC (2021)

2. METHODOLOGY

The methodology shows the selected research methods and the information that has been gathered. Quantitative research methods – TOPSIS method and correlation have been selected for the study. Additionally, evaluations have also been conducted which primarily focus on the performance comparisons between countries based on indexes.

2.1. TOPSIS Method

Firstly, the Industry 4.0 Index has been built in order to rank the selected countries' performance in relation to Industry 4.0 to use in the final evaluations. As a Multi-Criteria Decision Making method, the *TOPSIS method* has been used for ranking selected countries.

The TOPSIS method - The Technique for Order Preferences by Similarity to an Ideal Solution was presented by Hwang and Yoon in 1981 in order to identify the best alternative. The basic principle originated from the concept of the compromise solution, which was to select the best option that was closest to the positive ideal solution and farthest from the negative ideal solution. Then, pick the best sorting result as the best alternative. (Tzeng, Huang 2011)

There is a set of alternatives which are described as $A = \{A_k \mid k = 1, \dots, n\}$, and a set of criteria, $C = \{C_j \mid j = 1, \dots, m\}$, where $X = \{x_{kj} \mid k = 1, \dots, n; j = 1, \dots, m\}$ signifies a collection of performance ratings and $w = \{w_j \mid j = 1, \dots, m\}$ is the set of weights.

Firstly, data should be put to the relevant places as the information table of TOPSIS below:

The Information Table of TOPSIS

Alternatives	C ₁	C ₂	...	C _m
A ₁	x ₁₁	x ₁₂	...	x _{1m}
A ₂	x ₂₁	x ₂₂	...	x _{2m}
⋮	⋮	⋮	⋮	⋮
A _n	x _{n1}	x _{n2}	...	x _{nm}
W	w ₁	w ₂	...	w _m

The stages of TOPSIS method are described as following. The the first stage does the normalization to form the matrix.

$$r_{kj}(x) = \frac{x_{kj}}{\sqrt{\sum_{k=1}^n x_{kj}^2}}, \quad k = 1, \dots, n; j = 1, \dots, m. \quad (1)$$

In the second stage, the weighted normalised ratings are calculated through the formula below:

$$v_{kj}(x) = w_j r_{kj}(x), \quad k = 1, \dots, n; j = 1, \dots, m. \quad (2)$$

In the third stage, positive ideal point (PIS) and the negative ideal point (NIS) are defined as below where J₁ is benefit attribute and J₂ is cost attribute.

$$\begin{aligned}
PIS = A^+ &= \{v_1^+(x), v_2^+(x), \dots, v_j^+(x), \dots, v_m^+(x)\} \\
&= \left\{ \left(\max_k v_{kj}(x) \mid j \in J_1 \right), \left(\min_k v_{kj}(x) \mid j \in J_2 \right) \mid k = 1, \dots, n \right\}.
\end{aligned}$$

$$\begin{aligned}
NIS = A^- &= \{v_1^-(x), v_2^-(x), \dots, v_j^-(x), \dots, v_m^-(x)\} \\
&= \left\{ \left(\min_k v_{kj}(x) \mid j \in J_1 \right), \left(\max_k v_{kj}(x) \mid j \in J_2 \right) \mid k = 1, \dots, n \right\},
\end{aligned} \tag{3}$$

The next stage is to calculate the distance between alterantive and the PIS/NIS separetly for each alternative though using these formulas:

$$\begin{aligned}
D_k^+ &= \sqrt{\sum_{j=1}^m [v_{kj}(x) - v_j^+(x)]^2}, \quad k = 1, \dots, n \\
D_k^- &= \sqrt{\sum_{j=1}^m [v_{kj}(x) - v_j^-(x)]^2}, \quad k = 1, \dots, n.
\end{aligned} \tag{4}$$

The final ranking based on similarities to the positive ideal solution is derived from this calculation:

$$C_k^* = D_k^- / (D_k^+ + D_k^-), \quad k = 1, \dots, n, \tag{5}$$

2.2. Methodology of the Industry 4.0 Index

As Industry 4.0 is also described as “smart manufacturing”, the list of the countries in the Industry 4.0 Index will be based on those *100 countries* listed in the World Economic Forum report- Readiness for the Future of Production Report 2018.

KPIs cover all the selected *6 dimensions* for Industry 4.0 from the PWC self-assessment test. Key performance indicators include and are based on all levels- *individual, business and government level*. In order to identify and select the KPIs appropriately, a lot of reports of international organizations have been considered. Finally, *4* of them were selected and used which include the Readiness for the Future of Production Report 2018, the Network Readiness Index 2019, Global Innovation Index 2019 and The Global Competitiveness Report 2019 and 2020 of the World Economic Forum. There are 100 countries assessed for the Readiness for the Future of Production Report 2018 of the World Economic Forum and those

countries will also be listed in the Industry 4.0 Index. If a confidence level is 95%, the sample size has to be 95. In the calculations, all the selected 100 countries were included to process the data, which consisted of developed, developing, and also least developed countries in order to sample data correctly. Data processing was conducted thereby using Excel.

In total, 17 KPIs have been considered directly relevant to the Industry 4.0 Index. All the indicators related to modern technologies, digital tools or computer software are the direct indicators of Industry 4.0. Data protection, IT security, and information security are essential prerequisites for Industrie 4.0 and collaboration across digital ecosystems. Recruiting and training young talent, as well as ensuring employability via continuing qualification, are thus major goals for every organization in Industry 4.0. Multi-stakeholder collaboration is also important, because societal change generally requires not only close collaboration at the corporate level but also involvement by all interested parties: from a dialogue between social partners in the individual company to cross-company and cross-sectoral factors of collaboration and issues encompassing the entire society in terms of the use of new technologies and artificial intelligence in our daily lives. In terms of regulatory frameworks, it is required the establishment of governance norms, reoptimizing regulations, policies and the growth of the innovation system, as well as the consideration of data autonomy and security, as well as the interests of employees and persons in general. According to PWC surveys with engineering and construction enterprises, some external factors such as organizations, culture, leadership are considered as the biggest challenges rather than external factors such as infrastructure, right standards, etc. (BMWi 2020; BMWi 2019; PWC 2016)

Areas, the name of the selected indicators, their explanations and sources have been shown below in Table 4:

Table 4. Methodology of the Industry 4.0 Index

DIMENSION OF THE KPI	THE NAME OF THE KPI	DESCRIPTION AND ITS SOURCES
Business Models, Product & Service Portfolio	Firm-level technology absorption	Business level KPI- In your country, to what extent do businesses adopt the latest technologies? (1 = not at all, 7 = to a great extent) Unit of measure: 1–7 (Readiness for the Future of Production Report 2018)
	Company investment in emerging technology	Business level KPI- In your country, to what extent do companies invest in emerging technologies (e.g. Internet of Things, advanced analytics and artificial intelligence, augmented virtual reality and wearables, advanced robotics, 3D printing)? (1=not at all, 7= to a great extent) Unit of measure: 1–7 (Readiness for the Future of Production Report 2018)
	Impact of ICTs on new services and products	Business level KPI- In your country, to what extent do ICTs enable new business models? (1=not at all, 7=to a great extent) Unit of measure: 1–7 (Readiness for the Future of Production Report 2018)

	Buyer sophistication	Individual level KPI- In your country, on what basis do buyers make purchasing decisions? (1 = based solely on the lowest price, 7 = based on sophisticated performance attributes) Unit of measure: 1–7 (Readiness for the Future of Production Report 2018)
Market & Customer Access	Business use of digital tools	Business level KPI- In your country, to what extent do businesses make good use of the latest digital tools to sell their goods and services (e-commerce, digital payment, mobile web stores, social media stores)? [1 = not at all; 7 = to a great extent] (The Network Readiness Index 2020)
	Internet shopping	Individual level KPI- Used the Internet to buy something online in the past year (%) (The Network Readiness Index 2019)
IT Architecture	Computer software spending	Business level KPI- Total computer software spending (% of GDP) It includes total value of purchased or leased packaged software such as operating systems, database systems, programming tools, utilities, and applications. (The Network Readiness Index 2019)
	ICT use	Individual level KPI- It is a composite index that weights three ICT indicators (33% each): (1) Percentage of individuals using the Internet; (2) Fixed (wired)-broadband Internet subscriptions per 100 inhabitants; (3) Active mobile-broadband subscriptions per 100 inhabitants. (Global Innovation Index 2019)
	Use of virtual social networks.	Individual level KPI- Number of active social media users (% of population) (The Network Readiness Index 2019)
	International Internet bandwidth	Government level KPI- International Internet bandwidth per Internet user (bit/s) (The Network Readiness Index 2019)
Compliance, Legal, Risk, Security & Tax	Legal framework's adaptability to digital business models	Government level KPI- In your country, how fast is the legal framework of your country adapting to digital business models (e.g. e-commerce, sharing economy, fintech, etc.)? [1 = not fast at all; 7 = very fast] (The Global Competitiveness Report 2019)
	IP Protection	Government level KPI- In your country, to what extent is intellectual property protected? [1 = not at all; 7 = to a great extent] (The Global Competitiveness Report 2019)
	Cybersecurity	Business level KPI- The Global Cybersecurity Index (GCI) provides a measure of the level of cybersecurity commitments of countries. It is a composite index made up of 25 indicators that are distributed across five main pillars: Legal Measures, Technical Measures, Organizational Measures, Capacity Building Measures, and Cooperation Measures. Scores are standardized to a scale of 0-1. (The Network Readiness Index 2019)
Organization & Culture	ICTs and organizational model creation	Business level KPI- In your country, to what extent do ICTs enable new organizational models (e.g., virtual teams, remote working, telecommuting) within companies? [1 = not at all; 7 = to a great extent] (Global Innovation Index 2019)
	R&D expenditure	Government/Business level KPI- Expenditures for research and development are current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge—including knowledge of humanity, culture and society—and the use of knowledge for new applications. R&D covers basic research, applied research and experimental development. (The Global Competitiveness Report 2019)
	Extent of staff training	Business level KPI- In your country, to what extent do companies invest in training and employee development?" [1 = not at all; 7 = to a great extent] (The Global Competitiveness Report 2020)

	Multi-stakeholder collaboration	Government/Business level KPI- In your country, to what extent do people collaborate and share ideas within a company? (1 = not at all, 7 = to a great extent); In your country, to what extent do companies collaborate in sharing ideas and innovating? (1 = not at all, 7 = to a great extent); and In your country, to what extent do business and universities collaborate on research and development (R&D)? (1 = not at all, 7 = to a great extent) Unit of measure: 1–7 (Readiness for the Future of Production Report 2018)
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Source: Author

2.3. Measurement scale levels

The majority of the measurement scales of the KPIs are 1-7 scale levels. Some of them are 0-100 scale level. In order to calculate through the TOPSIS method and compare the performance results of countries for group evaluations, all 0-100 scale level data have been converted to 1-7 scale levels. For this purpose, the formula to convert different likert scale level was used. Thus, transforming different likert scales to a common scale has been done through the formula below(IBM 2020):

$$Y = (B - A) * (x - a) / (b - a) + A$$

B/A- maximum and minimum values of the scale level accordingly which we need to convert that scale.

b/a- maximum and minimum values of the scale level accordingly which is needed to be converted.

In this case, as 0-100 scale level will be converted to 1-7 scale level, calculations will be as below:

$$Y = (B - A) * (x - a) / (b - a) + A = (7 - 1) * (x - 0) / (100 - 0) + 1 = 6x / 100 + 1 = (3/50) * x + 1 = 0,06x + 1$$

For example, if datum is 60, which is a 0-100 scale level datum, it should be transformed to 7-scale level through 0,06x+1 formula – it is 0,06*60+1= 4,6 in 7-scale level.

2.4. Weights for the indicators

In terms of weights for the indicators in the TOPSIS method, the KPIs included Business Models, Product & Service Portfolio dimension are being considered more important and have more weights as they characterize digitization of products and services. The weights for each KPI are as below in Table 5:

Table 5. Weights of KPIs

The KPI number	KPI	WEIGHT (%)
1	Firm-level technology absorption	9
2	Business use of digital tools	8
3	Computer software spending	3
4	Impact of ICTs on new services and products	10
5	ICTs and organizational model creation	6
6	International Internet bandwidth	7
7	ICT use	3
8	Use of virtual social networks	2
9	Internet shopping	3
10	Buyer sophistication	8
11	IP Protection	7
12	Cybersecurity	7
13	Legal framework's adaptability to digital business models	7
14	Multi-stakeholder collaboration	6
15	R&D expenditures	8
16	Company investment in emerging technology	3
17	Extent of staff training	3

Source: Author

2.5. Correlation

The correlation coefficient is calculated to test the strength of the relationship between X and Y if there is a statistically significant linear relationship between variables. Its value ranges between -1 and 1 where +1 means a perfect positive correlation, -1 means a perfect negative correlation.

$$r = \frac{\text{cov}(X,Y)}{S_X S_Y} \quad \text{cov}(X,Y) = \frac{\sum_{i=1}^n (X_i - \bar{X})(Y_i - \bar{Y})}{n - 1} \quad S_X = \sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2}{n - 1}} \quad S_Y = \sqrt{\frac{\sum_{i=1}^n (Y_i - \bar{Y})^2}{n - 1}}$$

Correlation of coefficient is to describe to what extent the relationship between the Global Innovation Index and Industry 4.0 Index is strong to show the degree of contribution of Industry 4.0 elements on innovation performance. (Berenson et al., 2012)

2.6. Methodology for group and individual evaluations of the countries

As Industry 4.0 have an impact on innovation processes and system, the Industry 4.0 Index will be built and a correlation between Industry 4.0 Index and GII will be identified in order to prove the close relationship between them. Then the impact of Industry 4.0 on innovation will be assessed based on the countries' performances through using both Indexes.

As the object of the study is to evaluate the impact of Industry 4.0 on innovation, this study will show the group and individual evaluations of country performances.

In Table 6, we can see the methodology of group evaluations. Firstly, two countries are strategically selected regarding their performance in GII. For example, 1. Country 1 is one of the top 5-10 countries and Country 2 is among 15-20th places. After 10 years, they *change their places to each other*. Country 2 is already among top 5-10th place, and Country 1 fell 10 places. So that these countries' performance should be evaluated to find the underlying reasons (appropriate KPIs in Industry 4.0 Index). 2. Second possible case is that, Country 1 and Country 2 were both among 20-25th place, after 10 years Country 1 advanced 10 places, *Country 2 did not improve* its position in the index or even went down. 3. Third possible case is that, there is a big gap between countries before. Country 1 is among rank 30-35, Country 2 is among 10-15. After 10 years, Country 1 jumped 20 places in the Index, Country 2 dropped 25 places. So that Country 1 not only advanced and but also has passed to have a better position compared to the *previous position* of Country 2. 4. The fourth potential example case is that, again there is a big gap between countries' places in the Index. For example, Country 1 is among 60-65th place, Country 2 is among 30-35th. After 10 years, Country 1 advanced 20 places and is positioned in 40-45th. But Country 2 has dropped a bit and is among 35-40th. Now they are *so close each other*, and it is expected that Country 1 will surpass Country 2 in the Index in the near future.

In the blue rows of Table 6, the countries are ranked between 1-35 in the Global Innovation Index 2021. In the red rows, countries are positioned after 35 in the GII. The first column shows the country name 1 and 2, *Country 1 is a country always a showing positive significant change in the Global Innovation Index* and *Country 2 shows negative result*. The second column shows the rank of country in the Industry 4.0 Index. The third column demonstrates the performance change between Global Innovation Index 2012 and 2021 (last 10

years). For example, if a country advances 5 places, it is shown as Country 1 (+5). If it has dropped 15 places, it means Country 2 (-15). Better KPIs are selected thereby evaluating the selected countries' performance in Industry 4.0 Indexes across selected Country 1 and Country 2. So that, the better KPIs column shows the *better KPI result of Country 1 compared to Country 2 in Industry 4.0 Index accordingly*. For example, Country 1 is showing better performance in KPI X, Y, Z compared to Country 2 in Industry 4.0 Index. The column Common KPIs is the more repeated KPIs in the column Better KPIs. The sequence of common KPIs is according to the priority level regarding the number of times and weights of indicators. The same principles also apply to Country 3 and 4 in red rows.

Table 6. Methodology for group evaluations

Country	Industry 4.0	Changes in Innovation index last 10 years	Better KPIs of Country 1 (1.1) or Country 3 (3.1) in Industry 4.0 Index	Common KPIs
Country 1 - Country 2	The place of Country 1- The place of Country 2 in Industry 4.0 Index	Country 1 (+Number) ; Country 2 (-Number)	KPI number X, Y, Z, ..	KPI number X, Y, Z,...
Country 1.1 - Country 2.1	The place of Country 1.1- The place of Country 2.1 in Industry 4.0 Index	Country 1.1 (+Number) ; Country 2.1 (-Number)	KPI number X, Y, Z, ..	
.....	
Country 3 – Country 4	The place of Country 3- The place of Country 4 in Industry 4.0 Index	Country 3 (+Number) ; Country 4 (-Number)	KPI number X, Y, Z, ..	KPI number X, Y, Z,...
.....	

Source: Author

The common KPIs should be at least 70 % of the number of countries' comparisons. For example, if there are 16 country group evaluations in blue rows, so the common KPIs should be repeated at least 11 times in the column Better KPIs. Or if there are 10 country evaluations in red rows, common KPIs should be the KPIs which repeated 7 times in the column Better KPIs. As blue rows refer the countries placing in the top 35 countries in Global Innovation Index and red rows show the countries placing in after the top 35 countries in Global Innovation Index, the common KPIs should be selected individually for blue and red row countries.

Table 7. Counting repeated KPIs

The number of KPI	The name of KPI	Times	Times
1	Firm-level technology absorption	k	k

2	Business use of digital tools	l	l
3	Computer software spending	m	m
4	Impact of ICTs on new services and products	n	n
5	ICTs and organizational model creation	...	...
6	International Internet bandwidth	...	...
7	ICT use	...	...
8	Use of virtual social networks	...	...
9	Internet shopping	...	...
10	Buyer sophistication	...	...
11	IP Protection	...	...
12	Cybersecurity	...	...
13	Legal framework's adaptability to digital business models	...	...
14	Multi-stakeholder collaboration	...	...
15	R&D expenditures	...	...
16	Company investment in emerging technology	...	...
17	Extent of staff training	...	...

Source: Author

Table 8. Counting common KPIs

70% of X (the number of countries' comparisons in blue rows)	MIN. The common KPI should be repeated 0.7*X times at least.
70% of Y (the number of countries' comparisons in red rows)	MIN. The common KPI should be repeated 0.7*Y times at least.

Source: Author

Table 9 shows the methodology for individual country evaluations. Here they are not compared with other countries. In the orange rows, countries have shown the significant negative results in the Global Innovation Index last 10 years. In the green rows, countries have shown the significant positive result in the Global Innovation Index last 10 years. The first column shows the Country name a, b, etc. Country a/b is a country showing a negative significant change in the Global Innovation Index and Country a.1/b.1 shows positive result. The second column shows the rank of country in Industry 4.0. The third column demonstrates the performance change between Global Innovation Index 2012 and 2021. For example, if a country advances 5 places, it is shown as Country a.1 (+5). If it has dropped 15 places, it means Country a (-15). Better/worse KPIs are selected thereby evaluating the selected countries' performance in Industry 4.0 Index. So that, the better KPIs column shows the better result of Country a.1/b.1 in Industry 4.0 Index. For example, Country a.1 is showing better performance

in KPI X, Y, Z in Industry 4.0 Index (the KPIs which have a result more than 4 in 7 scale level) or vice versa for country a/b.

Table 9. Methodology for individual evaluations

Country	Industry 4.0	Changes in Innovation index last 10 years	Better KPIs of Country a.1 (b.1) or Worse KPIs of Country a (b) in Industry 4.0 Index accordingly	Common KPIs
Country a	The place of Country a in Industry 4.0	(-Number)	KPI number X, Y, Z, ..	KPI number X, Y, Z,...
Country b	The place of Country b in Industry 4.0	(-Number)	KPI number X, Y, Z, ..	
.....	
Country a1	The place of Country a1 in Industry 4.0	(+Number)	KPI number X, Y, Z, ..	KPI number X, Y, Z,...
Country b1	The place of Country b1 in Industry 4.0	(+Number)	KPI number X, Y, Z, ..	
.....	

Source: Author

In general, the result of more than 1.5 out of 3 is considered a good result. But in different likert scale levels, it is hard to define which result should be taken into account as a good or bad result. As the scale level of KPIs in Industry 4.0 Index is 1-7 scale levels, it should be transformed to a 0-3 scale level in order to identify bad/good results from a 1-7 scale level.

Thus, transforming different likert scales to a common scale has been done through the formula below (IBM 2020):

$$Y = (B - A) * (x - a) / (b - a) + A$$

B/A- maximum and minimum values of the scale level accordingly which we need to convert that scale. b/a- maximum and d minimum values of the scale level accordingly which is needed to be converted. (IBM 2020) In this case, as 1-7 scale level will be converted to 0-3 scale level, calculations will be as below:

$$Y = (B - A) * (x - a) / (b - a) + A = (3 - 0) * (x - 1) / (7 - 1) + 0 = (x-1)/2$$

The results are shown in the Table 10:

Table 10. Equivalent of 1-7 scale level in 0-3 scale level

1	0
2	0,5
3	1
4	1,5
5	2
6	2,5
7	3

Source: Author

So that the KPIs which have result more than 4 are showing good performance or vice versa.

3. RESULTS

3.1. Industry 4.0 Index

Firstly, the data over 100 countries have been collected from 4 different international reports including Readiness for the Future of Production Report 2018, the Network Readiness Index 2019, Global Innovation Index 2019 and The Global Competitiveness Report 2019 and 2020 of the World Economic Forum. Then the data having 0-100 scale levels have been converted to common likert scale level - 1-7. After that according to the stages of the TOPSIS method, x^2 (sum of the x squares of all countries' results based on one indicator) and the square root of x^2 (SQRT) have been calculated, then normalization, weighted normalized ratings and PIS/NIS were defined. In the next step, we are close to the ranking which is shown below in Appendix 1. After all these calculations, rankings of countries are demonstrated in Table 11.

The final ranking of Industry 4.0 is below which is the final Industry 4.0 Index based on 17 more relevant and appropriate key performance indicators. We can see each country's performance in relation to Industry 4.0 in Table 11.

Table 11. Final ranking of Industry 4.0 Index

Industry 4.0 index	Ranking	Portugal	27	Mauritius	54	Pakistan	81
United States	1	Spain	28	Croatia	55	Cameroon	82
Switzerland	2	Czech Republic	29	Egypt	56	Botswana	83
Sweden	3	Qatar	30	Dominican Republic	57	Sri Lanka	84
Finland	4	Saudi Arabia	31	Costa Rica	58	Ghana	85
Germany	5	Italy	32	Jordan	59	Peru	86
Denmark	6	Lithuania	33	Mexico	60	Guatemala	87
Belgium	7	Hungary	34	Romania	61	Cambodia	88
Netherlands	8	Thailand	35	Viet Nam	62	Paraguay	89
Israel	9	Turkey	36	Georgia	63	Ecuador	90
Japan	10	Russian Federation	37	Serbia	64	Honduras	91
Singapore	11	Poland	38	Kuwait	65	Tanzania	92
Austria	12	Slovak Republic	39	Morocco	66	Algeria	93
Korea, Rep.	13	Kenya	40	Ukraine	67	Uganda	94
Norway	14	Brazil	41	Philippines	68	Mongolia	95
United Kingdom	15	Bulgaria	42	Kazakhstan	69	Zambia	96

France	16	Chile	43	Nigeria	70	Kyrgyz Republic	97
Canada	17	South Africa	44	Armenia	71	El Salvador	98
Australia	18	India	45	Panama	72	Bosnia and Herzegovina	99
China	19	Cyprus	46	Bangladesh	73	Ethiopia	100
Malaysia	20	Oman	47	Colombia	74		
New Zealand	21	Indonesia	48	Argentina	75		
Ireland	22	Azerbaijan	49	Lebanon	76		
United Arab Emirates	23	Bahrain	50	Senegal	77		
Estonia	24	Uruguay	51	Moldova	78		
Slovenia	25	Greece	52	Tunisia	79		
Hong Kong SAR	26	Latvia	53	Albania	80		

Source: Author

3.2. Correlation between Industry 4.0 and Global Innovation Indexes

The coefficient of correlation has been calculated in Excel for each last three years. It measures the strength of a linear relationship which means a strong positive relationship. In Table 12, we see that correlation between Industry 4.0 Index and Global Innovation Index 2019/2020/2021 is 88%, 87%, 88% respectively.

Table 12. Correlations between Industry 4.0 Index and GII

correl 2019	0,877
correl 2020	0,873
correl 2021	0,882

Source: Author

This means that if a country has a good position in Industry 4.0 Index, it also has a good innovation environment and system, or vice versa. So that being prepared for Industry 4.0 age creates a condition to be close to Innovation 4.0, to find new innovations, identify new approaches to innovation, and to track the current and future trends in this line.

3.3. Evaluations

Firstly, the Industry 4.0 Index covering 100 countries' ranking has already been done. Secondly, the close relationship between Industry 4.0 and innovation has been proved through the calculations of correlation between the indexes.

It is well-known that acquiring leading technologies can be more challenging for emerging/least developed countries. Therefore, they can invest on computer software instead of great investment on emerging technologies. (Dalenogare et al., 2018) Software aids in the

optimization of all processes and tasks, whether conducted by humans or machines. When everything in the virtual world functions well, the results are sent to the physical world. (Kaeser 2018) Therefore, it is assumed that computer software spending will be an important direction for the countries which intend to maintain the position in the GII at least. Additionally, as the countries should invest in R&D, there will not be any development without it, it is also assumed that indicator R&D will be a priority for almost every country group.

In this part of the study, final evaluations will be carried out in order to evaluate the impact of Industry 4.0 on innovation and find the key drivers of innovation in relation to Industry 4.0. Firstly, based on strategic selections of country comparisons, 16 groups of selected countries have been formed and shown in the blue rows. These countries are the TOP 35 countries in the Global Innovation Index 2021. 7 groups of countries have been formed and shown in the red rows which are the countries after Top 35 in the Global Innovation Index. After the selection of 2-country groups, evaluations start and is demonstrated in Table 13.

Example case for The Republic of Korea-Ireland- Korea was in the 21st place in the Global Innovation Index 2012. After 10 years, it is in 5th place in the GII. As it rose 16 places, in the third column it is shown as Korea (+16). Ireland was in 9th place in the Global Innovation Index 2012. After 10 years, it is in 19th place in the index. As it dropped 10 places, in the third column it is shown as Ireland (-10). As a result, Korea has improved its position and not only reached Ireland's previous position in the ranking, but also passed and ranked the 5th after 10 years. In the second column, we also see that Korea has placed before Ireland in the Industry 4.0 Index as well. In the next stage, Korea's KPIs showing better results compared to Ireland in the Industry 4.0 Index were being chosen. Thus, the Republic of Korea has a better performance compared to Ireland in KPI number 2, 7, 8, 9, 10, 12, 13, 15. Consequently, the Republic of Korea has better performance based on Ireland's performance in Industry 4.0 and Global Innovation Index 2021. KPIs number 2, 7, 8, 9, 10, 12, 13, 15 are the KPIs that advance Korea in Industry 4.0 Index and in the same time trigger the advancements in Global Innovation Index in this scenario.

In general, all of these KPIs showing better results of Countries 1 were identified. Then, common KPIs repeated at least 70% of 2-country group evaluations (11 times) in blue rows were defined in Table 15. In these group evaluations (blue rows) which include the countries placing in the TOP 35 in the Global Innovation Index 2021, KPIs number 15, 10 have been identified as the most frequently repeated – common KPIs in group evaluations.

With the same principles, the 2-country group evaluations in the red rows were being completed which include the countries placing in after the TOP 35 countries in the Global Innovation Index 2021. The common KPIs should be repeated at least 5 times in a 2-group

evaluation for red rows. KPIs number 15, 12, 14, 5, 16 have been identified as the most frequently repeated – common KPIs in these group evaluations.

The sequence of the KPIs is based on firstly the number of times and secondly weight percentages of the KPIs. Later, these identified common KPIs and their sequence will be used while building the decision tree to define the national priorities for each country.

Table 13. The results of group evaluations

Country	Industry 4.0	Changes in Innovation index last 10 years	Better KPIs of Country 1 (1.1) / Country 3 (3.1) in Industry 4.0 Index	Common KPIs
USA-Singapore	USA-1st; Singapore-11st place	USA (+7); Singapore (-5)	1, 2, 3, 5, 7, 9, 10, 12, 13, 14, 15, 16	15, 10
Korea-Ireland	Korea-13rd; Ireland-22nd place	Korea (+16); Ireland (-10)	2, 7, 8, 9, 10, 12, 13, 15	
Germany-Norway	Germany- 5th; Norway- 14th place	Germany (+5); Norway (-6)	5, 10, 13, 14, 15, 16	
Germany-Singapore	Germany-5th; Singapore-11st place	Germany (+5); Singapore (-5)	1, 2, 3, 5, 7, 9, 10, 14, 15, 16	
Germany-Canada	Germany- 5th; Canada- 17th place	Germany (+5); Canada (-4)	1, 2, 4, 5, 7, 10, 13, 14, 15, 16	
Germany-Hong Kong	Germany-5th; Hong Kong-26th place	Germany (+5); Hong Kong (-6)	1, 2, 3, 4, 5, 9, 13, 14, 15, 16	
Japan-Ireland	Japan-10th; Ireland-22nd place	Japan (+12); Ireland (-10)	1, 2, 7, 10, 11, 12, 13, 15, 16, 17	
Japan-Singapore	Japan-10th; Singapore-11st place	Japan (+12); Singapore (-5)	2, 7, 10, 15	
China-Ireland	China-19th; Ireland-22nd place	China (+22); Ireland (-10)	8, 10, 12, 13, 15	
China-New Zealand	China-19th; New Zealand- 21st place	China (+22); New Zealand (-13)	3, 10, 12, 15	
France-New Zealand	France-16th; New Zealand-21st place	France (+13); New Zealand (-13)	2, 3, 4, 12, 15	
France-Australia	France-16th; Australia-18th place	France (+13); Australia (-2)	3, 4, 5, 7, 12, 15, 16	
Italy-Latvia	Italy-32nd; Latvia-53rd	Italy (+7); Latvia (-8)	1, 3, 4, 8, 9, 10, 12, 14, 15, 16	
Israel-Norway	Israel- 9th; Norway-14th place	Israel (+2); Norway (-6)	4, 8, 11, 13, 14, 15, 16	
Austria-Canada	Austria-12nd; Canada-17th place	Austria (+4); Canada (-4)	1, 11, 14, 15, 17	
Canada-New Zealand	Canada-17th; New Zealand-21st place	Canada (-4); New Zealand (-13)	3, 5, 10, 12, 15, 17	
Turkey-Latvia	Turkey-36th; Latvia-53rd place	Turkey (+33); Latvia (-8)	1, 3, 4, 8, 10, 12, 13, 14, 15	15, 12, 14, 5, 16
Thailand-	Thailand-35th; Chile-	Thailand(+14);	5, 6, 10, 12, 14, 15, 16,	

Chile	43rd place	Chile (-14)	17
India-Tunisia	India-45th; Tunisia-79th place	India-(+18); Tunisia (-12)	1, 2, 5, 10, 11, 12, 13, 14, 15, 16, 17
Greece-Jordan	Greece-52nd; Jordan-59th place	Greece (+19); Jordan (-25)	3, 6, 7, 9, 15
Mexico-Kuwait	Mexico-60th; Kuwait-65th place	Mexico (+24); Kuwait (-17)	1, 4, 5, 12, 13, 14, 15, 16
Viet Nam-Kuwait	Viet Nam- 62nd; Kuwait-65th place	Viet Nam (+32); Kuwait (-17)	4, 5, 12, 14, 15, 16
Indonesia-Chile	Indonesia-48th; Chile-43rd place	Indonesia (+13); Chile (-14)	5, 12, 13, 14, 16, 17

Source: Author

Table 14. The repeated KPIs

The number of KPI	The name of KPI	Times	Times
1	Firm-level technology absorption	7	3
2	Business use of digital tools	8	1
3	Computer software spending	8	2
4	Impact of ICTs on new services and products	6	3
5	ICTs and organizational model creation	7	5
6	International Internet bandwidth	0	2
7	ICT use	7	1
8	Use of virtual social networks	3	1
9	Internet shopping	5	1
10	Buyer sophistication	11	3
11	IP Protection	3	1
12	Cybersecurity	9	6
13	Legal framework's adaptability to digital business models	8	4
14	Multi-stakeholder collaboration	8	6
15	R&D expenditures	16	6
16	Company investment in emerging technology	9	5
17	Extent of staff training	3	3

Source: Author

Table 15. The threshold for Common KPIs

70% of 16 country comparisons	MIN. The common KPI should be repeated 11 times at least.
70% of 7 country comparisons	MIN. The common KPI should be repeated 5 times at least.

In terms of individual evaluations, these countries have been decided to be evaluated individually. Qatar, Saudia Arabia and Oman have shown significant negative performance in the Global Innovation Index 2021 compared to the results from the Global Innovation Index

2012. The measurement scale level is 1-7 in the Industry 4.0 Index. In general, the results of more than 4 in 1-7 scale level is considered as good result and KPIs which show these results are being considered as better KPIs, or the KPIs which show less than 4 in 1-7 scale level are being considered as worse KPIs. As shown in Table 16, KPIs number 15, 3, 14 are the common KPIs showing negative results in Qatar, Saudia Arabia and Oman’s performance in Industry 4.0 Index which triggered the negative performance in Global Innovation Index last 10 years.

With the same principles, Morocco, Ukraine and Phillippines have showed significant positive performance in the Global Innovation Index 2021 based on the results from the Global Innovation Index 2012. KPIs number 4, 1, 2, 6, 11, 12, 5, 17 are the common KPIs showing positive results in Morocco, Ukraine and Phillippines’ performances in Industry 4.0 which triggered the positive performance in Global Innovation Index last 10 years.

Table 16. The results of individual evaluations

Country	Industry 4.0	Changes in Innovation index last 10 years	Better KPIs of Country a.1 (b.1) or Worse KPIs of Country a (b) in Industry 4.0 Index accordingly	Common KPIs
Qatar	30th	(-35)	3/15	15, 3, 14
Saudia Arabia	31st	(-18)	3/9/14/15	
Oman	47th	(-29)	3/10/14/15	
Morocco	66th	(+11)	1/2/4/5/6/11	4, 1, 2, 6, 11, 12, 5, 17
Ukraine	67th	(+14)	1/2/4/5/6/12/17	
Phillippines	68th	(+44)	1/2/4/5/6/8/11/12/17	

Source: Author

The common KPIs will be used to build the decision tree for all developed, developing and least developed countries to make a decision for the industrial and innovation strategic documents at the governmental level. The final set of common KPIs and their exact sequence is as in Table 17:

Table 17. The final set of common KPIs based on the group and individual evaluations

2-country group evaluations based on TOP 35 countries in the Global Innovation Index (blue rows)	15, 10
2-country group evaluations based on the countries after 35 th place in the Global Innovation Index (red rows)	15, 12, 14, 5, 16
Countries showing negative results based on individual evaluations	15, 3, 14
Countries showing positive results based on individual evaluations	4, 1, 2, 6, 11, 12, 5, 17

Source: Author

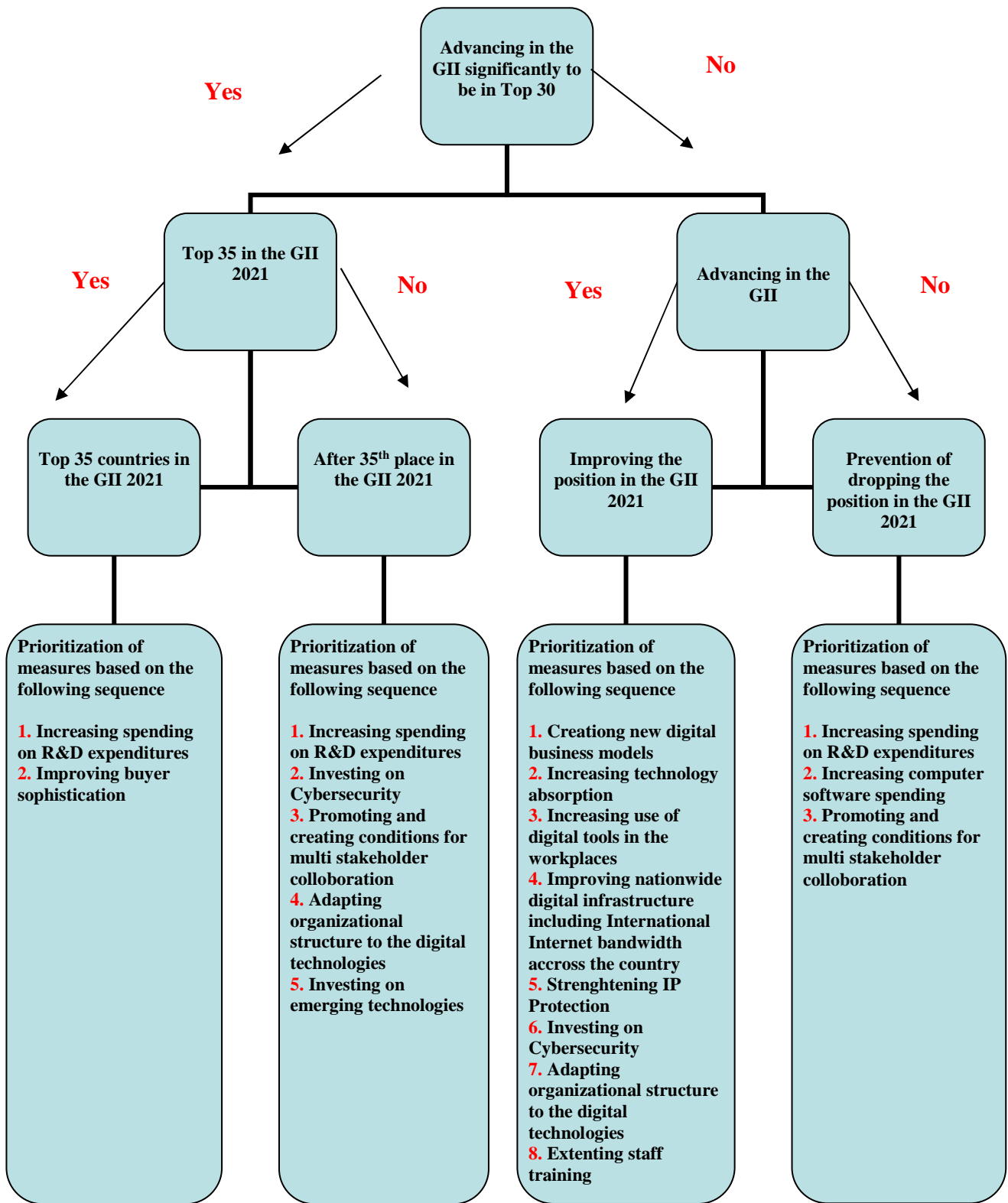


Fig. 7. Decision Tree to rise (or maintain position) in the Global Innovation Index (GII)

Source: Author

CONCLUSIONS

1. Smart manufacturing is staying at the center of the new industrial revolution. However, the Fourth Industrial Revolution does not only mean smart manufacturing, but also is close interaction of its technologies with physical, digital and biological areas. It is contributing values to individuals, society, industry and firms.

2. The Fourth Industrial Revolution presents unlimited possibilities for the next wave of innovation, has an impact on firms' innovation processes and brings new approaches and methods to innovation. It creates a favorable condition for a progressive rise in the efficiency and effectiveness of the socioeconomic system's operations.

3. The countries, consider the importance of Industry 4.0, significantly grow in innovation environment and get a competitive advantage in innovation development. In terms of businesses, digitally maturing companies are becoming more innovative.

4. In terms of the new innovation methods and tools derived from Industry 4.0, they are used by businesses to support the innovation which are Open Innovation, Design Thinking, Agile Approach and Lean Start-up.

5. Decision tree has been created and it provides empirical insight into the measures to be taken for innovation in Industry 4.0. The governments can find themselves in the decision tree and use the key findings while prioritizing national policy directions in the government strategic plans to reach Society 5.0.

6. According to the decision tree in Figure 7, Top 35 countries in the GII 2021, which intends to advance significantly in the index to be in the Top 30, should follow the first way. The countries listed after 35th, which plans to advance significantly in the index to be in the Top 30, should follow the second way. The countries, which intend to advance in the index but do not plan to be in the Top 30, should follow the third way. The countries, which only plan to maintain the current position in order to prevent dropping in the index, should follow the last way.

7. The first key finding is that Research and Development are important for the countries intending to grow significantly in the GII.

8. It is well-known that an increase in connected devices rises the probability of cyberattacks which is one of the biggest challenges of Industry 4.0. Therefore, businesses should be prepared for cybersecurity. Businesses must be aware of the significance of digital security and privacy, and they should provide particular training to their staff in order to pass specialized skills, as well as invest in the upgradation of the security systems.

9. Based on study analysis, adoption of emerging technologies can be challenging for developing/least developed countries and investment on computer software is recommended

for them. Thus, it has been assumed and proved that computer software spending is an important direction for the countries which intends to maintain their position in the GII.

10. Society 5.0 is considered and characterized as a more sustainable future and more environmentally friendly where the environmental, social, and economic issues are related and integrated with each other. Thus, multi-stakeholder collaboration is also important, as social changes require the involvement of all interested parties.

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APPENDICES

APPENDIX 1. Calculations of Industry 4.0 Index

Industry 4.0 index	Di+	Di-	Di+(+)Di-	Rj
Sweden	0,005261	0,02262201383	0,811304517	3
United States	0,004162	0,02353735010	0,849758436	1
Netherlands	0,006958	0,02034313660	0,745150253	8
Switzerland	0,005035	0,02282619839	0,819280767	2
Finland	0,005239	0,02211348351	0,808461854	4
Norway	0,007312	0,01897177084	0,721818985	14
Israel	0,007472	0,02137344809	0,740976071	9
Denmark	0,006337	0,02129910842	0,770693189	6
United Arab Emirates	0,011798	0,01722790564	0,593539716	23
Germany	0,005731	0,02190287722	0,792609074	5
United Kingdom	0,007823	0,01954724869	0,714180996	15
Singapore	0,007322	0,02031964810	0,735111463	11
Japan	0,007600	0,02113056559	0,735463313	10
New Zealand	0,010879	0,01686717238	0,607906820	21
Malaysia	0,010749	0,01699097812	0,612501956	20
Qatar	0,013806	0,01541291413	0,527498079	30
Austria	0,007428	0,02047488698	0,733785870	12
Estonia	0,011813	0,01677063257	0,586714040	24
Ireland	0,010826	0,01639574232	0,602307926	22
Lithuania	0,014296	0,01468764466	0,506758978	33
Korea, Rep.	0,007840	0,02160896380	0,733765045	13
Australia	0,009239	0,01777790833	0,658034443	18
Belgium	0,006629	0,01939553099	0,745266468	7
Canada	0,009190	0,01772609950	0,658576764	17
Hong Kong SAR	0,012273	0,01595127297	0,565165196	26
Portugal	0,012082	0,01493092541	0,552737081	27
France	0,008028	0,01871886131	0,699860295	16
Saudi Arabia	0,013469	0,01499499923	0,526804686	31
Czech Republic	0,012263	0,01449006827	0,541617209	29
Bahrain	0,016650	0,01214794002	0,421827900	50
Panama	0,018755	0,01040983398	0,356935618	72
Kenya	0,015579	0,01281903401	0,451402533	40
Chile	0,016295	0,01229721213	0,430085353	43
South Africa	0,015485	0,01167645431	0,429896961	44
Indonesia	0,017146	0,01280322415	0,427500720	48
Costa Rica	0,016949	0,01128435872	0,399688716	58
Guatemala	0,020256	0,00862501494	0,298638555	87
Thailand	0,015103	0,01321103682	0,466590091	35
Jordan	0,017040	0,01121736996	0,396969531	59

Azerbaijan	0,017105	0,01270473439	0,426191058	49
Slovenia	0,011530	0,01565535151	0,575883081	25
Turkey	0,014871	0,01300460142	0,466518429	36
Slovak Republic	0,015219	0,01268304203	0,454548032	39
Senegal	0,017598	0,00923446068	0,344154618	77
Mauritius	0,017671	0,01222227745	0,408869686	54
Philippines	0,018071	0,01061279547	0,369988047	68
Oman	0,016938	0,01267059194	0,427943438	47
Spain	0,012576	0,01496875126	0,543441505	28
Poland	0,014848	0,01273313012	0,461658967	38
Mexico	0,016935	0,01100171532	0,393804795	60
China	0,009669	0,01647328322	0,630138787	19
Brazil	0,015118	0,01179811174	0,438328576	41
Italy	0,012899	0,01411122318	0,522446107	32
Morocco	0,016988	0,01020770031	0,375343695	66
Cyprus	0,016309	0,01220835159	0,428107177	46
Honduras	0,020616	0,00797184195	0,278852107	91
Bulgaria	0,015828	0,01206283284	0,432495371	42
Latvia	0,017263	0,01194204594	0,408908069	53
Uruguay	0,016542	0,01206446039	0,421741250	51
Kuwait	0,018259	0,01098450414	0,375623780	65
Albania	0,019570	0,00967696353	0,330874266	80
Russian Federation	0,014727	0,01285372421	0,466036792	37
India	0,016220	0,01219048417	0,429078217	45
Greece	0,016077	0,01119465625	0,410480048	52
Armenia	0,018377	0,01022551565	0,357501707	71
Sri Lanka	0,019506	0,00879002714	0,310640790	84
Nigeria	0,015118	0,00871733667	0,365724408	70
Kazakhstan	0,018710	0,01093419270	0,368842971	69
Dominican Republic	0,013959	0,00929643116	0,399748662	57
Colombia	0,018474	0,01011912617	0,353906310	74
Ukraine	0,017627	0,01036848201	0,370359993	67
Mongolia	0,020694	0,00790727166	0,276464966	95
Lebanon	0,015208	0,00806082554	0,346425016	76
Pakistan	0,018851	0,00904529075	0,324248500	81
Cambodia	0,020318	0,00856451325	0,296527235	88
Croatia	0,017139	0,01166422480	0,404959473	55
Bosnia and Herzegovina	0,021943	0,00720882892	0,247282673	99
Viet Nam	0,017424	0,01060131093	0,378272589	62
Ecuador	0,019274	0,00781300599	0,288439007	90
Romania	0,017380	0,01081122333	0,383497102	61
Bangladesh	0,015007	0,00827705906	0,355481849	73
Ghana	0,019082	0,00858970412	0,310410753	85

Botswana	0,018796	0,00847830685	0,310848106	83
Egypt	0,017089	0,01138075965	0,399755580	56
Argentina	0,017901	0,00950804118	0,346892511	75
Tanzania	0,020262	0,00776713654	0,277113307	92
Peru	0,020005	0,00856905384	0,299891691	86
Moldova	0,019099	0,00979410251	0,338980970	78
Uganda	0,020784	0,00795928850	0,276913103	94
Georgia	0,018348	0,01108616087	0,376636809	63
Hungary	0,014627	0,01282513538	0,467179975	34
Paraguay	0,020581	0,00841858147	0,290297289	89
Tunisia	0,018380	0,00921702363	0,333981498	79
Cameroon	0,015303	0,00703255081	0,314858799	82
Zambia	0,020656	0,00730278455	0,261200113	96
El Salvador	0,021787	0,00752818161	0,256805262	98
Serbia	0,017445	0,01051417309	0,376051779	64
Algeria	0,019947	0,00763992437	0,276943877	93
Kyrgyz Republic	0,021688	0,00757655523	0,258902318	97
Ethiopia	0,021343	0,00594104981	0,217751725	100

APPENDIX 2. Industry 4.0 Index and Global Innovation Index 2021

Industry 4.0 index	Rj	Global Innovation Index 2021	Rj
United States	1	United States of America	3
Switzerland	2	Switzerland	1
Sweden	3	Sweden	2
Finland	4	Finland	7
Germany	5	Germany	10
Denmark	6	Denmark	9
Belgium	7	Belgium	22
Netherlands	8	Netherlands	6
Israel	9	Israel	15
Japan	10	Japan	13
Singapore	11	Singapore	8
Austria	12	Austria	18
Korea, Rep.	13	Korea, Rep.	5
Norway	14	Norway	20
United Kingdom	15	United Kingdom	4
France	16	France	11
Canada	17	Canada	16
Australia	18	Australia	25
China	19	China	12
Malaysia	20	Malaysia	36

New Zealand	21	New Zealand	26
Ireland	22	Ireland	19
United Arab Emirates	23	United Arab Emirates	33
Estonia	24	Estonia	21
Slovenia	25	Slovenia	32
Hong Kong SAR	26	Hong Kong SAR	14
Portugal	27	Portugal	31
Spain	28	Spain	30
Czech Republic	29	Czech Republic	24
Qatar	30	Qatar	68
Saudi Arabia	31	Saudi Arabia	66
Italy	32	Italy	29
Lithuania	33	Lithuania	39
Hungary	34	Hungary	34
Thailand	35	Thailand	43
Turkey	36	Turkey	41
Russian Federation	37	Russian Federation	45
Poland	38	Poland	40
Slovak Republic	39	Slovak Republic	37
Kenya	40	Kenya	85
Brazil	41	Brazil	57
Bulgaria	42	Bulgaria	35
Chile	43	Chile	53
South Africa	44	South Africa	61
India	45	India	46
Cyprus	46	Cyprus	28
Oman	47	Oman	76
Indonesia	48	Indonesia	87
Azerbaijan	49	Azerbaijan	80
Bahrain	50	Bahrain	78
Uruguay	51	Uruguay	65
Greece	52	Greece	47
Latvia	53	Latvia	38
Mauritius	54	Mauritius	52
Croatia	55	Croatia	42
Egypt	56	Egypt	94
Dominican Republic	57	Dominican Republic	93
Costa Rica	58	Costa Rica	56
Jordan	59	Jordan	81
Mexico	60	Mexico	55
Romania	61	Romania	48
Viet Nam	62	Viet Nam	44

Georgia	63	Georgia	63
Serbia	64	Serbia	54
Kuwait	65	Kuwait	72
Morocco	66	Morocco	77
Ukraine	67	Ukraine	49
Philippines	68	Philippines	51
Kazakhstan	69	Kazakhstan	79
Nigeria	70	Nigeria	118
Armenia	71	Armenia	69
Panama	72	Panama	83
Bangladesh	73	Bangladesh	116
Colombia	74	Colombia	67
Argentina	75	Argentina	73
Lebanon	76	Lebanon	92
Senegal	77	Senegal	105
Moldova	78	Moldova	64
Tunisia	79	Tunisia	71
Albania	80	Albania	84
Pakistan	81	Pakistan	99
Cameroon	82	Cameroon	123
Botswana	83	Botswana	106
Sri Lanka	84	Sri Lanka	95
Ghana	85	Ghana	112
Peru	86	Peru	70
Guatemala	87	Guatemala	101
Cambodia	88	Cambodia	109
Paraguay	89	Paraguay	88
Ecuador	90	Ecuador	91
Honduras	91	Honduras	108
Tanzania	92	Tanzania	90
Algeria	93	Algeria	120
Uganda	94	Uganda	119
Mongolia	95	Mongolia	58
Zambia	96	Zambia	121
Kyrgyz Republic	97	Kyrgyz Republic	98
El Salvador	98	El Salvador	96
Bosnia and Herzegovina	99	Bosnia and Herzegovina	75
Ethiopia	100	Ethiopia	126