Benefits of a Product's Industry 4.0 Compliancy

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As mankind gets Smarter, a man doesn't.

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The latest industrial revolution, the fourth one labeled Industry 4.0, has been ongoing for over a decade. Still, the topic seems to be surrounded by ambiguity with lacking some of the details defining what it really means, what is the purpose of the Indsutry 4.0? Inspired by a cloud integration project implemented by Cryotech Nordic for an Italian company in autumn 2021, the aim of this thesis is to answer some of the questions that arose during the project related to Industry 4.0 by looking at the issue from the perspective of product features, while discussing the benefits that different stakeholders seek and obtain from the implementation of Industry 4.0 technologies and systems. The thesis utilises two methods for its two research questions, one where national Industry 4.0 initiatives and known Industry 4.0 products are studied and another where a literature review is conducted to find answers from group of articles. The outcome of the thesis is a construction of a Minimum Viable Product model and a categorisation for the benefits and for stakeholders receiving the benefits from the Industry 4.0 implementations with a statistical distribution of the found benefits into these categories.

Keywords: industry 4.0, stakeholder, benefits, iot, cloud computing, digitalisation

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List of acronyms

2IR Second Industrial Revolution

3IR Third Industrial Revolution

4IR Fourth Industrial Revolution

AI Artificial Intelligence

AR Augmented Reality

ASP Application Service Provider

AWS Amazon Web Services

BMaaS Bare-Metal as a Service

CIoT Consumer Internet of Things

CNC Computer Numerical Control

CPS Cyber Physical Systems

CTN Cryotech Nordic ltd.

FaaS Function as a Service

HMI Human Machine Interface

IaaS Infrastructure as a Service

ICT Information and Communications Technology

IEEE Institute of Electrical and Electronics Engineers

IIoT Industrial Internet of Things

IoE Internet of Everything

IoT Internet of Things

M2M Machine to machine

MVP Minimum Viable Product

OS Operating System

OTA Over-the-Air

PaaS Platform as a Service

PLC Programmable Logic Controller

R&D Research & Development

SaaS Software as a Service

SME Small and Medium-sized business

USB Universal Serial Bus

1 Introduction

The age of internet has taken full control of society, and increased connectivity has shaped the world in many ways. It is easy to generate new information through automation, and it is fast to acquire and share information through and with different systems. The automation has come to a point where in some situations people might not even know when they are interacting with a machine instead of a human. This new age has also come with increased computing power with more precise sensors enabling the creation of more autonomous robots that can work in unison with people and other machines without extra effort. Amongst all this a term, Industry 4.0, has grown popularity attempting to describe the general direction of where all of these new technologies and methods are taking the society. Many countries have started their own Industry 4.0 initiatives to drive the society to enable all the benefits which are possible through the introduction of the new technology and to boost up their competitiveness in the global scene. This thesis attempts to create a concrete example of what means when product is seen as Industry 4.0 compliant and also to analyse the suggested benefits of the Industry 4.0 while viewing these from the different stakeholder perspective.

1.1 Background for Topic Selection

This thesis is inspired by a cloud integration project which was commissioned by an Italian company from Cryotech Nordic ltd (CTN) . The project took place between

August and November 2021. The requirements of the project was to implement Industry 4.0 features to CTN's health tech products such as remote monitoring of usage data and some form of remote control of the devices. At that time my knowledge of the Industry 4.0 concept was very limited and I started wondering, what does the client benefit from the Industry 4.0 capability of the device? Why would the client need features that are designed to optimise the output of the product manufacturer?

The project went on and was quickly completed due to the fact that CTN already had up and running infrastructure for Industry 4.0 capabilities with their Cryocabindata.info service launched back in 2017 which operates on and utilizes Amazon Web Services (AWS). This readiness of the system without truly ever researching the "standards" of Industry 4.0 during the creation of the system sparked even more questions such as: Are there even any standards developed for the Industry 4.0 or is it just a marketing tool created for consults to fool their clients? Is it something concrete that is really invented or is it just fancy words put on phenomena that would occur anyway?

After the project it became clear that this subject could be potentially a good topic for thesis research but the emerged questions just needed some adjustment. The scope of research was broadened and the resulting research questions are as follows:

RQ1: When a product is Industry 4.0 compliant?

RQ2: What are the benefits received by different stakeholders from Industry 4.0 compliant product?

1.2 Structure

The structure of this thesis is divided into 6 chapters where after the Introduction chapter, chapter 2 introduces the reader into the topics of industrial revolutions and some of the technology enabling the latest industrial revolution. Chapter 3 is dedicated for answering RQ1 by studying different Industry 4.0 initiatives, known Industry 4.0 products and their requirements. In chapter 4 a literature review is conducted for answering RQ2. Chapter 5 is reserved for discussion and reflection of the gathered results. It will also include a section to reflect the results to the CTN project. Finally, chapter 6 concludes the whole thesis.

2 Background

This chapter covers the topics discussed in this thesis and explains the backgrounds for the main concepts and technologies enabling the fourth industrial revolution.

2.1 Industrial Revolutions

Industrial revolutions or Industry X.0 as they are more commonly labeled nowadays, are periods of time in history when collection of innovations and rapid improvements in technology have profoundly changed the socio-economic state of mankind. These revolutions have brought new technology and methodology for the world and often the inventions of one revolution act as an enabling technology for the next revolution and its major inventions. It is easy to pin point and define periods of rapid development of technology and society in history when sufficient time has passed but it becomes more difficult when one is still ongoing.

This chapter opens up the history of these revolutions, their key points and effects to society but also discusses why the newest additions to the list are not as clearly defined as the ones in the distant history. The impact of these revolutions on society and industry are so complex and there are hundreds of different important inventions made during these revolutions, so to keep this thesis coherent, this chapter will keep the focus on the impact on the Information and Communications Technology sector.

2.1.1 Industry 1.0

The First Industrial Revolution started off in England in the late 18th century. This revolution had huge impact on how the society works as a whole and this was made possible by the inventions such as the steam engine and spinning jenny which then enabled the birth of different kinds of new and revolutionary machinery. As the human and animal labour was replaced by the machinery, the output of the processes increased massively. However, this increase of the outputted goods did not change the accessibility of these goods for the common citizen in this time period yet, but the foundation of the factories meant the start of urbanisation which would eventually shape the world towards the modern society we live in today. [1]

During this period also the first steps towards ICT were taken. The first typewriter prototype, The Typographer, was introduced in 1829, which was designed to speed up the office work. It ultimately failed to fill this promise, but it sparked the idea for the future typewriter innovations. One innovation that fulfilled its potential, though, was the electrical telegraph. This can be traced back as the starting point of Electrical Engineering and also Telecommunications Engineering.

Table 2.1: Notable Industry 1.0 Innovations

Category	Notable Innovations
Manufacturing Industry	Spinning Jenny, Power Loom
Machinery	Watt Steam Engine
Transportation	The Locomotive
ICT	Typographer, Telegraph
Electricity	The Faraday Disk

2.1.2 Industry 2.0

The Second Industrial Revolution (2IR) is considered to be taken place roughly between mid 1800s and the start of first World War in 1914. During this time period the human welfare increased massively which can be perceived from the mortality rates from that time and how they declined. This was due to the innovations not only for the industry section but also innovations meant for households. This period is best known for the rise of mass production of goods, made possible by the electrification of society. As the industrialisation continued, the growth of the cities also continued with it. Slowly, the incomes started to rise and the work-hours decrease, meaning that the working class could now afford products and services they previously could not. The previously invented, now in many places fully implemented railroads shortened the world for humans enabling the easy, quick and reliable flow of the products and people from many points of interest to another.[2]

The advancements made on the field of electrical engineering prior and during the 2IR allowed the expansion of the telegraph communication networks which accelerated the flow of information during this era. The commercial industry of telecommunications was born. The discovery of radio waves accelerated the flow of information even further enabling innovations on wireless communication. The wireless telegraphy was one of the first applications to utilise this new discovery and it was especially useful for example in boat-to-boat communication. The mankind was also able to harness the sound to the means of electrical telecommunication with the invention of telephone. It easy to point out the inventions themselves but as important for the whole network of communication are the innovations developed for the transmission lines enabling the long-distance communications. During 2IR the first submarine cables were invented and by 1871 every continent was connected to a telegraph network meaning it was technically possible to reach every corner of the world within days from anywhere in the world.[2]

2.1.3 Industry 3.0

Closing in on modern day, the start of the Third Industrial Revolution (3IR) is under debate and depending on sources it is thought to be started either in late 1960s or 1990s [3], [4]. The key aspects of this revolution, whether the starting point is earlier or later, are definitely the introduction of microchips and computers and their integration to the society and industry standards, although there are also many other revolutionary innovations created during this time period, like nuclear power. This ICT revolution accelerated the flow of information to completely new levels and the ability to perform complex calculations with unprecedented speeds helped the industries to take the optimisation game up a par.

The invention of programmable logic controller (PLC) introduced computers to factory setting. Its role was to replace complicated electromechanical relay systems which drove different manufacturing machinery, increasing the reliability and precision of these systems [5]. Robotics allowed the design of completely new kinds of production lines and ways of creating products while further automatising and optimising the tasks at factories. The introduction of personal computers increased the availability of computing power in home and business use which grew the demand for different kind of software, greatly expanding the new born software industry. The interconnectivity of the computers was sought after right at the beginning and the foundation for the internet was created in the 1960s by the US Department of Defense. [4]

It is difficult to overstate the impact of the Information and Communications Technology (ICT) revolution. The general purpose nature of microchips and computers has made sure that they have infiltrated to each and every possible industry segment and today you find them in places where you least expect them. Because of this ubiquitous nature of the inventions of Industry 3.0, the old picture of "industry" meaning a factory manufacturing goods is not sufficient to cover all the nuances of this revolution but it also makes the topic quite vague. Is it even feasible to label them as revolutions of industry when the major effects are seen on society?

2.1.4 Industry 4.0

The Fourth Industrial Revolution (4IR) was first mentioned in 2011 with the term "Industrie 4.0" (later Industry 4.0 in English literature) at the Hannover Fair in 2011 by Professor Wolfgang Wahlster and his partners [6]. This speech focused on the future of the industrial setup with the concept of smart factories and cyber physical systems (CPS) in general. But like every other industrial revolution before, the effects of it are far greater than just what happens in factories and its value chains. In 2016 Klaus Schwab made more broader definition for the Industry 4.0 technologies and methods and how they affect the socio-economic state of mankind. He listed new technologies, "Megatrends", under three different categories: Physical, Digital and Biological. In his description, the physical category consist of Artificial Intelligence (AI) powered technology like autonomous vehicles and advanced robotics, 3D printing and advances in materials sciences. The digital category consist mainly of Internet of Things (IoT) but also technologies like Blockchain and Digital Platforms and how they act as enablers for economic changes such as on-demand economy. The last category, Biological trends, he describes ways of gene manipulation and how these methods will revolutionise the way we treat different medical conditions.[7]

With the introduction of the term Industry 4.0, there have been a rise of multiple different "4.0" terms such as Education 4.0, Health 4.0 and Construction 4.0 to name a few. This is due to fact that the original Industrie 4.0 term defined a scope which considered the effects of the enabling technologies mainly for the manufacturing industry setting. These other 4.0 terms are described with the same enabling technologies as the Industry 4.0 but with a different perspective and purpose. This can be seen as an indicator that although the term Industry 4.0 can be and is used interchangeably with the term Fourth Industrial Revolution, the latter term does have a more general and broader scope to its tone and with that it properly includes all the "4.0" terms in itself. Nevertheless, each of these new terms just emphasize the vast effects the enabling technologies have brought to the whole economy.[8]–[10]

2.1.5 Evolution of Manufacturer-Customer Feedback Loop

During the early phases of the industrialisation, the scope which could be considered as part of the manufacturing and development process of a product, can be quite easily restricted to the things happening in the factories and laboratories. If their products were faulty and they were (or were not) returned to them after they had broken down, these companies were solely relying on the feedback the client could tell them about the incident and the possible inspection of the faulty product. This kind of feedback can be helpful, but often may leave a lot blank spaces from the whole story and sometimes the client may even lie if the product has broken down because of their actions, thus hindering the rate of which the correct upgrades to the product can be developed.

The current emergence of almost real-time data flows from different sources has made it possible to create different kinds of feedback loops for businesses. The IoT technology has made it possible for manufacturing companies to receive automatic feedback, the usage data, from their products, removing the human factor from the equation, allowing them more easily and precisely to fine tune and further develop their products. This expanding reliance of data coming outside the factory setting has created some interesting dependencies where companies not only want the data from their machines and products but also desperately need it. This kind of behavior has been common for pure software companies where getting the data from the clients were trivial for the most part but now this same ideology is being transferred to manufacturing businesses as well. When companies rely on data coming from the products held by the customer, it is obvious that the ideal situation is that the product stays intact without third party modification, but as legal cases like Right to Repair have shown, this is not without its pitfalls. Of course there is also a strong economical interest of not letting clients to use third party repair services as after sales-services are a huge business for many companies or they might also have a sales strategy where old and broken items wont be fixed but rather replaced with new ones. [11]

2.1.6 Criticism of Industry 4.0

The rapid emergence of a new industrial revolution after 3IR has not passed unnoticed by sceptics. The critique revolves around a single issue, the lack of "new" technology, something that has not been around before. In 2021, Jongho Lee and Keun Lee used mathematical models to analyze and compare different metrics such as originality and generality of the US patents from 3IR and 4IR era and found that the technologies emerging during the 4IR were not as ground breaking and unique when compared to 3IR technologies [3]. The 4IR, especially the term Industry 4.0 has been blamed to be just a marketing strategy for consultants and the emergence of the many new 4.0 terms has definitely not silenced those voices. Farkash wrote an article to IndustryWeek magazine in 2019 stating that the current hype around the so-called Industry 4.0 is just another sequel of the Digital Revolution, the 3IR, started in the 1950s [12].

2.2 Internet of Things

When the term "internet of things" was first used in late 1990's by Kevin Ashton (or possibly in a publication of International Telecommunications Union) [13], the applications to be considered such technology were very limited. Ashton was promoting the then-new RFID technology which he described as a prerequisite for IoT, or at least when it comes to automated tracking of items. It is easy to say after 2 decades that even if RFID itself did not solve this specific problem it definitely was the kick start for the computer aided traceability of items and even people. From its early days the capabilities and data processing abilities of even the smallest devices have grown exponentially, shaking and reforming the definition for the word IoT multiple times to a point where it is really difficult to clearly pin point the actual meaning of Internet of Things.

2.2.1 Definition

Despite IoT having the word internet in its name, the definition for it can be simplified as a network of physical objects [14]. This broad definition, which was described as fuzzy in IEEE publication [13], varies depending on sources, but usually it leaves out general purpose computers, like PC's, laptops and smart phones of its scope. This said, there are also sources that include these devices as part of the IoT [15]. Some instances prefer the term Internet of Everything (IoE) when referring to every possible device that has network capabilities while differentiating them from more specific purpose IoT devices [13]. IoT is also used interchangeably with the term CPS, especially in the United States, although this may be slightly misleading as CPS usually refers to more autonomous and complex systems with physical control over some other appliances or systems common in industrial setting [13].

The IoT can also be considered from more broader technical angle, where the focus is not on the devices, the nodes in the network and how they are built but rather what data they can provide and how this data can be processed into information and further into knowledge. This view emphasizes the autonomous machine-to-machine (M2M) communication, data acquisition and big data processing [13], [16]. Whitmore et al. summarised this definition as: "a paradigm where everyday objects can be equipped with identifying, sensing, networking and processing capabilities that will allow them to communicate with one another and with other devices and services over the Internet to achieve some objective" [16].

2.2.2 Characteristics

As its name suggests, IoT device's main function is that it can connect to some network using some standardised communication method while having a unique id to separate it from other devices. IPv6, IPv4 and MAC address are the more common ways of identifying a device while WiFi, Ethernet, LTE and Bluetooth LE are some of the most known communication methods among the IoT devices. Another aspect that is very true for every IoT device is that they truly exists in a form of a physical *thing*. These are perhaps the only features that can be attributed to each and every IoT device [13], [16].

Other common ability of an IoT device is to collect data and pass it forward. In the simplest form this means e.g. measuring a temperature reading and broadcasting it on a bluetooth service. But here lies the problem when it comes to distinguishing general purpose computers from the more specialised IoT devices: each and every general purpose computer can and will measure something - even if we ignore all the temperature sensors on the motherboard and other components of the system and all the diagnostic data it can pass to the manufacturers - and that something is the meta data of the usage of the computer and its applications which can be passed to the software providers. This characteristics is attributed to almost any active IoT device apart from passive devices like some RFID tags which task is to identify an object, leaving them into the questionable zone of maybe not being an IoT device at all. [16]

Broader characteristics can be attributed to the more complex systems these multiple connected IoT devices can form. Here, common attributes to these formed networks are (big) data analytics, usually AI driven, and automatised actions decided by the controller of the network from the gathered data and which are then published for the nodes in the network [16].

2.2.3 Consumer IoT

Number of different IoT subcategories have emerged due to the vast number of applications and use cases for the technology. Although these different categories overlap in many cases, the categories help to understand the purpose of the technology, what kind of interfaces they need to have to bring value and in what kind of situations they are being used.

Consumer IoT (CIoT) is the most common category, at least for typical consumers. In this category you find products that aim to ease the everyday living of people, like robot vacuum cleaners, smart watches and air quality sensors etc. In this category, the standards for the automated actions and accuracy of measurements are not necessarily very demanding, which is why the average price of these devices remain affordable for an average consumer. The autonomy of these devices is quite restricted and they usually require user input to be operated. The architecture of these devices and the networks they form usually are heavily linked to smart mobile devices which are used to control and monitor the acquired data from the devices via apps provided by the manufacturer. The devices in this category usually links either directly to the mobile devices via bluetooth or the connection can established via a cloud server providing more functionality. [17]

2.2.4 Industrial IoT

Industrial IoT (IIoT) consists more of the technology and systems that can be attributed to CPS. The technology is aimed to especially boost productivity and efficiency of operations. Here the autonomy of the devices and the M2M connectivity are the keys for concepts like smart factories where multiple autonomous (robot) systems can interact with each other forming a network of subsystems with a common goal etched together by controlling cloud software. With this kind of setting the reliability of these smaller systems and devices has to be many times higher when compared to systems in CIoT as the reliability of the whole system is rated from its weakest parts, making them significantly more expensive when compared to CIoT systems. Boyes et al. defined this as: "A system comprising networked smart objects, cyber-physical assets, associated generic information technologies and optional cloud or edge computing platforms, which enable real-time, intelligent, and autonomous access, collection, analysis, communications, and exchange of process, product and/or service information, within the industrial environment, so as to optimise overall production value." [16].

2.3 Cloud Computing

The first ideas of publicly available computing assets, cloud computing as it is nowadays called, were composed in the 1960's by John McCarthy [18]. The term "Cloud" was coined by AT&T and General Magic in 1993 during their launch of Telescript and PersonaLink technologies and the "Cloud Computing" by Compaq in 1996 although the usage of cloud symbol as a representation of a network asset was introduced with the ARPANET in 1977, before the now ubiquitous internet was even born [19]. Today, there are multiple different cloud services offered for different client and business needs ranging from infrastructure level services to small apps running in cloud environment. Cloud computing can be defined as the on-demand delivery of computing assets such as storage, networks, applications, databases etc. which can be easily commissioned, decommissioned and reconfigured with minimal effort [16].

2.3.1 Service Models

There are many different cloud service models like Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) that have been around for over a decade but new models have been emerging as of late such as "Serverless computing" services also known as Function as a Service (FaaS), which aims to minimize the expenses by turning off when the service is not required and Bare-Metal as a Service (BMaaS), which offer single tenant top performance cloud resources. [16]

These different service models attribute to how much control does the client have over the service and its resources. IaaS provides scalable computing assets like database storage and management, multiple customisable virtual machines with scalable performance and networks to connect these different assets. It is meant for situation where the client needs a scalable substitute for on-premise server, but does not have the need for running software on the local server, does not have the need for customisability of the hardware of the local server or does not consider the cost of purchasing and maintaining the local hardware to be feasible. AWS is seen as the father of the IaaS model with their elastic computing cloud, EC2, which was officially launched in 2008, followed by many big players like Google and Microsoft with their cloud services after it. The BMaaS model offers similar computing assets but with better performance due to the fact that each deployed virtual machine runs on dedicated piece of hardware, "Bare-Metal", sharing no resources with other tenants. [16]

PaaS, which aims to serve as platform for cloud deployed applications with minimal configuration, has gained a lot of popularity among software developers in recent years due to the rise in popularity of containerisation of software. Many simple applications do not require the full scale ability to configure and utilise the (virtual) operating system they run on and thus they can be deployed to container which is easy to maintain and deploy. This sort of software development has created a whole new architecture model, microservices, for software design, where small parts of the software are independently deployed to optimise the operations of that particular piece of software and to prevent the whole software from failing during an error. FaaS has pushed this idea even further by making the deployments only to activate when their actions or operations are requested, thus minimising the wasted computation resources even further. [16]

SaaS as a term, on the other hand has been around for quite some time first appearing on US Patent in 1985. The first SaaS like services started to appear in 1990's when Application Service Providers (ASP) started to offer different kinds of software services over the internet. As of now, most notable SaaS are the likes of Microsoft Office 365 and Google Workspace services, which offers e.g. file storage, email, spreadsheets and word processing applications through the web browser. T. Mäkilä et al. lists the definition of SaaS to be a software that is used through web browser, that it is not tailor made for each client, it does not need local installation nor special integration and the pricing of the software is based on actual usage of the software [20]. With the internet filled with different web applications and SaaS services, it is sometimes difficult to differentiate these two from each other as many web applications also meets the definition of SaaS for the most part and that is why SaaS can be defined also as collection of software with usage based pricing, ready to be deployed on-demand through web browser.

2.3.2 Benefits and Disadvantages

The clear benefits of any public cloud based solutions are the on-demand scalability and availability of the services and the usage based pricing models. These factors are especially important for start-ups and small and medium sized businesses (SME) reducing the risks of software and IT service acquisitions and making it easy for them to upscale the services as the operations of the business grows. [21]

The most obvious disadvantages of using cloud-based services stem from the fact that they are usually hosted remotely by a third-party operator. This can be a security risk for some companies handling confidential data. When comparing SaaS applications to locally installed applications the responsiveness and performance can be reduced due to delays when fetching data from remote locations. In IaaS multi-tenant models, although very rare but plausible situation is that the performance of other tenants services may be suddenly degraded due to increased resource load of a neighbouring tenant. This is called the noisy neighbour effect. The multi-tenancy can also be data security issue in a situation where an attacker can infiltrate to one virtual machine risking the other tenants' data in the same physical machine. Many of these issues can be dealt with by improving the cloud automation with techniques like load balancing, resource management, monitoring and access management. [21]

3 Product's Industry 4.0 Compliancy

Organisation's level of Industry 4.0 compliancy can be measured with a maturity model like in Sprint 4.0 [22] but what does it mean to have a 4IR compliant product? Industry 4.0 is not a standard in a similar fashion like for example USB with physical properties and specific protocols, which can be identified immediately, but rather a concept with collection of tangible and intangible properties which can be seen as a critical part for reaching the next level of business and living standard, the society as a whole. Given the vague nature of 4IR, a more narrow scope for the broad term Industry 4.0 is needed to focus research on specific topics, as 4IR can be viewed from many perspectives, and with these perspectives the requirements and standard levels of enabling technologies differ to some degree.

3.1 Methods for Definition

To define what is Industry 4.0 compliancy, the best way to find the answer is to look for a product that serves as a Minimum Viable Product (MVP) with respect to Industry 4.0. There are huge and complex projects that can easily be declared 4IR compliant, but as systems begin to simplify and the details become more apparent, the true meaning and practical standard of 4IR may be revealed.

Many vague and ambiguous definitions of 4IR compliance can be found in literature, but to understand what is required of a 4IR compliant product, different 4IR project cases and especially government sponsored projects and their list of requirements are a good place to start. These 4IR initiatives around the world aim to increase industrial and business capabilities and overall knowledge in the region. Fourth Industrial Revolution initiatives are most often referred to as "digitalisation", "advanced manufacturing" or "Industry 4.0", the latter two being manufacturing-specific, while the former is a broader term, and these initiatives can be targeted at a variety of purposes, including the public sector and education. This broader term also makes it difficult to provide a detailed description of a 4IR product, and therefore this thesis focuses more on defining the product in an industrial context, while also taking into account the broader context.

The second option is to analyse the most obvious 4IR products: products that are proven to enable or embody the fourth industrial revolution i.e. products that represent the megatrends of Industry 4.0. By analysing the characteristics, components and methods of these systems and products, the results should reveal whether there is a common factor or factors in these systems and products.

3.1.1 Industry 4.0 Initiatives

The definitions for the 4IR product in the industrial initiatives revolve around the Smart Factory and Industrial Internet theme. In the EU there are union wide initiatives, such as Horizon Europe, that create the top level guideline goals for the member states to follow, but the details and how to implement these guideline goals is up to the member states. Businesses can seek grants from these state backed operators for their different activities and projects, e.g research & development (R&D) projects or acquisition of new software or hardware to improve their competency and the operators will define a set of requirements which the activity will need to meet in order to receive the total amount of the grant.

Table 3.1: Examples of National Industry 4.0 Initiatives

Country	Initiative
Finland	DIMECC - MANU
France	Industrie du Futur
Germany	Industrie 4.0
Italy	Piano Nazionale Industria 4.0
Netherlands	Smart Industry
United Kingdom	CATAPULT - High Value Manufacturing

When going through documents related to the initiatives, it came clear that they did not give detailed answers on what kind of products were adequate for their programme, but instead they just mentioned a list of 4IR enabling technologies (AI, CPS, IoT etc.). This may be due to the fact that every applicant had to have their project accepted by a supervisor who would ultimately decide if the acquisitions and development outcomes would fit their funding scheme. Italy's Piano Nazionale Industria 4.0 was an exception though, and more specifically its Super and Hyper depreciation programme, which defines the requirements of an adequate physical product in three descriptions as shown in the Appendix A and its section A (Allegato A) and for software products that are related to these section A products in section B (Allegato B). The physical products are divided into three categories: "Capital goods whose functioning is controlled by computerised systems and/or managed by means of appropriate sensors and drives", "Systems for quality assurance and sustainability" and "Devices for human-machine interaction and for the improvement of ergonomics and safety in the workplace in logic 4.0". The first category consist of products mainly for factory setting but the interesting part of the definition is the second and third list of items. These describe characteristics and features of an adequate IOT/CPS product in detail and give a great insight of how 4IR compliant product should operate. This definition uses the word factory, but it was later adjusted to allow products for example in health tech segment and agriculture to be accepted as well, bending the strict word "factory" towards something more of a lenient word like "business". The second list (items 1-5) consists of mandatory requirements the product should meet and the third list (items 6-10) are a set of features which aims to "make them assimilable and/or integrable to CPS" and the product also has to meet 2 out of 5 of them. The combined list is as follows [23]:

Piano Nazionale Industria 4.0 IOT/CPS Requirements

1. It is controlled by Computer Numerical Control (CNC) and/or PLC
2. It has interconnection to factory computer systems with remote loading of instructions and/or part programs
3. It has automated integration with the factory's logistics system or with the supply network and/or with other machines in the production cycle
4. It has simple and intuitive Human Machine Interface (HMI)
5. It has compliance with the latest standards in terms of safety, health and hygiene at work
6. It enables remote maintenance and/or remote diagnostics and/or remote control systems
7. It enables continuous monitoring of working conditions and process parameters by means of appropriate sets of sensors and adaptability to process drifts
8. It has characteristics of integration between physical machine and/or plant with the modelling and/or simulation of its behaviour in the process
9. It has devices, instrumentation and intelligent components for integration, sensing and/or interconnection and automatic process control also used in the modernization or revamping of existing production systems

10. It has filters and systems for the treatment and recovery of water, air, oil, chemical and organic substances, dust with systems for signalling the filtering efficiency and the presence of anomalies or substances alien to the process or dangerous, integrated with the factory system and able to warn the operators and/or stop the activities of machines and plants

The Appendix A section B (Allegato B) consist of software that are related to the section A physical products. This includes software that enable and/or improve the factory's Cybersecurity, Augmented (AR) and Virtual Reality capabilities, Digital Twin capabilities, Production system optimisation via simulation or data analysis, Production monitoring, Management and coordination, Interconnectivity of devices (IIoT), Transition to cloud based systems, HMI's, AI capabilities and Predictive maintenance capabilities. These applicable software solutions are listed as follows [23]:

Piano Nazionale Industria 4.0 Software Solution Requirements

1. Solutions for the design, performance definition/qualification and production of artefacts in nonconventional or high-performance materials, capable of enabling the design, 3D modelling, simulation, experimentation, prototyping and simultaneous verification of the production process, the product and its characteristics (functional and environmental impact), and/or the digital archiving and integration in the company's information system of information relating to the product life cycle (EDM systems, PDM, PLM, Big Data Analytics),

2. Solutions for the design and re-design of production systems that take into account material and information flows,

3. Software, systems, platforms and decision support applications capable of interpreting data analyzed from the field and displaying specific actions to line operators to improve product quality and production system efficiency,

4. Solutions for the management and coordination of production with high features of integration of service activities, such as factory logistics and maintenance (such as intra-factory communication systems, fieldbuses/fieldbuses, SCADA systems, MES systems, CMMS systems, innovative solutions with features referable to IoT and/or cloud computing paradigms),

5. Solutions for monitoring and controlling the working conditions of machines and production systems interfaced with factory information systems and/or cloud solutions,

6. Virtual reality solutions for the realistic study of components and operations (e.g. assembly), either in immersive or visual-only contexts,

7. Solutions of reverse modelling and engineering for the virtual reconstruction of real contexts,

8. Solutions capable of communicating and sharing data and information both with each other and with the environment and surrounding actors (Industrial Internet of Things) thanks to a network of interconnected smart sensors,

9. Solutions for asset dispatching and product routing in manufacturing systems,

10. Solutions for quality management at the production system and process level,

11. Solutions for access to a virtualized, shared and configurable set of resources to support production processes and production and/or supply chain management (cloud computing),

12. Solutions for Industrial Analytics dedicated to the treatment and processing of Big Data from IoT sensors applied in the industrial field (Data Analytics & Visualization, Simulation and Forecasting),

13. Solutions of Artificial Intelligence & Machine Learning that allow machines to show an intelligent ability and/or activity in specific fields to guarantee the quality of the production process and the reliable functioning of the machinery and/or plant,

14. Solutions for automated and intelligent manufacturing, characterised by high cognitive capacity, interaction and adaptation to context, self-learning and reconfigurability (cybersystem),

15. Solutions for the use along production lines of robots, collaborative robots and intelligent machines for worker safety and health, end-product quality and predictive maintenance,

16. Solutions for the management of augmented reality through Wearable devices,

17. Solutions for devices and new human/machine interfaces enabling the acquisition, delivery and processing of information in speech, visual and haptic formats,

18. Solutions for plant intelligence that ensure energy efficiency and decentralisation mechanisms in which energy production and/or storage can also be delegated (at least partially) to the factory,
19. Solutions to protect networks, data, programs, machines and plants from attacks, damage and unauthorized access (cybersecurity),
20. Virtual Industrialization solutions which, by virtually simulating the new environment and uploading the information to the cyber-physical systems at the end of all the checks, make it possible to avoid hours of testing and machine downtime along the real production lines.

These two lists provide great insight of what is required from 4IR compliant product. Although there are lots of different views of what features a 4IR compliant should have, these lists give a strong suggestion that the interconnectivity of the devices and remote management of CPS is the desired outcome of these initiatives.

3.1.2 Industry 4.0 Compliant Products and Systems

As discussed in the previous chapter 2, the megatrends of 4IR describe many technologies such as 3D printing, AR/VR and advanced robotics. With this in mind, it is possible to find some established products that can be seen as embodiment of the 4IR. Studying the features of these established products can give proper insight of what features the products have in common. In other words these common features can be seen as the requirements for the MVP. In this section, three different products were selected for review, representing robotics, additive manufacturing and augmented reality. These megatrends were selected because it is fairly easy to find representatives for them. Two of the selected products, Ultimaker 3D printers [24] and Microsoft HoloLens [25], were chosen purely because they are widely known in the industry and I have previous knowledge of these systems. Gausium's industrial robot vacuums were chosen because they were the first hit (March 2023) in a Google search query for "industrial robot vacuums" and with a quick glance at their website it was clear that these products meet several of the Piano Nazionale Industria 4.0 list of features [26].

Gausium Industrial Robot Vacuums

The robot vacuums of Gausium are highly autonomous and equipped with great connectivity enabling features such as remote control, monitoring, Over-the-Air (OTA) software updates and M2M communication. The ecosystem consist of the robot vacuum equipment and their periphereferals, cloud service and mobile app. [26], [27]

Ultimaker 3D Printers

The 3D printers of Ultimaker are well known in the industry. These printers are equipped with Debian Linux operating system (OS) based computers [28] and they can be connected to an ecosystem of printers via WiFi and Ethernet. The management software of Ultimaker makes it possible to control and monitor the devices remotely and they also enable OTA updates for the firmware. [24], [29]

Microsoft HoloLens AR Equipment

Microsoft HoloLens is one of the high-end AR products in the market. It is widely used in different scenarios from education to marketing to maintenance and more. Running on a version of Windows 10, the HoloLens utilises Windows ecosystem in its operations and it has nearly all the capabilities of a desktop computer. The Microsoft Intune also adds remote management of these devices and Windows Updates ensures the OTA updatability of these devices. [25]

Table 3.2: Established Industry 4.0 Products' Identified Common Features

Feature\Product	Ultimaker 3D Printers [24], [28], [29]	Gausium Robot Vacuums [26], [27]	Microsoft Hololens [25]
Runs on OS	Debian Linux	No information available	Windows 10
Internet connectivity	WiFi and Ethernet	WiFi	WiFi
Remote management	Digital Factory and Cura	Gausium App	Microsoft Intune
Remote monitoring	Digital Factory and Cura	Gausium App and Cloud Platform	Microsoft Intune
OTA updates	Cura	Cloud Platform	Windows Update

The Table 3.2 above lists common features of these 3 products. Because of the different purposes of these devices, the common features tend to be more general in nature. The results of this listing also emphasizes the importance of internet connectivity and remote controllability of any CPS.

3.2 Minimum Viable Product

When inspecting the Piano Nazionale Industria 4.0 requirements lists and the Table 3.2 the key enabling concept of a 4IR compliant product is without a doubt the interconnectivity of devices - the ability to connect to internet. It is the backbone of the transformation to the new age of manufacturing and the society as a whole. Although there are sources that indicate IOT alone is not the initiator of the emergence of 4IR technologies the best way to counter this, is to consider a hypothetical situation where a 4IR product is designed without IOT capabilities, perhaps a 3D printer or AR/VR system with no internet connection, locally developed AI that has no access to remote data and cannot be accessed from outside or an autonomous factory robot which can communicate with other local factory devices with BLE but does not send data to any server. Would these definitions fulfill the 4IR compliancy? Technically they might, but the practical usage of these applications would be drastically hindered when compared to similar applications with IOT capabilities to a point where they would not match the continuously developing characteristic of a

4IR product.

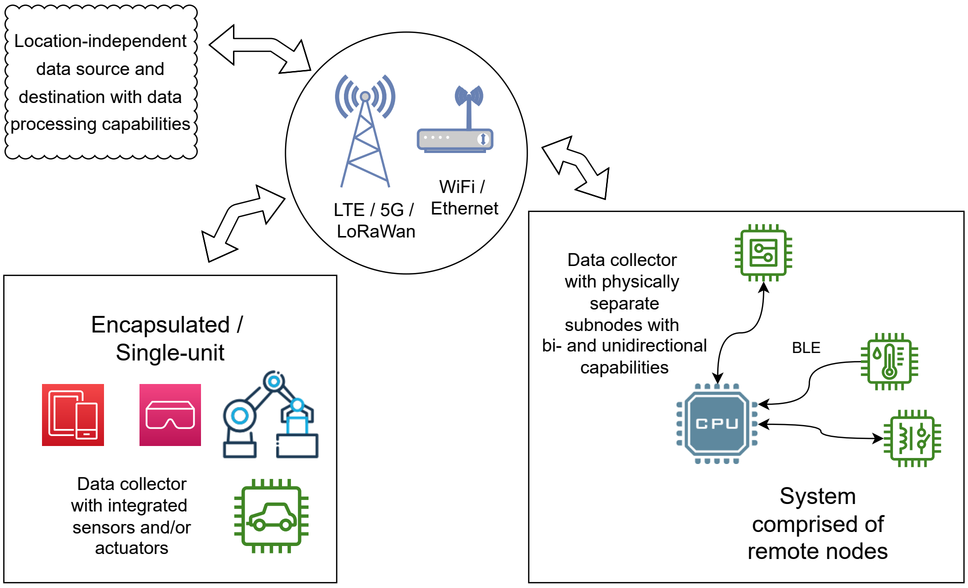

Figure 3.1: Illustration of Simplified 4IR MVP Systems

How does this then shape the 4IR MVP? The word "product" may be a bit misleading here, as the system consists of several software and hardware products, but when the system is simplified, **its requirements can be described as a client-server relationship**, where the devices "in the field" are clients, in this case data collectors or nodes, and the server is the final recipient of the collected data, but also the source of possible commands and updates to these data collectors. This is illustrated in the Figure 3.1 above. In the figure, the nodes are divided into two categories, the one on the left representing a unit with no remote modules, while the one on the right represents a system consisting of remote nodes located close to each other. This is not an absolute definition, and encapsulated units may also contain remote modules as sub-nodes. This model also views the sub-nodes as equipment capable of remote communication but without the ability of communicating over the internet and thus making them dependent of a some sort of data processor between them and the data destination.

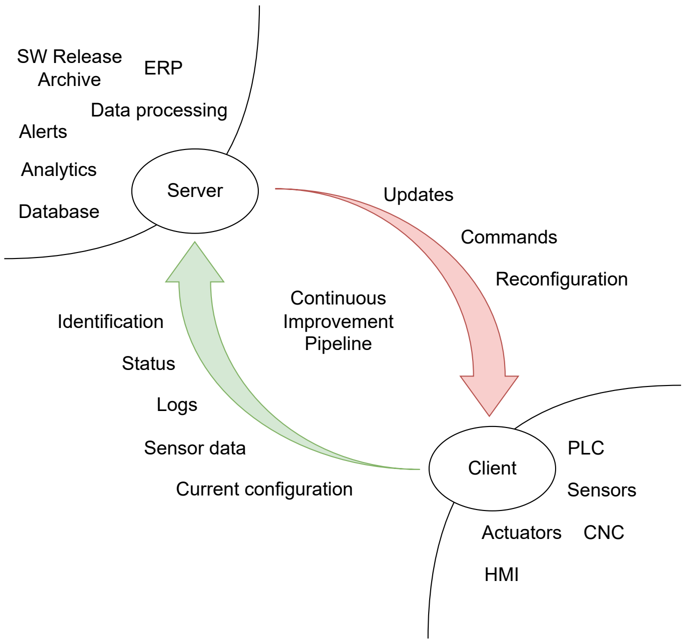

Figure 3.2: Simplified 4IR MVP Client-Server Relationship

If the abstraction is taken a step further, the underlying CPS on the client side becomes irrelevant. This is illustrated in Figure 3.2. **This model focuses on the idea of continuous improvement of the client systems and emphasizes the architecture which allows automated modification of the running software from remote location.** A common example of such architecture is mobile applications and their application stores. The simplest way to implement such a system is to build a software solution on top of computers that already have all the necessary network tools and are capable of running OS. Of course, this is not mandatory, and custom solutions are sometimes the only option, but in many cases the use of operating systems ensures the use of standardised methods for networking using established software tools.

Table 3.3: Piano Nazionale Industria 4.0 IOT/CPS Requirements vs. MVP

#	Short Item Description	Matches MVP Characteristics
1	CNC / PLC controlled system	No
2	Remote loading of instructions	Yes
3	Automated integration to logistics system or supply network	Yes
4	HMI	No
5	Safety compliance	No
6	Remote maintenance / diagnostics / control	Yes
7	Continuous monitoring and automated adaptability to process drifts	Yes
8	Integration between physical machine and simulation of its behaviour	Yes
9	Sensing / interconnection and automatic process control	Yes
10	Automated process anomaly recognition and warning system	Yes

When compared to the list of requirements for a physical product drawn up by Piano Nazionale Industria, MVP does not meet three of them as they do not have any reference to interconnectivity of devices. Item 5 is more general in nature and does not take any technical position, while items 1 and 4 are very closely related to IT but not directly to the features of the client-server architecture. Instead they focus on the design of the underlying CPS, its user experience and visual design of the system (4) or to how its physical actions are controlled (1).

Table 3.4: Piano Nazionale Industria 4.0 Software Solution Requirements vs. MVP

#	Short Item Description	Depends on MVP Characteristics
1	EDM systems, PDM, PLM, Big Data Analytics	Only client to server data flow
2	Design software capable handling data from real context	Only client to server data flow
3	Data interpretation and action suggestions	Only client to server data flow
4	Management and coordination of production	Yes, completely
5	Monitoring of machines and working conditions	Yes, completely
6	VR	Only client to server data flow*
7	Reverse modelling and virtual reconstruction	Only client to server data flow*
8	IIoT	Yes, completely
9	Asset dispatching and production routing	Yes, completely
10	Production system quality management	Only client to server data flow
11	Cloud computing	Yes, completely
12	Data Analytics & Visualization, Simulation and Forecasting	Only client to server data flow
13	AI/ML	Depends on implementation
14	Self-learning and reconfigurability	Depends on implementation
15	Predictive maintenance and quality control	Yes, completely
16	AR	No
17	HMI	No
18	Plant energy production and storage management	Yes, completely
19	Cybersecurity	No*
20	Virtual system simulation and integration to real context	Yes, completely

When examining the list of requirements for software solutions and comparing them to the MVP, most of them cannot be directly linked to client-server architecture and continuous improvement. However, a significant number of the items (1, 2, 3, 10, 12) relate to data analytics designed to analyse the data received from clients in the field, and although they do not have a direct control on clients, they generate suggestions or visualisations from the received data for operators to use to adjust the processes and devices, meaning that the software system greatly benefits from the MVP features. There are also items on the list (13, 14) that are AI/ML related and depending on the implementation of the system the end product may or may not require the MVP characteristics. Items 6 and 7 are also dependent on the implementation of the modelling system: it may require the real life data from the processes and systems to be able to construct the virtualisations, but again this is not mandatory and also the data flow here is only from client to server.

Item 16, although part of a clear IOT solution, represents the "data collector with remote nodes" -system illustrated in Figure 3.1, where the wearables are the nodes surrounding the collector. Although the system is most likely built on top of a device utilising a client-server architecture, this is not mandatory and thus is not dependent on the MVP characteristics. Item 17 is HMI related and thus not depend on the MVP characteristics. Finally, the item 19 which defines a cybersecurity characteristic, is an important one. It can be argued that without the client-server architecture, the cybersecurity would not be a thing at all but does it really depend on it? Another argument is that without cybersecurity any reliable grand scale networking would be impossible so is it really the enabler for the client-server architecture? I would argue that this is the case and the cybersecurity aspect will get more attention in the future as the networking standards will mature especially in the case of remote nodes utilising e.g. bluetooth.

3.3 RQ1 Conclusion

The two listings in the Section 3.1.1 describing the requirements of Piano Nazionale Industria 4.0 and the Table 3.2 describing the common features of the representatives of the 4IR megatrends draws a picture of a 4IR compliant MVP which clearly relies on the interconnectivity of devices. This dependency on interconnectivity, as depicted on the Figures 3.1 and 3.2, enables the architecture on which a two-way data flow can be built upon and which ultimately enables the continuous improvement pipeline. With this analysis of the chapter 3 the research question "RQ1: When a product is Industry 4.0 compliant?" can be concluded as follows: CPS (also IOT / IOE device) which is following the client-server architecture and thus enables remote management and monitoring of such device and more further the continuous improvement pipeline, can be seen as the embodiment of the Industry 4.0 and then is also Industry 4.0 compliant. Industry 4.0 compliancy cannot be achieved with only the physical product but it also requires the software ecosystem around it handling the two-way data flows.

This definition is not absolute and does not take due account of conflicts caused by products representing technology not directly relying on interconnectivity and data flows such as virtualisation/digital twin or AI. Nevertheless, the definition gives a fairly good general idea of the minimum features that a CPS must have in order to be considered Industry 4.0 compliant.

4 Literature Review

This chapter describes the process of gathering the data from the relevant literature and explains the choices made during the classification of the resulted datasets. The first section covers the methods utilised to process the data, the second section describes the source materials used in this literature review and the third how the data was categorised. Many case reviews regarding Industry 4.0 have already been conducted in the past and these articles provide great means of processing the data and focusing on the relevant points in the source material. The aim of this chapter is to find answers to the RQ2: What are the benefits received by different stakeholders from Industry 4.0 compliant product?

4.1 Review Methods

Following the example of Awan et. al. [30], this literature review utilises a systematic literature search methodology but instead of following it strictly, the rules of the method are customised allowing for example the introduction of source material outside the search queries that is already proven to contain valuable information. The reason for not following the method strictly is purely related to time issues and the amount of work it would require. Also, when searching material for the chapters 2 and 3, many interesting articles were found with related data. The goal of systematic literature search method is to summarise existing literature to answer specific scientific question. It reflects the notion that review is based on selected criteria to answer a focused question, leading to a conclusion. The systematic review method also requires a time frame in which the literature can be selected, making it more comprehensive and well-defined review when method compared to others.

The time frame for this literature review can be drawn starting from 2011 (the year the term Industry 4.0 was coined) and ending to this year 2023. Although the digitalisation of the society and businesses has started earlier than 2011 and projects and cases similar to Industry 4.0 can be found prior to that, there is no need to extend the time frame any further and naturally it also makes it easier to find cases using actively the term Industry 4.0. The tool used finding the source material was University of Turku's Volter. The first step in collecting source data is to define the search queries and identify the data. This is followed by a screening process, which removes irrelevant material from the identified articles. A protocol is followed here, first checking for possible duplications, then going through the titles of the articles and finally reading the abstracts of the articles to ensure that no irrelevant material remains.

Finally, in order to find relevant information in the literature to answer RQ2, it is necessary to focus on the benefits that can be clearly demonstrated as a result of the adoption of 4IR technology. As Industry 4.0 is heavily marketed and promoted by consultants, the benefits are polarised into expected benefits and benefits that are actually recorded after deployment. Because of this reason, literature covering retrospects of Industry 4.0 implementation are of the highest value.

Table 4.1: Volter Search Queries and Identified Articles

Query	Hits	Amount After Screening
"industry 4.0+stakeholders"	8	8
"industry 4.0+benefits"	13	6
"industry 4.0+case"	28	13
Total	49	27

Table 4.1 above expresses the search queries used for finding the material for this literature review. As RQ2 is "What are the benefits received by different stakeholders from Industry 4.0 compliant product?", the term "industry 4.0" is mandatory here. Also the "stakeholders" term is key in finding relevant articles. This is well displayed on the first item of the table as none of the hits were deleted after screening. Term "benefits" did also get hits, but alas, many were irrelevant for this study. The last attempt was to use term "case". The logic behind it was to find case reviews and studies about industry 4.0 and it did result in quite many hits, although there were a lot of duplicates among them.

In the screening process, the abstracts of the articles were read to get some sort of understanding what the article is discussing and also search terms "stakehol" and "benef" were used within the articles to see if there were any indication within the text that it might contain useful data, if the abstract itself could not give sufficient information. The reason for using only part of a complete word as a search term was to also hit the possible inflected forms of the word as well. The screening process was designed to yield as little articles as possible with the most probability of still finding relevant data for the study as time was of essence. After screening, the total amount of accepted articles was 27.

4.2 Selected Literature

In addition to the data sources found with the systematic search method, a few useful sources were identified outside the search scope during the process of finding information for the chapters 2 and 3. These sources contain data where different Industry 4.0 stakeholder definitions already exist through implementation of such case or cases like in *DIMECC's MANU –future digital manufacturing technologies and systems* [31] as an example.

Table 4.2: Selected Articles for the Literature Review

Title
Search Query "industry 4.0+stakeholders"
Aligning digitalisation and sustainable development? Evidence from the analysis of worldviews in sustainability report [32]
Linking stakeholder and competitive pressure to Industry 4.0 and performance: Mediating effect of environmental commitment and green process innovation [33]
Enabling the Circular Economy transition: a sustainable lean manufacturing recipe for Industry 4.0 [34]
Service Oriented, Holonic and Multi-Agent Manufacturing Systems for Industry of the Future: Proceedings of SOHOMA 2020 [35]
Systems-based approach to contemporary business management: An enabler of business sustainability in a context of industry 4.0, circular economy, competitiveness and diverse stakeholders [36]
A Survey on Decentralized Consensus Mechanisms for Cyber Physical Systems [37]
Industry 4.0, digitization, and opportunities for sustainability [38]
Industry 4.0 and the circular economy: A literature review and recommendations for future research [30]
Search Query "industry 4.0+benefits"
Managing industry 4.0 automation for fair ethical business development: A single case study [39]
Digital Business Strategies in Blockchain Ecosystems: Transformational Design and Future of Global Business [40]
The Potential of Smart Factories and Innovative Industry 4.0 Technologies —A Case Study of Different-Sized Companies in the Furniture Industry in Central Europe [41]
Can Livestock Farming Benefit from Industry 4.0 Technology? Evidence from Recent Study [42]
Multistage implementation framework for smart supply chain management under industry 4.0 [43]
Software readiness for data analytics and big data: Expand industrial data access and get more out of it with tools such as message queuing telemetry transport (mqtt) on the way to industry 4.0 benefits. [44]
Search Query "industry 4.0+case"
Implementing Industry 4.0: assessing the current state [45]
Digital servitization and competence development: A case-study research [46]
Towards smart production planning and control; a conceptual framework linking planning environment characteristics with the need for smart production planning and control [47]
Industry 4.0 enabling technologies as a tool for the development of a competitive strategy in Italian manufacturing companies [48]
A Theoretical Framework for Industry 4.0 and Its Implementation with Selected Practical Schedules [49]
Symbiosis of life-cycle structural design and asset management based on Building Information Modeling: Application for industrial facility equipment [50]
Deindustrialization and Implementation of Industry 4.0 - Case of The Republic of Croatia [51]
MPC-Based Process Control of Deep Drawing: An Industry 4.0 Case Study in Automotive [52]
Applied Machine Learning in Industry 4.0: Case-Study Research in Predictive Models for Black Carbon Emissions [53]
Challenges and opportunities for problem-based learning in higher education: Lessons from a cross-program Industry 4.0 case [54]
Intelligent Systems in Production Engineering and Maintenance [55]
Handbook of Research on Integrating Industry 4.0 in Business and Manufacturing [56]
Blockchain Technology for Enhancing Supply Chain Performance and Reducing the Threats Arising from the COVID-19 Pandemic [57]
Outside the Search Scope
DIMECC MANU –future digital manufacturing technologies and systems [31]
S-BPM in the Production Industry [58]
Organizational Engineering in Industry 4.0 [59]

The Table 4.2 lists the articles selected for the review. With the inclusion of the sources outside the systematic search method the total amount of articles is 30. The selected literature varies from case reviews discussing what was achieved after 4IR project or projects were completed to literature reviews collecting data from other scientific articles discussing 4IR and the relevant technology around it and creating statistics and finding useful insights from them. The lengths of the articles varied also from only a couple pages to article collections and books with almost 700 pages. Circular economy and sustainability in general were some of the key themes among the articles. The businesses and industries mentioned in the articles were diverse, but as one might expect, many of them were related to manufacturing and processing of materials.

4.3 Categorising the Data

The first step on finding the key benefits of industry 4.0 implementations for different stakeholders is to identify these different stakeholders. The source material may or may not specify which stakeholder a specific benefit belongs to and this is a clear issue when trying to categorise this data. This is why the idea is to first utilise as much already conducted case reviews and their possible categorisation. With this it is also possible to find stakeholders for benefits that are mentioned in some articles without this linking. If after this no stakeholder can be identified for certain benefits, these will be labeled as a general benefit.

4.3.1 Identifying the Stakeholders

Because of the nature of the articles, the most common stakeholder to be mentioned as a receiver of a benefit was an organisation (company/business). Especially in articles explaining theoretical benefits of the 4IR, an organisation would be mentioned as the beneficiary almost exclusively. This was so common that even if the word organisation or its synonyms would not be mentioned directly, the description of the benefit would leave no room for imagination. On the other hand, articles dealing with multiple case reviews or literature reviews could present multiple different stakeholders for a single benefit. Such articles were also great sources for identifying multiple different stakeholders in general.

4.3.2 Categorising the Benefits

When analysing the material it came clear that the word benefit is subject to interpretation. Many things can be presented as a benefit and this creates a dilemma where the accepted data to process and the amount of time to find this data would grow immensely if not filtered properly. Luckily, while scanning through the material, a list of generalised 4IR benefits were presented by Kraft et al. [42]:

1. **Digital individualization**: The possibility to offer completely customised products and services cost-effectively
2. **Flexibilization**: The ability to scale the production with the fluctuations in demand
3. **Demand orientation:** The ability to shift business models towards X-as-a-service paradigm
4. **Sustainability**: More efficient use of resources, energy etc. and the general shift towards greener processes
5. **Consistent process orientation**: Transparency of the overall production process
6. **Automated knowledge and learning**: Data analytics and simplified knowledge management
7. **Collaboration competence**: Enabling technology for automated data sharing between value-added partners
8. **Productivity optimization**: Every item above improves productivity so anything that does not fit those categories will be categorised as Productivity optimization

These items will be used as categories into which the benefits found in the articles will be placed. This facilitates the definition of benefits, otherwise it can be difficult to determine when something is clearly a benefit. If for some reason the found benefits will not fit the already defined categories and a clear pattern emerges among them, the possibility of additional categories is considered.

The benefits are also divided into two groups: expected and confirmed benefits. The latter group consist of benefits that are empirically proven. In this case it means that the source material of the benefit is either a retrospect of a 4IR implementation project, the benefit has been found through an interview/questionnaire from representatives who has been the stakeholder for the 4IR project or the source material is utilising these two methods in quantitative manner and can prove that the data is not theoretical but empirical. If the benefit cannot be undoubtedly proved as empirically proven benefit, it will be placed as expected benefit. Many expected benefits were also found in the case review documents, as there were usually chapters where the motivations for the project were described.

It is also important to notice that the articles may only discuss about one specific Industry 4.0 technology and its benefits, but when the benefits are collected, this information is filtered out. The idea here is to focus on the benefits of the Industry 4.0 as a whole and not to specific enabling technology. In some instances it is also difficult to specify what enabling technology is utilised, especially in complex projects where multiple 4IR technologies are utilised simultaneously.

4.4 Results

After reviewing the 30 articles, total of 367 benefits were identified amongst them, of which 261 were categorised as expected benefits and 106 were seen as confirmed benefits [60]. The total of unique stakeholders identified was 41. The different queries provided following number of benefits:

Table 4.3: Search Query vs. Benefits

Query	Total	Expected	Confirmed	Articles with No Hits
"industry 4.0+stakeholders"	126	122	4	0
"industry 4.0+benefits"	71	10	61	2
"industry 4.0+case"	125	105	20	4
Outside the search criteria	45	24	21	0
Total	367	261	106	6

The interesting thing about the distribution of the benefits to the queries presented on the Table 4.3 is that even though the "industry 4.0+case" -query had the most articles, it did not provide the most hits in terms of benefits. It however provided the most articles with no found benefits at all (4). The Expected/Confirmed polarisation between the results of the queries "industry 4.0+stakeholders" and "industry 4.0+case" when compared to the query "industry 4.0+benefits" is quite significant. The reason for this is quite simple: the two queries provided articles with more theoretical text while the "industry 4.0+benefits"-query had more of the articles with retrospects of 4IR implementation. Also, there was a tendency among the articles, that if they were more theoretical, they were presenting benefits more frequently, but the descriptions for the benefits were "quote"-like, straight out of encyclopedia, with little new information and the proposed stakeholder was almost certainly Organisation (or one of its synonyms). The articles selected outside the search criteria performed very well in terms of finding both sets of benefits in balanced manner.

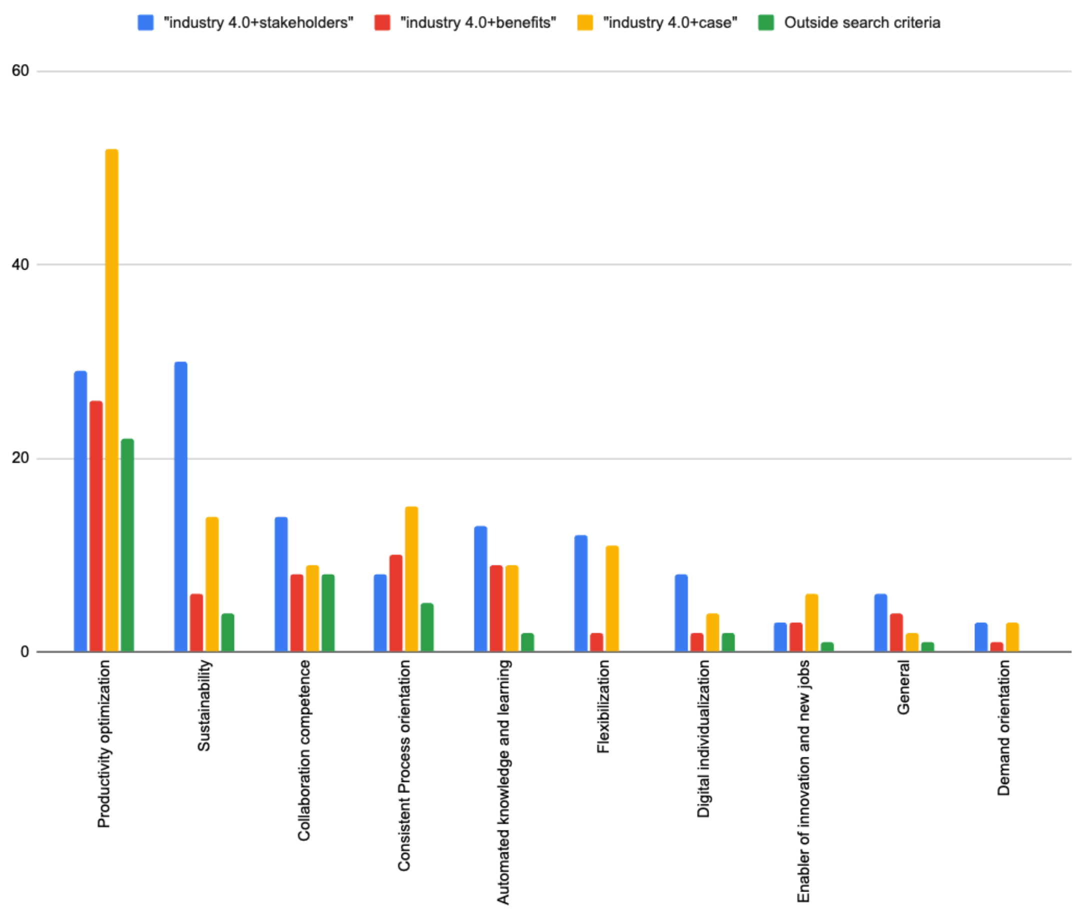

Figure 4.1: Distribution of Resulted Benefits in Queries into Categories

The Figure 4.1 depicts the distribution of the benefits into categories in terms of the search queries. Apart from the Productivity optimization and Sustainability categories, the distributions among the different search queries were fairly even. The spike of the Sustainability and the "stakeholders" query can be explained with the fact that there were significant amount of articles discussing green processes, circular economy and sustainability in general among those articles. The spike of "case" and Productivity optimization is explainable with the nature of the articles resulted by the query as they yielded more general benefits with the viewpoint of company. The Flexibilization category also stands out here with somewhat uneven distribution, but the total number of benefits in that category is bit on the low side which makes it hard to asses the reason for the result.

4.4.1 Identified Stakeholders

The number of stakeholders identified for the different benefits was 41. However, some of these unique stakeholders were named companies with unique characteristics, or companies working in a particular industry, which gave them a specific characteristic. Also definitions of a specific sized companies such as "Small businesses (up to 50 persons, turnover up to 10 million EUR)" were identified as unique stakeholders. Another significant group of unique identified stakeholders were stakeholders of company's production value chain. These include entities such as Suppliers, OEM and Freight Forwarder. Such entities were found from articles describing effects of 4IR technologies throughout a manufacturing or production value chain. Members of companies, namely, different job positions were also found during this search. These include workers and managers as is and with specific industry segment as well. A rough categorisation from the found stakeholders can be made by taking their sizes into consideration: Large entities, in which belong the likes of State and Institutes. Organisation-sized entities (Medium), namely the different businesses and finally different Professionals and Workers (Small), which represents the benefits for different individuals in different job positions.

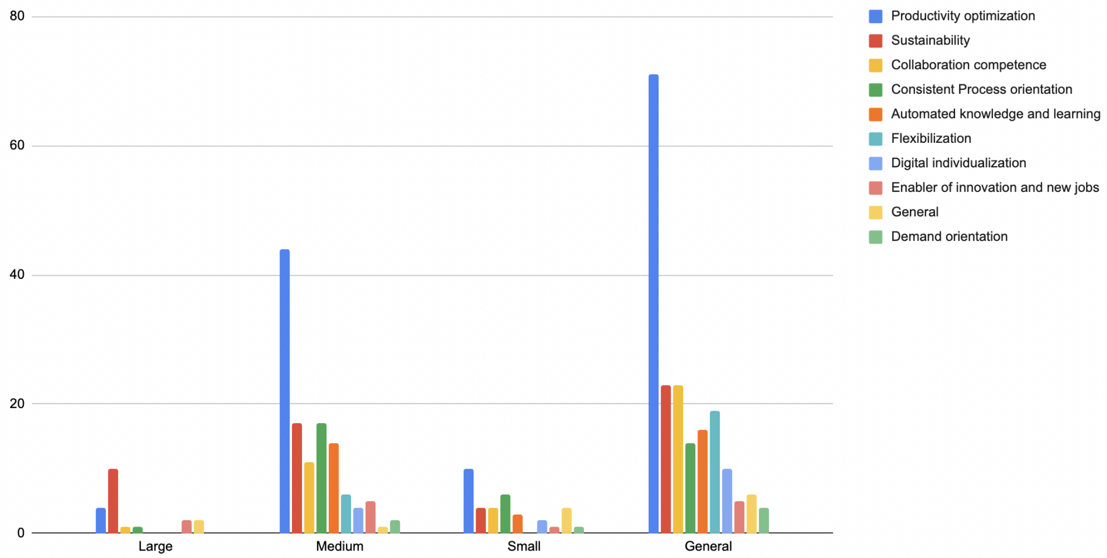

Figure 4.2: Stakeholder Entity Sizes vs. Benefit Categories

Figure 4.2 depicts the distribution of the benefits in the categories to these rough stakeholder categorisations. A category was also added for the General stakeholder, because there were many articles where the stakeholder were not properly expressed, as discussed earlier. However, the distribution of the categories in the Medium and the General is very similar due to the fact that they both in most cases represent organisations with their aspirations. Some differences can be observed in the nature of the benefits associated with a particular stakeholder or group of stakeholders. In the cases of different job positions, as one would expect, the nature of a job position also reflected on the nature of the benefits found for the entities. While benefits found from the managerial perspective usually were quite well aligned with the benefits found where a company is the stakeholder, like optimizing the processes, the benefits targeted for workers, while also included similar benefits, included benefits that described completely different views. For example the growth of responsibility of workers after 4IR implementation were seen as a benefit from worker perspective, but it is difficult to align it with the benefits found where company is the stakeholder. In the cases where the benefits were pointed towards society or state, the nature of the benefits would drastically change. Here, the public welfare was mentioned, a theme that did not occur in any other cases. Sustainability, however, was mentioned for practically every unique stakeholder.

4.4.2 Identified Benefits

The identified benefits divided into expected (261) and confirmed (106) benefits in roughly 71 - 29 relation. The reason is clear: large number of the articles did not have empirical data in them and those which had empirical results also usually had a section which was completely theoretical or the article was structured in a such way that in the early parts of it the expected benefits were listed first. Especially the expected benefits which were picked from the theoretical sections were quite repetitive as they were usually referenced from big and well known sources discussing about Industry 4.0 or its enabling technologies.

The two most common benefits found in the literature were either exactly named as or with small detail differentiations named as "cost savings" and "time savings". The "problem" with these benefits is that they are very obvious, at least when portraying expected benefits. This is because each and every move that any stakeholder trying to improve their business efficiency, or any system, is aiming for these and it does not necessarily need 4IR technologies to find improvements on these departments. Although their importance for running business is imperative, when printed out as is, they give little information about the root causes of what truly led to the improvements on these departments. This is also why they were categorized as "Productivity optimization" and one of the reasons why the category got by far the most hits. The distribution of all the identified benefits into the categories can be seen on the Figure 4.3.

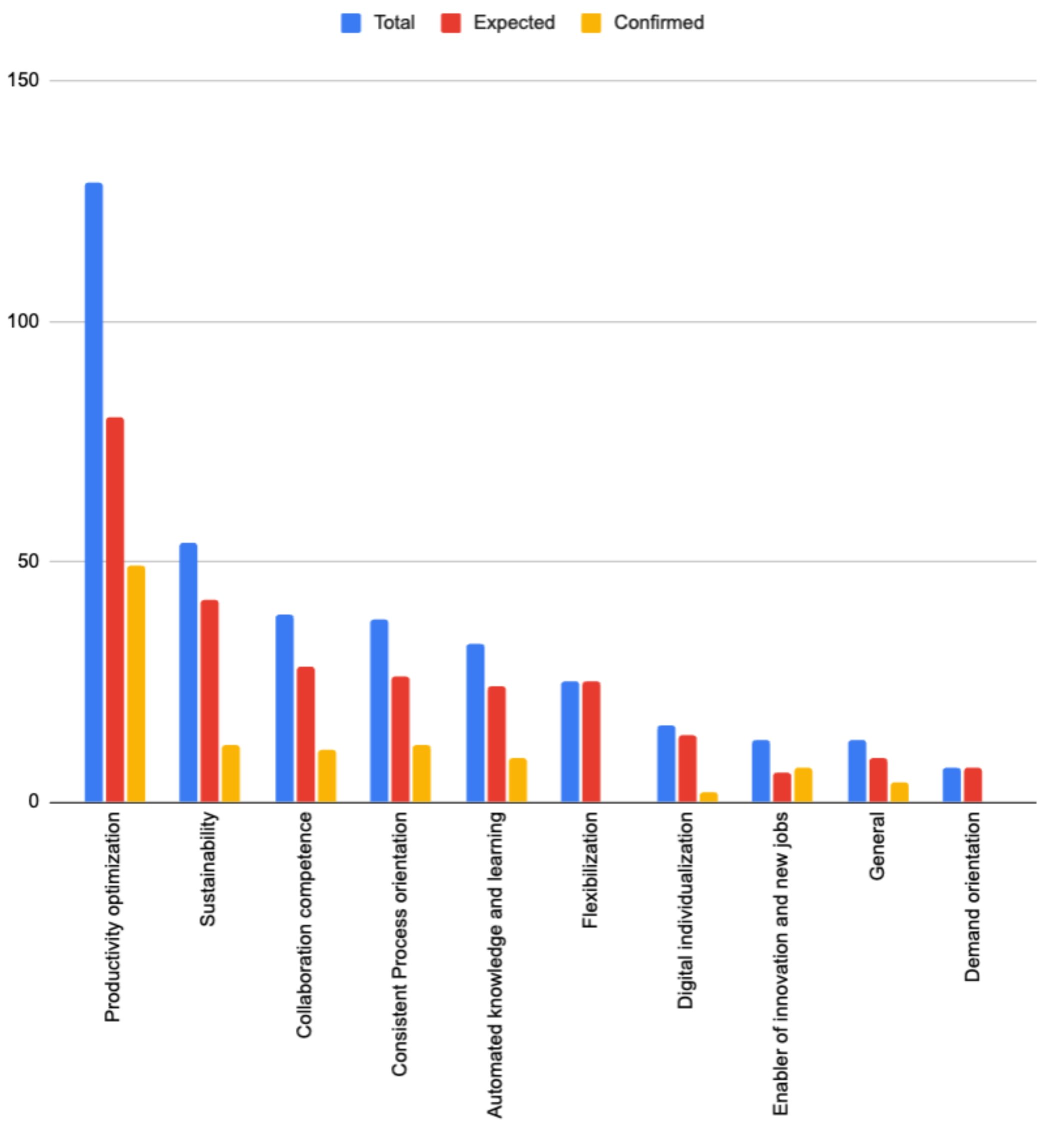

Figure 4.3: Distribution of Expected and Confirmed Benefits into Categories

Once the categorisation of the benefits had started, it came clear that the proposed categorisation template suits best those benefits found for the viewpoint of companies and business in general. The articles mostly viewed the benefits from this viewpoint, so the categorisation worked well in most cases. However if the article took a broader standpoint, for example including how the implementation of 4IR technologies affects bigger entities such as State or Society, the categorisation was not as optimal. Due to these kinds of situations a General category was created. Although General category, or in this case it could be labeled also as "others", is far from optimal due to its vague nature, the number of benefits in that category at the end was only 13, so it within the acceptable range. Within General category were also few benefits targeted for workers, but the amount of them is not high enough to justify for creation of their own category. One benefit type which was in between two categories were benefits related to safety and risk management. In this case they were labeled under the Productivity optimization through the idea, that problem prevention will decrease downtime in processes, meaning more optimized productivity. On the other hand they could have been placed to General category as well.

The benefits of one group can be found in all articles: "Enabler of innovation and new jobs". This category is fairly self-explanatory, but the main benefits placed in this category either directly mentioned that 4IR creates new jobs, or it enables the creation of something completely new and innovative. However, the benefit "new jobs" is a double-edged one. This is because the creation of new jobs usually means the loss of some other position. This is why "new jobs" are not classified as a benefit to workers and making a "Benefits for workers"-category possible, because in the end it may not be the workers who are the real beneficiaries, but the larger entity, because it is a shift to something new at the expense of something old.

Like mentioned previously, sustainability was one of the most important benefits discussed in the articles, and this is clearly shown in the Figure 4.3. Although some articles focused directly on the circular economy, where sustainability was a key concern, many articles discussing materials processing and manufacturing also highlighted the importance of sustainable processes. The reason for this is process optimisation, where, for example, reducing combustion waste in some processes increases process efficiency or achieving same manufacturing results with less material waste.

Some of the benefits belonging to categories "Collaboration competence", "Consistent process orientation" and "Automated knowledge and learning" had similar characteristics and sometimes it caused problems when trying to categorise them to right slots. The reason for this is that these categories are heavily linked to different types of communication improved by the 4IR technology, namely M2M, M2H, H2M and H2H. An example here would be that in the "Consistent process orientation" category, there are benefits that are acquired through the implementation of systems which enables transparency in e.g. said company's manufacturing process and those systems utilise heavily automated data gathering and transfer systems equipped with automated data analysis systems. In such case it could be argued that the benefit could go to either of the "Consistent process orientation" and "Automated knowledge and learning" categories. "Collaboration competence" and "Consistent process orientation" also had such conflicts between the benefits of them where the improved transparency of the company's processes improved the collaboration between different parties.

From the categories, only two of them were left without any confirmed benefits in them. "Demand orientation" got very few benefits in total and the reason for it is the acquired source material. With a considerable probability, the structure of the Figure 4.3 would have looked completely different if search queries mentioning "digitalisation" would have been included and the added articles would have dealt more with businesses operating completely digital environment. This, however, does not explain the uneven result of the "Flexibilization" with zero confirmed benefits. With the low number of source material used for this review, a proper assessment on the matter if "Flexibilization" can be seen as confirmed benefit after 4IR implementation, cannot be drawn and its benefit distribution may be due to chance.

4.4.3 Limitations

When considering the distribution of the benefits into the categories as a whole, the key reason for such distribution characteristics is undoubtedly the source articles: when using the keyword industry 4.0, big chunk of found articles will display the benefits from the perspective of companies and especially those who operate in the processing and manufacturing industries. Industry 4.0 is a marketed term especially towards businesses and thus it causes biases towards the viewpoints of which the benefits are most likely considered. For this review, the viewpoint of the company is acceptable, even desirable. If however, there is a need for assessing the benefits for some other stakeholder, a specific group of professionals or state scale entity, the article search should be conducted some other way. Focusing on implementations of just some of the 4IR enabling technology could also yield different results.

The benefit category selections should also be viewed critically. Given the broad and vague nature of 4IR and the many stakeholders affected by it, it can be argued that no generalisable and "one size fits all" categorisation is possible or reasonable. The stakeholder or group of stakeholders for which the study is conducted, should be clearly defined from the start and the categorisation should be made from the expectations of the results prior starting the study and the categories should reflect the aspirations of the stakeholders in question. Also, having a list of predetermined categories affects the search of these benefits: the searcher will have at least some bias towards finding benefits that fits the given categories.

Finally, it is easy to find and list the theoretical and expected benefits of the enabling technology of 4IR, but the value of such lists is very limited. Thus, future studies should definitely focus more on data that address the empirical results of the adoption of 4IR through different article selection methods or through interviews and surveys of selected individuals using qualitative methods.

4.5 RQ2 Conclusion

Implementing 4IR enabling technology comes with many different benefits. The increased interconnectivity of sensors, machines and even humans, accelerates exchange of data, enabling the improved generation of valuable knowledge. The new technology allows us to visualise our plans and foresee possible shortcomings of them before any resources have been consumed and massive amount of time have been wasted. This new technology also enables the creation of something completely new that was not previously possible.

The RQ2: "What are the benefits received by different stakeholders from Industry 4.0 compliant product?", can be a bit misleading as the word "product" usually refers to single entity, physical or digital. While this can be true in smaller implementations, however, in larger Industry 4.0 implementations the "product" is a system consisting of multiple smaller systems within it. That said, a conclusion from the review data gathered for the RQ2, can be drawn. As seen from the Figure 4.2, when the stakeholder entity size is organisation or smaller, the 4IR technology will bring productivity optimisation benefits. For companies this means savings in costs and time and for an individual it means getting more done with less effort. Companies, their partners and individuals can benefit from the improved communication, automated data gathering and the transparency of different processes to collaborate and steer their activities more efficiently and with more precision. Customers can order products better suited for their needs without it being too costly for them and for the producer. As the efficiency of different processes increases due to increased knowledge, it also brings sustainability benefits. Stakeholder entities of all sizes globally will receive the benefits of greener and less waste generating processes. This is also true for the increased innovativity and possibilities the new technology will bring and these innovations will shape the job positions to something different. Finally, workers can enjoy more safer production facilities, when the technology gets smarter and the "heavy lifting" can be conducted by different CPS, while their role will shift towards supervising these new smart machines.

5 Discussion

As Industry 4.0 is such a broad topic, with many details and also grey areas, the conclusions are easily open to interpretation. This chapter discusses the results gathered in the previous chapters and reflects on the CTN project that gave rise to the idea for this study.

5.1 When a Product is Industry 4.0 Compliant

The chapter 3 attempted to tackle the question of Product's Industry 4.0 compliancy. As noted in the conclusion of the RQ1, the term "Product" may be bit misleading when discussing about Industry 4.0 compliant MVP because of its nature relying on at least two or more acting systems (Client, Server), thus making term "System" perhaps bit more correct. This semantic issue is not the only thing that can cause controversy when discussing the 4IR compliant product. As the variety of technologies and methods under the term Industry 4.0 is considerable and the way of utilising these differs greatly, any simplification made from the selection of these representatives of technology is bound to have significant margin of error in some situations. Like mentioned in the chapter 3, the example of AI software, which is created and taught completely locally will not fit the MVP description in any cases. Such applications of the technology can potentially have possible use cases, where the domain is very specific and the datasets used to teach the AI need to be strictly controlled. However, the example of theoretical 3D printers with no continuous connections is plausible, it is likely to remain a theoretical example.

An issue that can be considered relating to the whole question of Industry 4.0 compliant product is the scale: is it necessary to measure the Industry 4.0 compliancy in product scale? As established in chapter 4, the benefits of these implementation are usually measured from the perspective of a company with a rather generalised way of categorising them and as such the details of the implementation might be left out with lesser attention. This can create an illusion where it seems that it really does not matter what technologies were utilised for the implementations as long as the outcome is satisfactory and fulfilling the expected benefits. Another fact that is supporting this view is that there are no known "standards" to audit the Industry 4.0 compliancy for products unlike in the case for company's Industry 4.0 compliancy where there exists maturity models to measure it. This, however, cannot be further from the truth as the technology, the products, are the base on which the company's Industry 4.0 compliancy is eventually build upon. More focus should be given to this topic in the future, as proper definitions for product Industry 4.0 compliancy could potentially remove some of the ambiguities associated with Industry 4.0.

5.2 Benefits for the Stakeholders

It can be stated that successful Industry 4.0 implementations will, with high probability, bring many different benefits for different groups of stakeholders. However, the expectations of these different stakeholders for the benefits varies greatly, as established in the chapter 4. This means that the impact of such implementation towards the expectations will be determined by the fact, who is the main targeted beneficiary for the implementation. How does this affect the results gathered from the literature review and for other similar reviews in the future then? In order to collect more accurate data, it would be better to identify the number of stakeholders for whom benefits are sought. In this way, the source material can be targeted to specific topics and themes, thus providing a wider range of categories better suited to the stakeholder in question. Otherwise the results and the resulting categories can be too general in nature for some stakeholders and they might lose some of the impact they might have in more detailed context. The advantage of more general categories, though, is that a quick glance gives an idea of the benefits that are sought and achieved through the deployment of Industry 4.0 technologies. And because categorisation, at least subconsciously, also affects data collection, general categories make it easier to identify benefits rather than having to ask the philosophical question "what is a benefit?" in so many situations during data collection. Maybe, if the study is conducted for a single stakeholder group, such situation will not be a problem as the number of unique benefits does not grow immensely in such context.

As the numbers in the chapter 4 show, theoretical and expected benefits are easy to find, and for future studies it is recommended to focus the scope only on the confirmed benefits, since the collection of theoretical benefits provides little, if any, information on how 4IR implementations succeed when the human element is added. Furthermore, the analysis of the articles revealed that some of the widely accepted theoretical 4IR benefits were not possible for all stakeholders depending on the nature of their business, which makes the selection of the desired stakeholders even more important. One such case was the source for the benefit categories template utilised in the chapter 4, where the theoretical benefits of Digital individualisation and Demand orientation were not found plausible due to practical limitations of livestock farming [42]. In addition, future studies could also analyse the success of Industry 4.0 implementations where different levels of human input are required. It may be possible that implementations that require very little human input are more heavily weighted than implementations that require much different levels of human input.

5.3 Reflection to the CTN project

When reflecting the expectations, the implementation and the results gathered from the CTN project, they align with results of this thesis. The key target of the CTN project was to enable remote controllability and monitoring of the product for the client and from the chapter 4 benefits categories perspective these can be read as the increase of the transparency (Consistent process orientation) of the usage process and also increased automated learning and knowledge. The product itself utilises the methodologies described in chapter 3's MVP. When questions were raised during and after the project about the legitimacy of the Industry 4.0 and whether it truly is something concrete, some satisfactory answers were collected during this study. The reason the project were completed as quickly as it were and why the infrastructure were almost complete already before the project even started, is that the level of IOT readiness, digitalisation and interconnectedness in general in Finland is at very high level. CTN had followed Industry 4.0 paradigm without knowing that such term even existed. And to be fair, the benefits 4IR technology and methods can offer are very logical: there are no super insights among them, just the results of the increased knowledge and the added possibilities.

6 Conclusion

This study has demonstrated two methods of addressing the two research questions related to Industry 4.0. The RQ1: "When a product is Industry 4.0 compliant?" was answered with compilation of features found in known Industry 4.0 compliant products and those found in Industry 4.0 initiatives, especially in Italy's "Piano Nazionale Industria 4.0" and concluded with the MVP model described in the chapter 3. The model emphasises the continuous improvement pipeline made possible by the Client-Server architecture on which the products will be built upon. The RQ2: "What are the benefits received by different stakeholders from Industry 4.0 compliant product?" was addressed with a literature review in chapter 4. The results of it are compiled into graphs of categories displaying the stakeholder group sizes with the resulted benefit categories. The main stakeholder group found from the articles was a generic company and the main benefits for it were related to Productivity optimization and Sustainability.

With all the ambiguity still surrounding the Industry 4.0, one of its technologies is already starting to take massive leaps towards its own "industrial revolution", the AI. While we have only seen glimpses of what this technology can achieve with the products like ChatGPT, we have yet to reach the level of generalised AI, let alone singularity. This technology has somewhat similar characteristics as when first electromagnetism related studies were conducted during the first industrial revolution and it then had acquired an ubiquitous nature during the second. Ubiquitous AI technology may have even more drastic changes how our society operates. Will it be labeled as Industry 5.0 or will some marketing team find some ***smarter*** brand name, remains to be seen.

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Appendix A Allegati A e B alla legge 11 dicembre 2016, n. 232 (legge di bilancio 2017)

Allegato A - Beni funzionali alla trasformazione tecnologica e/o digitale delle imprese in chiave Industria 4.0

Beni strumentali il cui funzionamento è controllato da sistemi computerizzati e/o gestito tramite opportuni sensori e azionamenti:
• macchine utensili per asportazione,
• macchine utensili operanti con laser e altri processi a flusso di energia (ad esempio plasma, waterjet, fascio di elettroni), elettroerosione, processi elettrochimici
• macchine per la realizzazione di prodotti mediante la trasformazione dei materiali o delle materie prime,
• macchine utensili per la deformazione plastica dei metalli e altri materiali,
• macchine utensili per l'assemblaggio, la giunzione e la saldatura,
• macchine per il confezionamento e l'imballaggio,
• macchine utensili di de-produzione e re-manufacturing per recuperare materiali e funzioni da scarti industriali e prodotti di ritorno a fine vita (ad esempio macchine per il disassemblaggio, la separazione, la frantumazione, il recupero chimico),
• robot, robot collaborativi e sistemi multi-robot,
• macchine utensili e sistemi per il conferimento o la modifica delle caratteristiche superficiali dei prodotti e/o la funzionalizzazione delle superfici,
• macchine per la manifattura additiva utilizzate in ambito industriale,
• macchine, strumenti e dispositivi per il carico/scarico, movimentazione, pesatura e/o il sorting automatico dei pezzi, dispositivi di sollevamento e manipolazione automatizzati, AGV e sistemi di convogliamento e movimentazione flessibili, e/o dotati di riconoscimento pezzi (ad esempio RFID, visori e sistemi di visione),
• magazzini automatizzati interconnessi ai sistemi gestionali di fabbrica.

Tutte le macchine sopra citate devono essere dotate delle seguenti caratteristiche:
✓ controllo per mezzo di CNC (Computer Numerical Control) e/o PLC (Programmable Logic Controller)
✓ interconnessione ai sistemi informatici di fabbrica con caricamento da remoto di istruzioni e/o part program
✓ integrazione automatizzata con il sistema logistico della fabbrica o con la rete di fornitura e/o con altre macchine del ciclo produttivo
✓ interfaccia uomo macchina semplici e intuitive
✓ rispondenza ai più recenti standard in termini di sicurezza, salute e igiene del lavoro

Inoltre tutte le macchine sopra citate devono essere dotate di almeno due tra le seguenti caratteristiche per renderle assimilabili e/o integrabili a sistemi cyberfisici:
o sistemi di tele manutenzione e/o telediagnosi e/o controllo in remoto,
o monitoraggio in continuo delle condizioni di lavoro e dei parametri di processo mediante opportuni set di sensori e adattività alle derive di processo,
o caratteristiche di integrazione tra macchina fisica e/o impianto con la modellizzazione e/o la simulazione del proprio comportamento nello svolgimento del processo (sistema cyberfisico),

• dispositivi, strumentazione e componentistica intelligente per l'integrazione, la sensorizzazione e/o l'interconnessione e il controllo automatico dei processi utilizzati anche nell'ammodernamento o nel revamping dei sistemi di produzione esistenti,
• filtri e sistemi di trattamento e recupero di acqua, aria, olio, sostanze chimiche e organiche, polveri con sistemi di segnalazione dell'efficienza filtrante e della presenza di anomalie o sostanze aliene al processo o pericolose, integrate con il sistema di fabbrica e in grado di avvisare gli operatori e/o fermare le attività' di macchine e impianti.

Sistemi per l'assicurazione della qualità e della sostenibilità:
• sistemi di misura a coordinate e non (a contatto, non a contatto, multi-sensore o basati su tomografia computerizzata tridimensionale) e relativa strumentazione per la verifica dei requisiti micro e macro geometrici di prodotto per qualunque livello di scala dimensionale (dalla larga scala alla scala micro- o nano-metrica) al fine di assicurare e tracciare la qualità del prodotto e che consentono di qualificare i processi di produzione in maniera documentabile e connessa al sistema informativo di fabbrica,
• altri sistemi di monitoraggio in-process per assicurare e tracciare la qualità del prodotto e/o del processo produttivo e che consentono di qualificare i processi di produzione in maniera documentabile e connessa al sistema informativo di fabbrica,
• sistemi per l'ispezione e la caratterizzazione dei materiali (ad esempio macchine di prova materiali, macchine per il collaudo dei prodotti realizzati, sistemi per prove/collaudi non distruttivi, tomografia) in grado di verificare le caratteristiche dei materiali in ingresso o in uscita al processo e che vanno a costituire il prodotto risultante a livello macro (es. caratteristiche meccaniche) o micro (ad esempio porosità, inclusioni) e di generare opportuni report di collaudo da inserire nel sistema informativo aziendale,
• dispositivi intelligenti per il test delle polveri metalliche e sistemi di monitoraggio in continuo che consentono di qualificare i processi di produzione mediante tecnologie additive,
• sistemi intelligenti e connessi di marcatura e tracciabilità dei lotti produttivi e/o dei singoli prodotti (ad esempio RFID - Radio Frequency. Identification),
• sistemi di monitoraggio e controllo delle condizioni di lavoro delle macchine(ad esempio forze, coppia e potenza di lavorazione; usura tridimensionale degli utensili a bordo macchina; stato di componenti o sotto-insiemi delle macchine) e dei sistemi di produzione interfacciati con i sistemi informativi di fabbrica e/o con soluzioni cloud,
• strumenti e dispositivi per l'etichettatura, l'identificazione o la marcatura automatica dei prodotti, con collegamento con il codice e la matricola del prodotto stesso in modo da consentire ai manutentori di monitorare la costanza delle prestazioni dei prodotti nel tempo e di agire sul processo di progettazione dei futuri prodotti in maniera sinergica, consentendo il richiamo di prodotti difettosi o dannosi,

• componenti, sistemi e soluzioni intelligenti per la gestione, l'utilizzo efficiente e il monitoraggio dei consumi energetici,
• filtri e sistemi di trattamento e recupero di acqua, aria, olio, sostanze chimiche, polveri con sistemi di segnalazione dell'efficienza filtrante e della presenza di anomalie o sostanze aliene al processo o pericolose, integrate con il sistema di fabbrica e in grado di avvisare gli operatori e/o fermare le attività' di macchine e impianti.

Dispositivi per l'interazione uomo macchina e per il miglioramento dell'ergonomia e della sicurezza del posto di lavoro in logica 4.0:
• banchi e postazioni di lavoro dotati di soluzioni ergonomiche in grado di adattarli in maniera automatizzata alle caratteristiche fisiche degli operatori (ad esempio caratteristiche biometriche, età, presenza di disabilità),
• sistemi per il sollevamento/traslazione di parti pesanti o oggetti esposti ad alte temperature in grado di agevolare in maniera intelligente/robotizzata/interattiva il compito dell'operatore,
• dispositivi wearable, apparecchiature di comunicazione tra operatore/operatori e sistema produttivo, dispositivi di realtà aumentata e virtual reality,
• interfacce uomo-macchina (HMI) intelligenti che supportano l'operatore in termini di sicurezza ed efficienza delle operazioni di lavorazione, manutenzione, logistica.

Allegato B – Beni immateriali (software, sistemi e /system integration, piattaforme e applicazioni) connessi a investimenti in beni materiali Industria 4.0

• Software, sistemi, piattaforme e applicazioni per la progettazione, definizione/qualificazione delle prestazioni e produzione di manufatti in materiali non convenzionali o ad alte prestazioni, in grado di permettere la progettazione, la modellazione 3D, la simulazione, la sperimentazione, la prototipazione e la verifica simultanea del processo produttivo, del prodotto e delle sue caratteristiche (funzionali e di impatto ambientale), e/o l'archiviazione digitale e integrata nel sistema informativo aziendale delle informazioni relative al ciclo di vita del prodotto (sistemi EDM, PDM, PLM, Big Data Analytics),
• software, sistemi, piattaforme e applicazioni per la progettazione e ri-progettazione dei sistemi produttivi che tengano conto dei flussi dei materiali e delle informazioni,
• software, sistemi, piattaforme e applicazioni di supporto alle decisioni in grado di interpretare dati analizzati dal campo e visualizzare agli operatori in linea specifiche azioni per migliorare la qualità del prodotto e l'efficienza del sistema di produzione,
• software, sistemi, piattaforme e applicazioni per la gestione e il coordinamento della produzione con elevate caratteristiche di integrazione delle attività di servizio, come la logistica di fabbrica e la manutenzione (quali ad esempio sistemi di comunicazione intra-fabbrica, bus di campo/fieldbus, sistemi SCADA, sistemi MES, sistemi CMMS, soluzioni innovative con caratteristiche riconducibili ai paradigmi dell'IoT e/o del cloud computing),
• software, sistemi, piattaforme e applicazioni per il monitoraggio e controllo delle condizioni di lavoro delle macchine e dei sistemi di produzione interfacciati con i sistemi informativi di fabbrica e/o con soluzioni cloud,
• software, sistemi, piattaforme e applicazioni di realtà virtuale per lo studio realistico di componenti e operazioni (es. di assemblaggio), sia in contesti immersivi o solo visuali,
• software, sistemi, piattaforme e applicazioni di reverse modelling and engineering per la ricostruzione virtuale di contesti reali,
• software, sistemi, piattaforme e applicazioni in grado di comunicare e condividere dati e informazioni sia tra loro che con l'ambiente e gli attori circostanti (Industrial Internet of Things) grazie ad una rete di sensori intelligenti interconnessi,
• software, sistemi, piattaforme e applicazioni per il dispatching delle attività e l'instradamento dei prodotti nei sistemi produttivi,
• software, sistemi, piattaforme e applicazioni per la gestione della qualità a livello di sistema produttivo e dei relativi processi,
• software, sistemi, piattaforme e applicazioni per l'accesso a un insieme virtualizzato, condiviso e configurabile di risorse a supporto di processi produttivi e di gestione della produzione e/o della supply chain (cloud computing),
• software, sistemi, piattaforme e applicazioni per Industrial Analytics dedicati al trattamento ed all'elaborazione dei Big Data provenienti dalla sensoristica IoT applicata in ambito industriale (Data Analytics & Visualization, Simulation e Forecasting),
• software, sistemi, piattaforme e applicazioni di Artificial Intelligence & Machine Learning che consentono alle macchine di mostrare un'abilità e/o attività intelligente in campi specifici a garanzia della qualità del processo produttivo e del funzionamento affidabile del macchinario e/o dell'impianto,
• software, sistemi, piattaforme e applicazioni per la produzione automatizzata e intelligente, caratterizzata da elevata capacità cognitiva, interazione e adattamento al contesto, autoapprendimento e riconfigurabilità (cybersystem),
• software, sistemi, piattaforme e applicazioni per l'utilizzo lungo le linee produttive di robot, robot collaborativi e macchine intelligenti per la sicurezza e la salute dei lavoratori, la qualità dei prodotti finali e la manutenzione predittiva,
• software, sistemi, piattaforme e applicazioni per la gestione della realtà aumentata tramite Wearable device,
• software, sistemi, piattaforme e applicazioni per dispositivi e nuove interfacce uomo/macchina che consentano l'acquisizione, la veicolazione e l'elaborazione di informazioni in formato vocale, visuale e tattile,
• software, sistemi, piattaforme e applicazioni per l'intelligenza degli impianti cha garantiscano meccanismi di efficienza energetica e di decentralizzazione in cui la produzione e/o lo stoccaggio di energia possono essere anche demandate (almeno parzialmente) alla fabbrica,
• software, sistemi, piattaforme e applicazioni per la protezione di reti, dati, programmi, macchine e impianti da attacchi, danni e accessi non autorizzati (cybersecurity),
• software, sistemi, piattaforme e applicazioni di Virtual Industrialization che, simulando virtualmente il nuovo ambiente e caricando le informazioni sui sistemi cyberfisici al termine di tutte le verifiche, consentono di evitare ore di test e fermi macchina lungo le linee produttive reali.