

Louvain School of Management

How the Covid-19 crisis accelerates Industry 4.0 in Belgium

Author: Pierrick De Bock
Supervisor: Per Joakim Agrell
Academic year 2020-2021
Business Engineering
Operations & Information Systems
Daytime schedule

Foreword

First of all, I would like to thank Jades, who supported, advised and helped me throughout the realization of this work, and for whom I am truly grateful. I also thank everyone who supported and encouraged me during the last year and a half.

I thank Mr. Agrell, for agreeing to be my supervisor and introducing me to Industry 4.0, and Mr. Decaux, for its availability and his numerous advices.

I would finally like to thank the contributors to my master's thesis, Mr. Oliviers, Mr. Huberts, Mr. Masscho, Mr. Van der Straeten and Mr. Vincke, who kindly agreed to answer my questions and gave me more than content to analyze.

Table of content

1. Introduction	1
2. Methodology	2
3. Literature review	3
3.1. Definitions	4
3.2. Characteristics	6
3.2.1. Integration	6
3.2.2. Digital.....	6
3.2.3. Connectivity and data exchange.....	7
3.2.4. Real-time	7
3.2.5. Customization and flexibility	7
3.2.6. Decentralization	8
3.2.7. Automation.....	8
3.2.8. Smart	8
3.3. Technologies.....	9
3.3.1. Cyber-physical Systems	9
3.3.2. Internet of Things	10
3.3.3. Cloud Computing	11
3.3.4. Artificial intelligence.....	12
3.3.5. Big Data.....	14
3.3.6. Simulation	15
3.3.7. Additive Manufacturing	16
3.3.8. Autonomous Robots.....	17
3.3.9. Blockchain.....	18
3.3.10. Augmented Reality	19
3.4. Pros of Industry 4.0	20
3.4.1. Strategic competitive advantage.....	20
3.4.2. Efficiency and effectiveness.....	21
3.4.3. Profitability.....	21
3.4.4. Customer experience and satisfaction	21
3.4.5. Responsiveness and agility.....	22
3.4.6. Quality	22
3.4.7. Operational improvement.....	22
3.4.8. Performance measurement	23
3.4.9. Transparency and accessibility.....	23
3.4.10. Corporate social responsibility	23
3.5. Barriers to Industry 4.0	24

3.5.1.	Infrastructure and integration	24
3.5.2.	Lack of skilled labor	25
3.5.3.	High Investment and lack of financial resources	25
3.5.4.	Return on investment	26
3.5.5.	Cybersecurity and privacy	26
3.5.6.	Connectivity	27
3.5.7.	Organizational resistance	28
3.5.8.	Lack of understanding	28
3.6.	Development	28
3.6.1.	Globalization	29
3.6.2.	Markets	29
3.6.3.	Competition	29
3.6.4.	Complexity	29
3.6.5.	Flexibility	30
3.6.6.	Demographic	30
3.6.7.	Sustainability	30
3.6.8.	Government	31
3.6.9.	Digital	31
3.6.10.	Technological development	31
3.6.11.	Improvements	32
3.7.	Implementing Industry 4.0	32
3.7.1.	How to implement?	32
3.7.2.	Success factors and favorable conditions	35
3.7.3.	Challenges and implications for organizations	36
3.8.	Situation before Covid-19	39
3.8.1.	State of the concept	39
3.8.2.	Where can it be found?	40
3.8.3.	SMEs vs large enterprises	40
3.8.4.	MNC and locals	42
3.8.5.	Countries features	42
3.9.	Impacts of COVID-19	43
3.9.1.	Digital	43
3.9.2.	Physical interactions	44
3.9.3.	Economy and performances	45
3.9.4.	Supply chain disruption	45
3.9.5.	Call for flexibility	46
3.9.6.	Short time to react	47

3.9.7.	Resilience	48
3.9.8.	Technological solutions.....	48
3.9.9.	Survive and recover.....	49
3.9.10.	Opportunities and innovations.....	49
3.9.11.	Increasing applications	50
3.9.12.	Other impacts.....	50
3.9.13.	Future trends	50
4.	Results and answers	51
4.1.	Interview 1	51
4.2.	Interview 2	53
4.3.	Interview 3	55
4.4.	Interview 4	57
4.5.	Interview 5	59
5.	Analysis	61
5.1.	Does the pandemic accelerated Industry 4.0?	61
5.2.	How does it accelerate Industry 4.0?	62
5.3.	Why did it accelerate?	63
5.4.	Nuancing the acceleration	66
5.5.	Where did it happen?	67
5.6.	The case of Belgium	68
6.	Conclusion.....	69
7.	Bibliography.....	71
8.	Appendices	
	APPENDIX 1: Interview guide	
	APPENDIX 2: Interview 1 – Matthieu Oliviers	
	APPENDIX 3: Interview 2 – Philippe Huberts.....	
	APPENDIX 4: Interview 3 – Francis Masscho.....	
	APPENDIX 5: Interview 4 – Johan Van der Straeten.....	
	APPENDIX 6: Interview 5 – Jochen Vincke	

1. Introduction

“*Covid-19 accelerates Industry 4.0*”. It is around this affirmation that this whole work revolves. Pointed out theoretically in many sources (Cognizant, 2020, Agrawal et al., 2020, McMahon, 2020, Griffen, 2021, ...), it doesn’t actually give much information. And if reading these sources should make a reader understand what is behind this phrase, two people reading two different sources may come up with different explanations.

Industry 4.0 is presented as the last industrial revolution, the fourth one, and it can be defined as simply as “*the transformation of industrial manufacturing and production systems by introducing new technologies*” (Yeeply, 2020).

The Covid-19 crisis is the crisis related to propagation of the “SARS-CoV-2”, which emerged in 2019 in Wuhan, China, and expanded progressively to the whole world. The virus can be fatal and is transmitted through close contact (Kern, n.d.), which has had many consequences and changed many things in the world.

The purpose of this master’s thesis is to understand how the Covid-19 crisis, which started in Belgium in March 2020 and is still pending at the time of writing, is impacting the fourth industrial revolution in Belgium. The focus is placed on the idea that the pandemic should accelerate Industry 4.0. Various questions can be asked from that statement: Does the crisis really accelerate Industry 4.0? What does the acceleration of Industry 4.0 mean? To what extent does it accelerate? What are the reasons why the pandemic accelerates Industry 4.0? Where can we find that acceleration?, ... All questions that are encompassed under the research question: “How does the Covid-19 crisis accelerate the Industry 4.0 in Belgium?”. Aspects laid out in those questions, but also leads of what could happen in the future are researched in the work.

Industry 4.0 is an ongoing process, which is said to revolutionize the way industries work, and should continue to do so. With an impact that is growing every day, and the significance that subject will have in the future, adding a study on that theme should be relevant and could be useful in the future. Everything related to Industry 4.0 can thus be considered actual, and combining it with the coronavirus pandemic makes the subject a hot topic, on which the focus of studies should be turned.

Being an area that plays, and will continue to play a large role, understanding how Industry 4.0 is impacted is relevant. Whether things have changed considerably or not, or where things are now, are aspects that should be known and understood in order to utilize the concept at best.

The characteristics of the crisis could also be replicated in another situation, and the results of that study transferred or compared to another crisis or event. Many elements that are pointed out in that study could be used by others, or at least it is the hope of the author.

The theme has been chosen because of the interest of the author in the subject of Industry 4.0, as a way to clarify the consequence for himself and the readers, to verify some statements or provide nuances, and to gather leads on what lay ahead, given the recency of the tackled subject.

The fact that Industry 4.0 is a wide area created some complications for the work. Many contradictions have appeared during the first phase of the literature review, and consensus about many of the ideas has not been reached yet. It was therefore handled with the best abilities of the author, in order to make the subject understandable and as complete as possible.

This master's thesis was conducted with a heavy load of research in the literature, for reasons that will be explained later, and on qualitative basis, due to the actuality of the questions laid out.

2. Methodology

In order to reach the objectives laid in the presentation of this work, multiple steps are followed.

Because the subject and question addressed have recently emerged, the Covid-19 crisis beginning in March 2020 in Belgium (Info-Coronavirus Belgique, 2021), and is still developing at the time of writing this work, data are still materializing, and the decision was taken to base the study on a qualitative analysis, based on interviews from relevant respondents. The literature will be used extensively both in order to lay the ground of the work for the reader, but also to gather as much information as possible on this recent subject.

The first goal is to understand the concept and state of the situation regarding the Industry 4.0. The literature review plays the biggest role in that aspect, and gathers the main articles existing on the subjects. The relevant papers related to Industry 4.0 were first gathered, and the elements relevant for its understanding identified. The researches for this paper was conducted with the goal to use the more cited papers as a basis, and completed with elements found in other articles. The authors for less cited literature, or other sources were checked.

The review is conducted in order to be relevant for the reader to understand the topic and give him the basis to understand the study. It is also directed and written in order to facilitate the

testing of hypotheses around the research question. Some leads of answers to the question, or hypothesis, are explored in the review.

The second step consists in finding inputs and content to bring answers from the field. The input of the respondent takes the form of interviews. An interview guide was developed with the objectives to get hard facts regarding the subject, gather experiences and knowledge from the respondents about what happened during the crisis, but also collect opinions and insights on the reasons for what happened, or what will happen.

The conversations were recorded and the transcriptions are presented at the end of the work. The writings are used in order to not denature what has been said during the interviews, and to compare and analyze them more effectively.

The people solicited for the interviews were identified as “Industry 4.0 experts”, with sufficient experience in their sector (more than 10 years). The profiles researched are professional working in Belgium, but also working, or having worked in consulting. Consulting experience is preferred in order for respondents to have a larger view on the issue.

The answers are confronted with the literature review and key elements identified for each interview. These answers are provided distinctively for each respondent, as a summary of the conversations. The interviews are then compared between themselves, and overall results are then provided based on these comparisons. The recurrence of the themes and points found in the answers of the various interviewees, or similarities and contradictions with the literature review, are used in order to conduct the analysis.

Finally a conclusion is provided, summarizing the relevant information that appeared in this master’s thesis, and giving leads on how things could be improved upon as well as research area related to the subject.

3. Literature review

In order to understand the impacts that Covid-19 has on Industry 4.0, the first step is to review the literature on the subject. In the first part, a presentation of the concept, including its definitions, characteristics and components are described, followed by the pros and cons it delivers. The development of the concept is then in focus, exploring the factors contributing to it. Implementation aspects are also explained, before that information about where the concept

can be found are presented. Finally, a preliminary review on the impact of the coronavirus on organizations, society and on Industry 4.0 is provided.

3.1. Definitions

Synonymous with the fourth industrial revolution, Industry 4.0 follows up on the advent of computers and digitized data storage and corresponds to the digital transformation of industries, characterized by various technologies. Following the third industrial revolution and the use of information communication technologies (ICT) to automate processes, the fourth one aims to enhance capabilities and respond to new demands and societal changes, while maintaining the economic condition previously attained (Lasi et al., 2014). The idea was first developed in manufacturing, but is present across the entire value chain, which is what makes it an industrial revolution (Rojko, 2017).

Many definitions of Industry 4.0 exist, focusing on various elements of the concept. Some definitions use its features, but most define Industry 4.0 by its components and encompass the concepts, technologies or ideas behind it. Impacts, benefits or the environment are also referred to in order to define it. Finally, sometimes a single component is used as a focal point around which the other elements revolve (Piccarozzi et al., 2018). In order to provide a first overall idea, a few of these definitions or their components are given below.

Originally defined by the German government as “*fostering strong customization of products under the conditions of highly flexible production, introduction of methods of self-optimization, self-configuration, self-diagnosis, cognition and intelligent support of workers in their increasingly complex work.*” (European commission, 2017), it is now more broadly understood, gathering “*the technological, organizational, economical and societal changes driven by enhanced digitization of the manufacturing industry*” (Bécue et al., 2021).

Oztemel & Gursev (2020) identifies the elements of Industry 4.0: “*Industry 4.0 is a manufacturing philosophy that includes modern automation systems with a cretin level autonomy, flexible and effective data exchanges encoding the implementation of next generation production technologies, innovation in design, and more personal and more agile in production as well as customized products.*”

Frank et al. (2019) simply refers to Industry 4.0 as the adoption of the new digital technologies in organization in order to gather data in real time, analyze those data and provide information that will be useful. Subic et al. (2018) describes it as an emerging era of connectivity and

interaction among parts, machines and humans that have the potential to create enormous production and efficiency dividends, improvements in the quality of life and sustainable environmental outcomes. And for Da Silva et al. (2020), Industry 4.0 is the connection of physical and digital technological resources, products, people and activities, and the digitalization of the real environment. Its goals are to make the processes in industries more adaptable and intelligent, using their resources in a better way, mainly through the intensification of ICTs in industries.

“Internet of Things” and “cyber-physical systems” are used as the core component of the definition in Sony (2020), where Industry 4.0 is explained as the use of the Internet of Things in industrial process, and in Liao et al. (2017), referring to the technical integration of cyber-physical systems in the supply chain.

According to Bauer et al. (2014) in Prause & Weigand (2016), *“Industry 4.0 is the intelligent real-time, horizontal and vertical integration of humans and machines with objects and information and communication technology systems ("digitalization") to enable a flexible and dynamic management of complex systems”*.

As mentioned, the term “Industry 4.0” has origins in the manufacturing context, which is why many definitions include it. Even though technologies are an essential part of it, the ideas behind the concept are equally necessary. *“A reconfiguration of work in the digital era”* is an expression in Tulip (2020) that encompasses it, and comprises the application of new technologies in industries and the changing interactions in and between humans and machines.

Finally, one of the most used definition appears in Sony (2020):

“Industry 4.0 refers to the integration of Internet of Things technologies into industrial value creation enabling manufacturers to harness entirely digitized, connected, smart, and decentralized value chains able to deliver greater flexibility and robustness to firm competitiveness and enable them to build flexible and adaptable business structures, [acquiring] the permanent ability for internal evolutionary developments in order to cope with a changing business environment as the result of a purposely formulated strategy implemented over time” (Piccarozzi et al., 2018).

The various features, concepts and technologies appearing in these definitions are presented in the next sections.

3.2. Characteristics

This section aims to identify and explain the particularities and features of the fourth industrial revolution. Like for the definitions, many various ways to present these features exist. The objective is here to give the adjectives and words necessary to qualify Industry 4.0, and explain the ideas behind.

Qin et al. (2016) presents two main pillars of Industry 4.0. The first one is interoperability, for which the core idea is integration. Three types of integration are implied: vertical integration of the systems, horizontal integration over the business value network, and end-to-end integration across all products and stages. Interoperability includes the digitalization, communication and connectivity, standardization, flexibility, real-time features, transparency and customizability of the concept. The second pillar is consciousness, which can be explained as physical objects being intelligent, discovering knowledge, making decisions and behaving independently. It comprehends the “smart” product, factory and systems, automation, as well as the decentralization and autonomous characteristics of Industry 4.0.

3.2.1. Integration

Horizontal integration corresponds to collaboration inter-company. That is, several companies inter-connected and sharing their information systems in order to enrich the activities and create value for the different players that share the network (Ghadge et al., 2020, Tupa et al., 2017). Different systems across the value chain are integrated in order to be more efficient in the overall output in products and services (Sony, 2020).

Vertical integration is the intra-company integration, and describes the exchange of information and utilization of ICTs in and between the different hierarchical levels of the organization (Ghadge et al., 2020).

End-to-end integration links and digitizes all phases of a product or service life cycle (Sony, 2020). Its purpose is to realize intelligent monitoring, manufacturing and logistics by using technology devices to coordinate everything involved in the offer (Yue et al., 2015).

3.2.2. Digital

The integration is mostly done through digital components, and all the technologies present a digital feature. It allows the concept to transform all processes, activities and actors of the organization of the company’s value chain. Physical to digital conversion truly classifies

Industry 4.0 (Cotteleer et al., 2019, Rojko, 2017), with the use of information systems in operations (Roblek et al., 2016). This digitalization is provided by devices and is present in all components of a factory, in products and equipment, or organizations (Tay et al., 2018).

3.2.3. Connectivity and data exchange

Integrations result in a key aspect of Industry 4.0: connectivity. Vertical and horizontal integrations make indeed everything connected. It creates a collaborative environment in how information flows within and between the different levels of automation. From engineering and supply chain operations to marketing and suppliers, as well as between various stages of the processes and level of the organization, connections and links are established and used, mainly via digital channels (Alcácer & Cruz-Machado, 2019). The connectivity created between devices allows the various (decision) systems to be linked.

The large amount of data present, analyzed and exchanged, and especially the inclusion of machines in that exchange, are key aspects in the fourth industrial revolution. Automatic data exchange enables the linkage of different sites, and the creation of comprehensive supply chains (Roblek et al., 2016), supporting further connectivity. Information exchange, networking and collaboration increase under the concept (Tupa et al., 2017).

3.2.4. Real-time

An important feature of Industry 4.0 is the enabling of real-time synchronization of flows (Moeuf et al., 2020). Having vertical integration means that the process for the exchange is digitized throughout the organization, and that data from the entire organizational process is shared and available in real-time (Alcácer & Cruz-Machado, 2019). The industrial wireless network is synonymous with instantaneous communication and capabilities, enabling fast operations as well (Yue et al., 2015).

3.2.5. Customization and flexibility

Flexibility is provided by Industry 4.0 as a response to the dynamic requirements of industries (Sony, 2020), and individualization of the demand (Lasi et al., 2014). The systems, benefitting from other features presented above, aim to be flexible in order to enable individualization and customization (Rojko, 2017). That feature allows organizations to produce unitary and customized products (Moeuf et al., 2020), among others. The concept thus offers flexibility in terms of specification of products, quality, design, volume and timing (Ortt et al., 2020).

3.2.6. Decentralization

Decentralization is the division of the system into smaller ones (Sorokač & Mišota, 2017). It corresponds to a transition from top-down to more bottom-up organizations (Prause & Weigand, 2016), decomposing traditional hierarchy into processes, and individualizing them (Lasi et al., 2014). The shift from centralized to decentralized networks allows the connected machines and tools to communicate with each other and make decisions independently, or being operable regardless of the location (Tay et al., 2018).

3.2.7. Automation

If digitalization is often expressed as a primary feature, it is added to the overall automation of the processes and every part of a company, and makes manufacturers and others able to minimize human input by using machines, as well as collaborate with them (Cotteleer et al., 2019). Automation is a key feature of the previous revolution, and is also present in an advanced form in the fourth one. Advanced autonomy in decisions relies on this characteristic, and is a base for Industry 4.0 (Oztemel & Gursev, 2020).

3.2.8. Smart

Da Silva et al. (2020) states that the concept is responsible for changes in organization and the industrial environment in general, changes brought by the implementation of new production techniques, new materials and digital systems, which make the industry “smart”. Smart is added because it refers to objects or systems taking action in an autonomous manner, and reacting adequately to the context (Rojko, 2017).

The processes being “smart” means that they bring the ability to generate data, communicate and interact with each other, by virtue of key features they possess (Oztemel & Gursev, 2020). It introduces and increases self-optimization, self-cognition, and self-customization (Cotteleer et al., 2019). Intelligent monitoring, manufacturing and logistics are results of industries being smart (Yue et al., 2015).

Overall, implementing Industry 4.0 implies a restructuration of the production system “*by transforming analog and centralized workflows into digital and decentralized production processes*” (Raj et al., 2020), and corresponds to a reconfiguration of the whole value chain. With it, the transformation of every industry is available through blending of physical and digital, advanced data treatment, all within an ubiquitous system (Tay et al., 2018).

Interoperability links the decentralized blocks and allows them to work together (Sorokač & Mišota, 2017). It makes the blocks, humans or machines, related to each through digital connection. Industry 4.0 has the capabilities to transit from physical to digital to physical again, in real time and with the ability to modify the process or let it, or the machine do the work intelligently (Tulip, 2020).

3.3. Technologies

What characterizes this revolution the most is the new, disruptive technologies that have emerged (Rojko, 2017). And the features presented above are all more or less present in the advanced process technologies of Industry 4.0.

The following elements can be a technology or the idea behind a technology. Because of the lack of concrete specific applications or their features, some are addressed more as an idea or goal to reach rather than a technology.

3.3.1. Cyber-physical Systems

A fundamental idea behind Industry 4.0, that can also be synonym, are cyber-physical systems (CPS). CPS represent the connection between machines and the real world (Roblek et al., 2016), the merging of physical and digital, making the two undifferentiated in a system (Lasi et al., 2014). The “cyber” dimension, e.g. the virtual or digital aspects such as data and artificial intelligence, are integrated into the physical element (Tay et al., 2018).

It leverages the intelligence, resilience and self-adaptivity of machines to manage systems combining physical with computational and statistical resources. They are defined as “*systems that combine statistics and computational approach with real-time data extracted from physical systems, to approach the response of a structure under various scenarios, with the goal of indicating the best decision*” (Pacchini et al., 2019).

Piccarozzi et al. (2018) explains these systems as integration between computation, networking and physical processes, supported by various technologies. This concept supports the integration along the whole value creation network (Tupa et al., 2017), and is sometimes thought of as the combination of the Internet of Things and smart applications (Frank et al., 2019, Roblek et al., 2016).

The physical objects can be a product, a machine, a system or an assembly line. These objects are organized in an environment that also contains virtual objects, and allows communication

and exchange between everything (Prause & Weigand, 2016). In other words, it integrates computation, networking and physical processes (Lasi et al., 2014).

3.3.2. Internet of Things

The Internet of Things (IoT) is the integration of sensors and computing through wireless communication in an internet environment (Frank et al., 2019). This technology allows connection between the internet and physical objects, connecting sensors, machines, mobiles and human devices (Pacchini et al., 2019), and can also be defined as the “*network of objects that communicate between themselves and other internet-enabled devices over the internet*” (Brous et al., 2020). It represents the interconnectivity of sensors, equipment, machines and the internet that form interactions between supply chain components, data and people (Butt, 2020).

Along with CPS, it is one of the building blocks of Industry 4.0 (Rojko, 2017), sometimes called the “Industrial Internet of Things” (IIoT), referring to the integration of IoT technologies that create value through the entire value chain (Piccarozzi et al., 2018). In Rojko (2017), Industry 4.0 is given as a specialization of the IoT when applied to industries, as it is the basis of the connectivity that characterize the concept.

The main feature of the IoT is the advanced connections it provides, bringing the ability to connect systems, services and physical objects at anyplace and anytime between them (Tay et al., 2018, Alcácer & Cruz-Machado, 2019). Growing the network of internet related objects, the nature of IoT is for them to be decentralized and heterogeneous (Alcácer & Cruz-Machado, 2019). It also decentralizes decision-making and analytic tasks (Rüßmann et al., 2015, Ghadge et al., 2020). Through these connections, IoT improves communication between objects and systems in a factory (Frank et al., 2019).

One of the main enablers of other Industry 4.0 technologies, IoT acquires large quantities of data directly from the “thing”, analyses it and stores it in the cloud. All this online-available content is accessible in real-time, and therefore allows real-time collaboration and information-sharing between all things and/or people (Brous et al., 2020). IoT brings the possibility to create new products, services and business models in all industries (Roblek et al., 2016). It is a basis for smart projects in an organization, with its important role of integration of smart devices.

Many advantages come along with the implementation of IoT technology in organizations. As already discussed, it is a key technology to digitize and connect organizations. Visibility of operations is possible with the help of sensors, even for remote operations. Implementing IoT

can result in cost and time-to-market reduction, and increase safety and mass customization, by permitting faster feedback. But some cons are associated with it as well (Butt, 2020).

IoT makes the industry more wireless, which has some risky implications. Especially in the public network, this makes information more exposed to intrusion, and requires organization to secure their data transfer. Access issues, security and privacy are therefore a danger to consider (Roblek et al., 2016). This technology also has high initial costs, and some uncertainty exists about the return this investment will bring. Other challenges are the qualification of employees to operate the technology, the lack of experimentation and standards and its integration in an established structure (Butt, 2020). IoT implementation increases internal operability, by providing more access to data, but may cause issues with external operability, raising difficulties for other players of the supply chain (Pacchini et al., 2019).

Its application in supply chains allows the increase of logistics and supply chain efficiency, by providing detailed and up-to-date information, improving product traceability. It allows for the (remote (Tay et al., 2018)) monitoring and control of manufacturing processes, and improves maintenance, production quality and energy management (Roblek et al., 2016). More sources and points of contact may increase reliability insurance on data and information gathered (Butt, 2020). In manufacturing, in-line quality assurance, or machine monitoring are some of the uses of the technology, and it aligns with philosophies of Just-In-Time and continuous improvement (Tulip, 2020).

3.3.3. Cloud Computing

The term “Cloud Computing” (CC) describes a remote access to an internet server or an external environment where data can be stored, managed and processed (Pacchini et al., 2019). It is the on-demand availability of computer-system resources, like computing power and data storage, without this system being directly managed by a human being (Butt, 2020).

When using CC, resources like hardware, software or information, are shared with and between various users through the internet, and can be compared to an outsourcing of data center operation to the cloud (Gupta et al., 2013). Yue et al. (2015) compares the cloud with a huge resource pool, from which services can be acquired and information requested as needed.

Advantages related with cloud computing are such as cost reduction, cutting the direct and indirect costs of IT infrastructure in an organization; portability, which CC enables by allowing internet connection from any type of device, anywhere in the world; and resource

rationalization, employees consuming only the computing resource they use (Alcácer & Cruz-Machado, 2019). CC reliable, as it offers backup for storage and recovery protocols, and encourages collaboration (Gupta et al., 2013). Using it enhances data sharing across all the organization, whether between departments, throughout the value chain or between sites/organizations (Ghadge et al., 2020).

The cloud can be considered an infrastructure for the other technologies (Tulip, 2020), and with its use, the integration of various devices is facilitated, having easy coordination capabilities and diminishing the dependence on physical closeness (Frank et al., 2019). Low on costs, it offers the ability to easily scale storage and computing power (Tulip, 2020), and encourages new competitors through its use (Butt, 2020).

Additionally, CC is highly flexible (Yue et al., 2015) and extremely fast (Pacchini et al., 2019). Silos and issues regarding data accessibility are limited or eliminated with the use of CC (Tulip, 2020). Because of its features, cybersecurity is inherently needed (Da Silva et al., 2020). Data security is indeed more at risk, even though the risk of complete loss is reduced (Butt, 2020).

From cloud computing emerges the concept of cloud manufacturing, which is its application in manufacturing systems (Alcácer & Cruz-Machado, 2019). In Babiceanu & Seker, (2016), cloud manufacturing is explained to be the idea of performing manufacturing operation through the cloud, and can range from product design, manufacturing, testing, management and every stage of a product life cycle. Many opportunities of collaborations or monitoring are possible and the overall drive from data is enhanced (Cotteleer et al., 2019). This technology matches the increasing individualization of product requirements, global cooperation and agility that characterize the industries today (Butt, 2020), and is highly relevant because today's competitive landscape depends a lot on real-time reactivity and fast information transfer and access (Yue et al., 2015).

3.3.4. Artificial intelligence

Artificial Intelligence (AI) is defined as “*the simulation of human intelligence in machines that are programmed to think like humans and mimic their actions*”. The actions performed are based on understanding from knowledge and reasoning, as well as perception, given to the machines. Machine Learning (ML), which is artificial intelligence generated and increased without human intervention, is a subset of AI (Frankenfield, 2021).

AI empowers machines and robots to learn from data and knowledge collected from previous activities (Riberio, 2021). The aim of AI is to represent, use and manage knowledge. With intelligence, the environment and its context can be recognized by systems, and the actions to produce are decided based on this intelligence (Pacchini et al., 2019).

Machines enabled with AI perform precise and complex tasks, because they are programmed to do so. Programming is indeed behind that, and the autonomy is therefore limited to that capacity (Riberio, 2021). AI uses data from the field into algorithms who grow more accurate and powerful with time (Tulip, 2020).

In an industrial context, AI is linked to the physical operations and systems of an organization, with the goal to improve its performances (Bécue et al., 2021). AI increases the power of automation activities, and organizations use data and AI in order to make complex decisions (Riberio, 2021). Overall quality is improved with AI, and often the costs can be reduced, as production is optimized (Frank et al., 2019). Error reduction, cost reduction in the form of decreased need for humans, and revenue growth consequence of fewer mistakes and focus of attention of employees, are advantages related to AI. By making organization overall more productive, it largely surpasses human labor efficiency (Riberio, 2021).

Monitoring applications of AI present advantages in quality control, allowing better inspection on a production line by example. The detection, predictive and diagnose power of operation in industries are decoupled with AI. Implementing it diminishes the risk of errors by humans, and accelerates the activities. Systems downtime and uncertainty are also diminished thanks to the automated process surveillance possibility of AI. In supply chain transportation, disruption risks are identified beforehand, and mitigate more easily.

Optimization through AI takes the form of process planning of the complex sequence in operation today, such as setups, sequencing and selection. In product design, which is more complex today due to their components being both physical and digital, AI facilitates and accelerates both the design and manufacturing. Benefits from it are time, quality, efficacy, cost, or yet again waste reduction (Bécue et al., 2021).

Applications of AI therefore exist, among others, in production lines, automating and improving processes, but also in agriculture, harvesting automatically and transportation, optimizing routes and transit time, among many. That trend and its presence is projected to grow (Riberio, 2021).

3.3.5. Big Data

Industry 4.0 is characterized by an important increase in data generated and collected. The huge amount of data of any type is the reason why Big Data (BD) is a key technology for the concept. The term “Big Data” describes these large volumes of high velocity, complex and variable data, and the advanced techniques that are required in order to capture, store, manage, distribute and analyze them (Alcácer & Cruz-Machado, 2019, Babiceanu & Seker, 2016). Big data analytics (BDA) is the assessing and improving of business practices through the use of statistics of mathematical tools on data generated by businesses (Butt, 2020).

Big data is the utilization of technology to conduct analysis on volume, the amount of data being large, variety, referring to the different formats under which the data are generated, and velocity, meaning that those data are continuously produced and managed (Babiceanu & Seker, 2016). It brings in the ability to deal with huge amounts of information through advanced analytical methods (Cotteleer et al., 2019).

The objective of big data is to produce accurate and fast information from those data for decision-making (Da Silva et al., 2020, Babiceanu & Seker, 2016). The insights provided by BD and the usefulness of the information it generates are the key benefits brought by the technology. By analyzing pattern, historical process data and relationship between processes steps, it allows an organization to optimize any processes or activities (Butt, 2020). It also improves efficiency and productivity, and enhances the opportunities of customization by increasing flexibility and agility in organization (Ghadge et al., 2020). It also optimizes production quality, improves services and use of resources, and saves energy.

BD has uses in root causes analysis, predictive maintenance, and the improvement of processes efficiency (Tulip, 2020). Applications exist in the optimization of product, process and supply chain overall, in quality testing, risk management, enterprise growth, production and overhead tracking and maintenance (Butt, 2020). Prediction of disruption is helped by the use of BDA, thanks to its accuracy and the sophistication of the possible scenarios (Ivanov et al., 2019).

BD and BDA present many synergies with the other technologies (Alcácer & Cruz-Machado, 2019). Because of the increase in ways to collect and store data, the numerous forms they take, BD is a must for a company wanting to move towards Industry 4.0 (Yue et al., 2015), as conventional data-processing technologies are unable to take on those large dataset (Butt, 2020). It can for example be interdependent with cloud computing, being the place where the

technical analysis thrive (Yue et al., 2015), and is driven by machine learning in many applications (Tulip, 2020).

3.3.6. Simulation

This component of Industry 4.0 is defined as “*the operation imitation, over time, of a system of real-world process*” (Alcácer & Cruz-Machado, 2019), and corresponds to a virtual representation of a real world process or system using real-time data through imitation, with the goal to determine or predict the output of a system or process (Cotteleer et al., 2019), as well as better understanding its dynamics (Alcácer & Cruz-Machado, 2019). Graphics are used to establish the approximation that is a simulation, and the behaviors represented are based on mathematical models and statistical tools (Butt, 2020).

Because of the complexity of today’s systems, the uncertainties are bigger and more frequent, and simulation allows organizations to experiment their products, processes, designs and configurations. Simulation is key to analyze operations and supports decision-making (Alcácer & Cruz-Machado, 2019) by allowing to test and optimize processes and systems, through trials (Cotteleer et al., 2019) and what-if scenarios (Alcácer & Cruz-Machado, 2019), before they are implemented or launched (Ghadge et al., 2020). In other words, it permits organizations to freely experiment various conditions and observe the results.

Assessing the impact of an investment, optimizing a production plan, a manufacturing process or resource allocation, testing the implementation of new techniques, conducting bottleneck analysis, ... those are some of the opportunities that are available with the implementation of this technology (Butt, 2020).

Simulation use historical records and observations as input, sometimes using big data generation, and real-time data available through CC and IoT (Ghadge et al., 2020). It tries to catch the operational features of the real system in order to better estimate and understand its behaviors, and has for goal to produce optimal or near-optimal system design that is found by a systematic search of the wide decision-space (Alcácer & Cruz-Machado, 2019) as well as weighing the pros and cons of any situation more accurately (Butt, 2020).

The real-time feature of this technology allows to analyze behaviors in milliseconds, which result in accuracy far better than previous. The consequences are shorter setup time and higher quality (Cotteleer et al., 2019). This increase in quality can reduce costs for an organization,

which are further brought down by the shorter development-life cycle that is possible with simulations (Alcácer & Cruz-Machado, 2019).

It is the basis of the virtual factory concept (Cotteleer et al., 2019), which is a simulation with high-fidelity, creating an environment using Virtual Reality to represent a factory. The ultra-high fidelity simulation is called the Digital Twin concept (Alcácer & Cruz-Machado, 2019).

3.3.7. Additive Manufacturing

Additive Manufacturing (AM) is a manufacturing process that creates three-dimensional physical objects by a computer controlled system. It relies on 3D printing, which forms the objects by assembling material, drop-by-drop. Other names of AM are “rapid prototyping”, “solid freeform manufacturing”, “layer manufacturing”, “digital manufacturing” or simply “3D printing”. With it, objects are produced from data files created by humans, and require no additional processing (Alcácer & Cruz-Machado, 2019).

This innovative technology allows to produce complex parts and unique batches in small quantities (Pacchini et al., 2019), offering production advantages and increasing customization (Ghadge et al., 2020). This variety is available in an organization's production without relying on multiple suppliers, decreasing the load on supply chains (Butt, 2020).

The capabilities of Additive Manufacturing is crucial for the implementation of Industry 4.0 (Cotteleer et al., 2019). An advantage of using AM is the new product design opportunity, by allowing the design of a great variety of parts, new geometrical form and hollow parts which weigh less (Alcácer & Cruz-Machado, 2019). Products can be manufactured without conventional surplus, using the same materials (Frank et al., 2019), granting an easier production of unique and non-frequently needed products, thanks to its flexibility (Alcácer & Cruz-Machado, 2019). There are reduction in manufacturing costs and shorter lead-time of design and manufacturing, thanks to small production runs and the shorter turnaround the technology permits (Butt, 2020), enhancing the control of organization over their inventory (Ivanov et al., 2019). This technology is also easily scalable.

In addition, the material utilization in 3D printing is also maximized, reducing waste, and has overall a smaller operational footprint for the capabilities offered (Alcácer & Cruz-Machado, 2019). For users of the technology, work can become safer, issues being less likely (Butt, 2020).

Companies have used AM for the design of parts to reduce the weight of the engine produced, while lowering the cost by switching from the expensive product that they replaced (Rüßmann et al., 2015). AM is equally added into the networks of SMEs, large organizations and governments (Ghadge et al., 2020). It stimulates advanced data technologies and smart production system utilization (Cotteleer et al., 2019), enabling new business models and supply chains (Alcácer & Cruz-Machado, 2019).

As explained, the small batch possibilities decrease delivery time, but it also slows down the process overall (Szász et al., 2020). The set up and maintenance of AM capabilities are also quite expensive (Sony, 2020). Large scale manufacturing is where this advanced engineering machinery can show real issues, being limited by a low throughput speed (Frank et al., 2019).

3.3.8. Autonomous Robots

This technology corresponds to robots interacting with each other and with humans, all collaborating together (Cotteleer et al., 2019). Working alongside humans, the aim is for the robots to learn and act by themselves in the future, to become truly intelligent, cooperative robots, called “Cobots” (Da Silva et al., 2020, Ghadge et al., 2020). These robots have a greater range of capabilities, cost less and are safer than the previous kind (Rüßmann et al., 2015).

Even though they work with humans, they perform the task without human intervention. Often combined with AI and presenting some similar characteristics, making autonomous decisions and independent acts is obviously part of their features. They can take on many forms and accomplish many different functions, depending on what they were built to do (Fitzgerald & Quasney, 2017).

Robots already offer many advantages, allowing organizations to perform and automate repetitive, dangerous and time-consuming tasks with more efficiency, accuracy, less errors and quicker (Butt, 2020). The presence of traditional robots increases the productivity of a firm, and is less susceptible to fatigue (Frank et al., 2019). Adding the “autonomous” feature allows these tasks to be conducted or controlled without the intervention of humans behind, and rather rely on programming for decision-making. The autonomy of the robots makes them respond to external cues on their own (Butt, 2020). In dangerous environments, using these robots makes risks lower and ensures safety (Fitzgerald & Quasney, 2017).

Autonomous robots provide advanced functions and high flexibility, and easy operation in various fields (Cotteleer et al., 2019). More complex assemblies are possible with Autonomous

Robots who are increasingly capable, and the quality they provide is more certain with them than without. They present the feature of precise data generation, used by and in many other technologies (Tulip, 2020). Decreasing costs in the long term, optimized operations and reduction of fixed costs are some results of its implementation (Fitzgerald & Quasney, 2017).

This paradigm is particularly relevant with the shift from mass production to customization that we can observe today, which demands wider product variation and flexibility (Cotteleer et al., 2019). Although robotics technology is already quite present in organizations today (Ghadge et al., 2020), especially in manufacturing and warehousing for example (Fitzgerald & Quasney, 2017), they are expected to become cheaper and more sophisticated in the future, increasing their omnipresence (Ghadge et al., 2020).

3.3.9. Blockchain

Blockchain (BC) is a way to store and transmit data, under the form of connected blocks that are protected against modification (Identity, n.d.). Each data and information transmitted or stored in it is recorded into a ledger that is shared between all parties involved in the transaction, and all nodes of the BC network (Alladi et al., 2019).

This technology is an answer to the challenges of trust. With it, transactions are not only untraceable, but also verifiable and permanent. It works as decentralized systems or ledger, making central unity such as banks or other intermediaries unneeded. *“[E]very agreement, every process, every task, and every transaction has a unique digital record and a signature that can be identified, validated, stored, and shared”* (Subic et al., 2018).

The platform offered by BC allows for safer collaboration. Transactions being monitored with transparency and in a secure manner, delays and human errors are limited (Alladi et al., 2019). Using BC enables people, machines and companies to communicate in an autonomous and easy manner, conducting transactions on their own and safely. It also supports environmentally and socially responsible procurement.

The directness of BC technology opens many possibilities, such as new business models and innovation in organization and work. It simplifies contracting, reporting and monitoring of workflows and data. End-to-end services are facilitated by the technology, and it limits frauds in the system. Combined with the other technologies, new services can be created, blockchain enabling ecosystems with useful capabilities, and redefining value.

BC is mostly known in its application of cryptocurrencies, but also has tangible potential in manufacturing, supply chains and logistics. In transportation, cost and time can be saved thanks to the application of its tracking power in shipment and transactions. Manufacturing can be made more agile and productive in the hyperconnected ecosystem enhanced by blockchain, where trust and ownership are verifiable (Subic et al., 2018). As an example, technical publication can utilize the framework of BC, making manuals for products accessible while keeping the capacity to update them easily, saving on paperwork and time doing so. Automobile parts availability are also given thanks to the tracking feature in real time.

Its application in an Industry 4.0 context is called Blockchain 3.0, and corresponds to the feature presented, applied with CPS. Some challenges exist, such as regulations, energy and cost efficiency, or resource constraints, but overall its use should result in benefits and is expected to grow (Alladi et al., 2019).

3.3.10. Augmented Reality

Augmented Reality (AR) is an expansion of the information from a physical environment, allowing humans to interact virtually with the real environment (Pacchini et al., 2019). It overlays digital content with the information and projects it in the real world through a display, eyeglasses, holograms, graphics or other interaction technology (Butt, 2020). The interplay is often presented in 3D and in real-time.

AR's aim is to increase human performance by providing the information necessary to perform a task. That information is supplied by using artificial information about the environment to increase our perception of it. AR indeed brings the ability to replicate knowledge and digital information together, closing the gaps between design thinking and actual operations (Alcácer & Cruz-Machado, 2019). Operations are flexible and easier to conduct with this technology, but it is mostly the insights it provides that are the important benefit of it.

AR's applications are mostly seen in maintenance, being a big support for business by increasing prediction accuracy, reducing the potential for errors and time needed for maintenance, as well as lowering its frequency to prevent unplanned reactive actions. The associated costs are also lowered with AR (Cotteleer et al., 2019). Overall effects are improvement regarding quality, speed and safety in production (Tulip, 2020).

Lots of various services can be supported by AR, like the design of warehouses' layout or production line, precise remote-instructions communication and more, but they are still

developing and at an early stage for now. Product development, production or assembly processes, quality and maintenance are all areas where using Augmented Reality is relevant (Ghadge et al., 2020). Virtual training, as well as instruction for the preparation of installation in a system, are some of the opportunities offered by Augmented Reality, interacting with machines through cyber representation, changing parameters and collecting feedback for them and the machines (Tulip, 2020, Rüßmann et al., 2015).

Coupling AR with other techniques or technologies of Industry 4.0 makes its value and benefits increase greatly, e.g. combining it with Cobots or Digital Twins (Ghadge et al., 2020).

3.4. Pros of Industry 4.0

Hereunder, the various advantages that a move towards Industry 4.0 can bring to organizations are presented. In order to understand if and why the concept has been accelerated by the coronavirus pandemic, understanding what it brings to the table is relevant.

3.4.1. Strategic competitive advantage

First, Industry 4.0 can be a source of strategic competitive advantage. The innovation capabilities and unique features that characterize Industry 4.0 can be used to differentiate oneself from competitors in value proposition. Business opportunities expand with the implementation of the concept, IT enabling any product creation and the processes to create them (Sony, 2020). Products and services become digital, as do channels, and the possibilities in design for manufacturing companies grow. Innovation regarding business models overall exist with new technologies (Horváth & Szabó, 2019).

With the increasing presence of technologies in industries, organizations that fail to join the trend will be at risk of being left behind. Product differentiation, customer segmentation, dynamic price-settings, more competitive prices and value added services are a few of the possibilities the concept offers (Sony, 2020).

Furthermore, that creates competition between organizations using the technologies (Moeuf et al., 2020), resulting in overall better products, at lower prices and more suited to customer needs (Sony, 2020). In a nutshell, Industry 4.0 allows organizations to create, maintain and expand their competitive position and enhance long-term success (Müller et al., 2018).

3.4.2. Efficiency and effectiveness

Second, and as it has been observed in the presentation of the various technologies, an organization that implements Industry 4.0 technologies can become more efficient and effective (Sony, 2020).

Through the automation of tasks, planning and control, sharing and exchange of information through and across the organization, efficiency is increased (Ghadge et al., 2020). By continuously analyzing data, operations have a greater agility and dysfunction are more easily identified, contributing to more efficient productivity (Da Silva et al., 2020). As observed in the previous section, the technologies contribute all in all a better functioning organization, more efficient and effective (Sony, 2020).

3.4.3. Profitability

Profitability is another perk related to Industry 4.0. The opportunities it offers can allow organizations to increase their market share and therefore their revenues (Horváth & Szabó, 2019). With established processes and intelligent products, operational and personnel costs decrease, as do costs related to material waste and quality issues (Sony, 2020). Other cost reduction can come from the predictive power, the autonomous management and optimization of service and resource consumption of the technologies (Tay et al., 2018). Inventory costs diminish thanks to the visibility and monitoring capabilities, along with information sharing between supply chain members (Ghadge et al., 2020).

Although the assets under Industry 4.0 have more expensive depreciation costs, their utilization is enhanced, and labor cost lowered (Szász et al., 2020). And while some cost may increase, such as maintenance, the overall effect of digital technologies, with the capabilities they bring, is positive on profitability in the long run, and can be so as well in a shorter term (Sony, 2020).

3.4.4. Customer experience and satisfaction

Technology can be a benefit in terms of customer experience and satisfaction as mentioned above. The features of Industry 4.0 give them more bargaining power, and control over their purchases. They can become more informed, and their experiences can become unique, as opportunities to co-create with the customer can come with the implementation of Industry 4.0 (Sony, 2020), and interactions take on a new form (Matt et al., 2015). The analytics, additional

information gathered and customization capability allow organizations to meet the personal customers demand more closely (Szász et al., 2020).

3.4.5. Responsiveness and agility

Responsiveness and agility allow this improved customer experience and more. It enables organization to respond more quickly, and with more quality. Along with contributing to customer service, long term performances are affected overall by these attributes, as being reactive allows for more sustainable trend following.

This flexibility is mainly there due to integrations in the organization (Sony, 2020). In the supply chain it corresponds to inventory risks mitigation, shorter lead time thanks to inventory control, planning quality through to ability to reconfigure and recover more often and easily (Ivanov et al., 2019). Overall, partly due to the interconnectivity of Industry 4.0, organizations will be able to react rapidly and adapt to changing factors (Horváth & Szabó, 2019).

New products can be produced in high mix and low volume depending on the demand, the manufacturing process of Industry 4.0 allowing it thanks to its connected and flexible nature. Having the future “smart” factory will be an advantage over other manufacturers, using big data in every step and allowing the process to be innovant (Sony, 2020).

3.4.6. Quality

Quality improvement is also provided through digitized supply chains and thanks to automated quality control systems. The literature shows that technology allows for opportunities to reduce quality issues through better identification and more performant control (Szász et al., 2020). With Industry 4.0, the life quality of (new) products and services is increased. Because it is self-aware, maintenance of the system is more performant, diagnosing malfunctions more easily (Oztemel & Gursev, 2020).

3.4.7. Operational improvement

All the operations of an organization with implemented Industry 4.0 should be improved. Thanks to some of the technologies presented before, such as simulation or AR, the operations should be optimized, whether in its preparation and prediction or reactive capabilities, by virtue of real-time feature and flexibility of the technologies.

The availability of data, awareness and coordination of the fourth industrial revolution will provide more capable and reliable systems along the value chain (Sony, 2020). Furthermore,

traceability features are present in the technologies (Da Silva et al., 2020), and making internal operations traceable allows optimizing control in activity flow (Frank et al., 2019). Assets have a very high utilization thanks to machine failure and downtime being reduced. In short, all operational dimensions, whether sourcing, planning and manufacturing, delivery and logistics, can potentially be improved in performances (Szász et al., 2020).

3.4.8. Performance measurement

Performance measurement and evaluation are facilitated by digital technologies, improving decision-making in management (Horváth & Szabó, 2019). Those decisions would become unbiased thanks to real-time and knowledge based information (Oztemel & Gursev, 2020). The collection and use of data support knowledge management and allow for fast decision making, which can result in performance improvements (Horváth & Szabó, 2019), which can also be bettered through collaboration opportunities and accuracy and visibility in the value chain (Ghadge et al., 2020).

3.4.9. Transparency and accessibility

Transparency, informed decision-making, and robotization in production can improve the quality of life of people (Sony, 2020). Workers can benefit from better working conditions through enhanced productivity and remote access, and the processes and information being more visible through all activities contribute to transparency (Frank et al., 2019).

Access is another benefit from Industry 4.0. In fact, personal information is more easily accessible thanks to digitalization, as is data about the process and monitoring, and other types of information. Subsequently, control is also more attainable, as opportunities to conduct and monitor operations remotely are available (Oztemel & Gursev, 2020).

That remote management is possible thanks to the digital connectivity and the continuous, access to machines or workers data and information. Apps and dashboards permit to keep an eye on performance, and interoperability facilitates operating at a distance. Visibility and continuous interactions with what is happening, in the form of KPI or communication, ensure that being remote does not overly affect operations (Tulip, 2020).

3.4.10. Corporate social responsibility

Finally, benefits also arise in environmental and social areas. Greenhouse gases and waste reduction, efficient resource uses and the diminishing of physical and logistic processes are all

positive for the environment (Sony, 2020). In addition, energy efficiency can be significantly increased with Industry 4.0 (Horváth & Szabó, 2019), through monitoring and improvement of resource management (Frank et al., 2019). The manufacturing environment under the fourth industrial revolution has been used for the development of green products and management which are more environmentally-sustainable (Horváth & Szabó, 2019).

3.5. Barriers to Industry 4.0

This section has an objective to present the reasons why the concept is not more developed. The cons and barriers for Industry 4.0 are discussed below, as they are equally important in order to understand the impacts of the Covid-19 pandemic.

3.5.1. Infrastructure and integration

First, having the required infrastructure is necessary to implement Industry 4.0 (Ghadge et al., 2020, Horváth & Szabó, 2019, Raj et al., 2020). If not present, digital networks, machines and other information systems will need to be constructed, developed and maintained. Some work is needed in order to host these technologies and use them, as they are not all universal or that easily accessible yet (Da Silva et al., 2020). If some IT needs are lacking or are not performant enough for technologies to be added, changes, which may be complex ones, need to occur in order to make the organization compatible (Prause & Weigand, 2016). Inadequate structures are an important barrier to Industry 4.0 and the integration of its components, tools and methods (Horváth & Szabó, 2019). Integration is a must to achieve Industry 4.0, and it cannot be done without the adequate digital infrastructure (Raj et al., 2020).

To create and develop the network in and between companies, that allows interconnection and integration, the systems have to be standardized and a referential architecture created. The infrastructure required in order to back the communications capabilities up need to be present as well, to ensure quality and reliability (Oztemel & Gursev, 2020). In fact, poor data quality can be an issue for the implementation (Ghadge et al., 2020). The large amount of data to deal with and their complex nature, makes measuring completeness and accuracy of those data a difficult task, and increases the risk of making wrong analysis. Sharing data with a multitude of “players” also generates doubt about integrity and consistency (Raj et al., 2020). Ensuring the quality of data is thus a challenge to deal with.

3.5.2. Lack of skilled labor

A second barrier to Industry 4.0 is the need for competent labor. Employees will need to be multiskilled, with state of the art knowledge, understanding of the technologies, process and concepts, but also technical and IT skills. Complexity comes along with Industry 4.0, and therefore requires competencies to operate (Sony, 2020, Da Silva et al., 2020). Without these, the potential of the transformation will not be caught (Raj et al., 2020).

Additionally, capacity in creative work, entrepreneurship or cooperation are more important than before. These social competencies will be required in the new connected organizations, and traits such as flexibility, eagerness to learn and handling pressure (Raj et al., 2020).

This implies a need for development and training (Ghadge et al., 2020) of the various skills required from actual and new personnel, in order to increase proficiency, or just to make them familiar with the changes. Some of the demands will also mean that competencies will need to be hired, if talent is not present or if the skills take too much time to teach.

The circumstances will change with such implementation, and meeting the new needs in terms of employees might be difficult (Sony, 2020), as the workforce needs to be qualified for what is, all in all, a different business (Raj et al., 2020).

3.5.3. High Investment and lack of financial resources

The implementation of Industry 4.0 in an organization is a transformation that requires important initial investment (Da Silva et al., 2020). High capital expenditure needs to be raised for implementing Industry 4.0 (Sony, 2020). Sepasgozar (2020) shares that *“According to Geissbauer et al. (2014), firms intent on implementing Industry 4.0 initiatives would have to commit to increasing their planned yearly capital investments by 50% for the next five years”*.

Companies that lack financial resources encounter difficulties to implement new technologies. As explained above, some structures are required and their constructions come with high costs, as does the purchase, installation and maintenance of the technologies (Da Silva et al., 2020).

Once installed adequately, the need to be qualified to operate them is also demanding financially in the form of formations, salary and possibly recruitment. The investment in people mainly impacts the beginning of the transformation, because of the massive workload that it implies. After which, the long term operation requires less qualifications and less money.

However that initial investment is not only financial. Time and effort are also massive in the initial phase that is design and introduction (Sony, 2020). One of the goals is to automate the operations, and developing the tools to achieve that is an important task that implies massive workloads. The formation, along with trials and errors, can also slow things down (Da Silva et al., 2020). As a result, the increased requirement for employee quality implies lots of effort in them, and competition may increase the efforts needed (Sony, 2020).

3.5.4. Return on investment

The financial demand of the implementation of Industry 4.0 are coupled uncertainties and risks about the returns. Finance prevents further the implementation of new technologies because the gains and scaling of the initial investment is not assured or certain (Ghadge et al., 2020). Doubts about unplanned events or wrong forecasts increase the reflection before launching an initiative with such investments (Cotteleer et al., 2019).

Cost-benefit analyses are then unclear (Ghadge et al., 2020, Raj et al., 2020), and how to measure financial returns is questioned by managers (Da Silva et al., 2020). There is a lack of business cases and studies to support the implementation, refraining some companies to make the initial investment (Horváth & Szabó, 2019).

Because the investment is sometimes seen as defensive, in the sense that it is a solution to issues organizations face, profitability prospects are sometimes challenged, and the reactive nature it takes is opposed to investment with the goal of future return (Cotteleer et al., 2019).

3.5.5. Cybersecurity and privacy

Cyber-attacks and loss of data integrity are risks related to Industry 4.0 (Tupa et al., 2017). Because everything is connected and transparent, digital threats are more frequent, and these security issues are to be taken into account.. In addition, with higher transparency, the risks of attacks increase as well (Sony, 2020).

Sometimes considered as one of its components, cybersecurity refers to policies and practices to monitor all the data and programs, as well as the computers and the network linking it all, that aim to limit the risks exposed above (Butt, 2020). Having cybersecurity is protecting not only the organization, but also the employee, through the implementation of technological solutions (Horváth & Szabó, 2019). It is a must in order to conduct reliable and secure

communication (Oztemel & Gursev, 2020). It also provides protection against process manipulation, data and product theft and other kind information thievery (Sony, 2020).

The accessibility of information and connectivity present therefore cybersecurity issues, but also the risk of giving and submitting data and information to third-party who provide Industry 4.0 products and services, like software companies, and to other actors of the value chain (Raj et al., 2020). Issues regarding data access and rights also arise (Sony, 2020).

Privacy is another problem linked with the digital, traceability and transparency being inherent to it. Surveillance of everything is increased and it can be problematic, as the exchange, processing and storage of individual data is endangered (Roblek et al., 2016), their privacy and safe handling not being assured (Horváth & Szabó, 2019).

The damage possibilities regarding cybersecurity can be quite significant. Protection against intrusion is mandatory in that environment, the consequence of an attack occurring being consequent, which is an additional thing to consider (Roblek et al., 2016). The reliance on digital makes dread the consequences of breaches in the system, as the entire production or running of the organization is at risk. An organization victim of the issues may lose reputation, customer, intellectual property, and more (Da Silva et al., 2020).

3.5.6. Connectivity

The interconnectedness comes along with many pros, but also major cons. The fact that a failure at one point of the value chain may cause disruption of the whole system is the main one. The propagation of issues due to the dependence and omnipresence of digital components is a risk that integrated technologies bring to the table, and could dissuade organizations from going toward it (Da Silva et al., 2020).

Relying on the connection provided by Industry 4.0 means that an issue can be propagated from one actor to another, and disruption is more likely because of the increased precision it provides, its capabilities hindering safety considerations outside of those provided by it (Ivanov et al., 2019). Performance will depend heavily on machines and tools that are complex and difficult to handle or fix in the case of an issue (Da Silva et al., 2020).

Another barrier could be related to the competitive landscape in which companies find themselves. Because Industry 4.0 is integrated and connected, a vast amount of data will be shared between companies, and as explained before, information is more transparent. This

argument for a barrier is mixed, but the idea is that because they don't want to share data, or for concurrent to have access to their data (Sony, 2020).

3.5.7. Organizational resistance

Organizational resistance is a powerful barrier to any change. It has significant importance for the introduction of new technologies as well. Whether linked to new skilled requirements that may lose employees their job, or the change in role of middle management which will be less about people and more about the technologies, refusal to cooperate in the changes is a possibility when implementing Industry 4.0 (Horváth & Szabó, 2019).

That resistance may come from a lack of understanding of the benefits that may come from the change, making employees reluctant to adopt it (Ghadge et al., 2020). The impact on the employees are quite important, automating or increasing the demand of jobs. They will need to learn new things, and it can raise anxiety about operating in the new system. Along with the trade unions, employee can influence the way changes occur (Sony, 2020). In general, any changes from accustomed existing patterns encounter resistance (Roblek et al., 2016).

3.5.8. Lack of understanding

The last barrier is linked to the multiplicity of perspectives about the concept that reveals a lack of hard truth and knowledge about it, which is a difficulty in order to make the transition. Knowledge is needed for using the technologies efficiently, and can be acquired and assimilated through cases (Da Silva et al., 2020), for which there is a lack thereof (Horváth & Szabó, 2019). In order to enable digital development, knowledge, experience and digital thinking is needed (Roblek et al., 2016).

The concept overall can be difficult to comprehend, being quite open and having a wide area of application of all kinds. Therefore utilizing it in a specific context and situation, and developing a strategy, plan or project around it, is not an easy task (Schumacher et al., 2016). Yet its understanding is needed in order to fulfil its potential and balance its risks with the advantage it presents (Müller et al., 2018).

3.6. Development

Today's industry has several characteristics that have contributed to the development of the concept of Industry 4.0 and the implementation of its technologies in industries.

All kinds of society's developments have had impacts on the way businesses, raising challenges that need to be tackled or considered, whether they are environmental, social, economic or technological (Schumacher et al., 2016). This section aims to provide context and reasons for the emergence and development of the concept.

3.6.1. Globalization

Industry 4.0 appeared in a period where internationalization was increasing. Globalization aims to increase international influence and develop operations abroad, motivated by competition, economic growth and development. It goes hand in hand with technological advances which facilitate it and contribute to the same goals (Industry Today, 2020, Telukdarie et al., 2018).

3.6.2. Markets

Globalization impacts markets, which demand more efficient technological improvement and push the development of new production processes (Schumacher et al., 2016). Markets have grown increasingly volatile, heterogenous and uncertain. Constant changes and fast adaptation are more and more required (Sony, 2020, Rojko, 2017, Horváth & Szabó, 2019), due to changes in expectation from consumers and the focus on the latter, who demands customization and personalization (Alcácer & Cruz-Machado, 2019, Lasi et al., 2014).

3.6.3. Competition

The level of competition between organizations has grown in recent times (Piccarozzi et al., 2018, Pessl et al., 2017), resulting in increases in productivity, capacity and innovation requirements, and other KPI such as lead-time, to be more demanding. In order not to be left behind by competitors, companies have invested in new digital technologies, and continue to do so with the goal to create decisive advantages for themselves (Horváth & Szabó, 2019).

3.6.4. Complexity

All this makes for an environment that is increasingly complex (Tupa et al., 2017). The causes are the increased number of variables and actors, be it products, customers and suppliers, materials, processes, or IT systems (Prause & Weigand, 2016), but also the use of technical and complex products and productions (Pessl et al., 2017). To better manage increasingly complex systems, going further into Industry 4.0 is interesting (Prause & Weigand, 2016).

3.6.5. Flexibility

Flexibility is therefore expected from organizations, in time and space, especially in production (Tupa et al., 2017), and Industry 4.0 can bring them that, as it allows more transparent, less hierarchical and decentralized flows (Horváth & Szabó, 2019). Companies need to be able to manage their whole value chain in a manner that is agile and responsive. Virtual and physical structures are therefore needed to adapt and cooperate in every step of the supply chain (Schumacher et al., 2016). Organizational structures have therefore changed, becoming more decentralized, less hierarchical as a response to the demand for faster decisions and procedures (Lasi et al., 2014). The value chain became more and more fragmented as a result (Prause & Weigand, 2016).

3.6.6. Demographic

Changes in demographic are always present during industrial revolutions. Industry 4.0 emerged as a response to an aging society. That fact has major implications for the labor market, as the workforce comprises fewer experience, and skills are staying with the aging workers. The automation of tasks, and decreased involvement of workers on repetitive, monotonous or physical tasks, free their time on more complex challenges and creative work (Kuka, n.d.).

The decrease in the working age population and the aim to reduce labor work are thus both drivers for the development of industrial technologies. Flexibility is also required in the workplace, not only in the processes, and it can be aimed at with Industry 4.0 (Rojko, 2017). Hierarchies and distinctions between employers and employees decreased, in the light of innovation, efficiency and productivity goals (Industry Today, 2020).

3.6.7. Sustainability

The demand for efficient use of resources and sustainability challenges also encouraged the implementation of new technologies which support these goals (Lasi et al., 2014). Society wants organizations to make more with less energy, something Industry 4.0 can help with (Rojko, 2017). Out with the outdated production system that can cause environmental damages, in with the new one, which meets those sustainability expectations by reducing waste and increasing quality (Horváth & Szabó, 2019). CSR concerns, and the possibility to be more environmentally friendly, contributed to the development (Lasi et al., 2014).

3.6.8. Government

Launched by the German government, the incentives to generate more economic activity, drive innovation, increase competition and increase average wages have attracted many other institutions to put in place conditions and context for the development of Industry 4.0. Research and development programs, infrastructure support for transport, energy and utilities, or communication were all favorable to the development of the concept and increased presence of technologies (Oztemel & Gursev, 2020).

3.6.9. Digital

The increased use of digital technology in everyday life has naturally triggered the transformation of industrial processes (Rojko, 2017). Every industry is impacted by the changes in the economy, and push towards digitalization (Szász et al., 2020). Changes in society make it more and more connected and networked. Those changes have affected and created challenges in and outside of businesses, and solution leads were presented by new technologies, (Horváth & Szabó, 2019). With the increasing need of volume, availability and the real-time requirements in industries, new infrastructures were needed in order to be able to handle these loads of data and information. The complexification of the world has an effect on industries and increased the reliance on data in order to perform (Tupa et al., 2017).

3.6.10. Technological development

Computer processing and storage capabilities have increased and become more performant, capabilities on which organizations want to capitalize. To that can be added the scalability and competition, and the resulting more affordable access to the technologies, all reasons for the development of the new ones. The emergence of the technologies has obviously heavily influenced the advances of the concept (Tulip, 2020). Among the technological advances, the infrastructures allow now faster, more secured, and reliable services, enabling real-time data handling (Rüßmann et al., 2015).

The speed at which technological evolutions occur needs to be pointed out as well. A few researches already suggests another revolution, and with it some obligations. The pressure on organizations to catch up, implement and integrate, is increasing, not wanting to be left behind in case the new advances become the norm (Oztemel & Gursev, 2020).

3.6.11. Improvements

Gubán & Kovács (2017) provides the five main incentives that pushed the progress of the concept. They are efficiency, effectiveness, service oriented, innovation and speed requirements regarding changes. In addition, advanced ICTs have already boosted the manufacturing industry, by allowing it to make better decisions and execute them more convincingly after having handled data smartly in an interconnected and reliable environment, providing it conscientiousness. With the implementation of the technologies, production should be faster and downtime be reduced, resulting in more efficient systems that save costs, are easy to maintain, and provide better quality products. Planning, prediction and control are three main fields of the value chain that organizations can improve with Industry 4.0, which optimize its dynamic autonomously (Tay et al., 2018). New products, services, and business models can be created with their help, in every industry (Roblek et al., 2016).

For Cotteleer et al. (2019), productivity and operational goals are the main factors that drive the digital transformation. The operational benefits, mentioned in a previous section, are of course an argument for the implementation of the technology. Overall, the challenges arising in society and for organization encouraged the development of the Industry 4.0. That can be observed in Gubán & Kovács (2017), which gives the main challenges that logistics organizations will face: *“Reduction of supply chain costs, changing customer demands, increasing volume of e-commerce, improvement of relations between supply chains, reduction of stock level, sensitivity and flexibility of supply chains, sustainability, application of new technologies, intermodality, cooperation in transport activities, reverse logistics, new transport corridors, increasing of global purchase”*.

3.7. Implementing Industry 4.0

The goal of this section is to get a grasp on what implementing Industry 4.0 consists of, practically. A focus is set on the speed of implementations, the overall process, and the conditions in which it is done.

3.7.1. How to implement?

When implementing Industry 4.0, the parts of machines and products are subject to relatively low changes compared to the whole processes. The elements part of the process usually stay the same, they are only “encapsulated” in the Industry 4.0 concept, making their functionality greater. New elements from an implementation are not part of the production process, it is rather

the relationship between the elements that changes, going from centralized to decentralized, or adding communication or awareness capability (Prause & Weigand, 2016). Connectivity is often the added functionality, by bringing sensors or ways to collect more information to the existing processes (Jarret, 2020).

The core of Industry 4.0 is the manufacturing revolution, and could be translated into industrial hardware, investment in new technology, or the use of software (Rojko, 2017). Many things could be called “implementing” Industry 4.0, and therefore making the first steps in that direction is easy. Small and incremental investments are possible and they could be a start for greater moves (Jarret, 2020).

3.7.1.1. Incremental implementation

Usually, moving toward Industry 4.0 is done in incremental steps (Jarret, 2020). The way to implement Industry 4.0 is often an upgrade of what the organization currently offers for Cotteleer et al. (2019), followed by incremental evolution to move further into the concept. Improving existing processes gives a good foundation and allows organizations to capitalize on the benefits.

The implementation sometimes implies the building of expensive infrastructure. Limiting the costs is a reason why individual functional increments are often done. The larger investment is divided into multiple smaller ones, part of a bigger project and moving the organization closer to the goal (Sorokač & Mišota, 2017). As a beginning towards transformation, some components are easy, quick and cost effective to add to existing machinery. That retrofitting process presents some advantages, such as the reduction of obsolescence, which is a heavy risk of Industry 4.0 (Jarret, 2020).

To develop goal-oriented solutions, experimenting and having a systematic approach is key for Veile et al. (2019), who recommends an incremental bottom-up approach. For Sepasgozar (2020) also, realizing Industry 4.0 is a staged process, and not a punctual event. Various steps need to be followed and often imply a feedback loop and experimentation, more than a clear series of tasks to follow (Sepasgozar, 2020). Kerl (2020) provides a roadmap for the implementation and also stresses the importance of having a pilot, evaluating the performance regularly and iteration.

Implementing a full transformation directly, in one go, is most times unrealistic. That is why the process usually takes place in phases and cases built on top of previous ones, and scaled to

other area of the business. The difficulty with that process is that the big picture needs to be known, and cases done towards it, and all the pieces need to fit together. It is through experiences and proof-of-concepts that organizations will be able to continue and quickly develop new ideas, or implement new technologies (Korbel et al., 2019).

Therefore, if Industry 4.0 is revolutionary, its diffusion should be more evolutionary, being implemented step by step and incrementally, each one being part of the larger picture for Industry 4.0 achievement (Prause & Weigand, 2016).

3.7.1.2. Where to invest?

Another direction taken is also to invest in prioritized aspects only, such as bottlenecks, and only incrementing it at first (Sorokač & Mišota, 2017). Choosing where to invest also depends on the forecasts of the company. There is a need to use that technology to the best of its capacity, and therefore it will be more relevant in certain areas where growth is planned (Klincewicz & Luss, 1985).

3.7.1.3. Speed

Gradually evolving the environment seems to be the preferred way to implement, but some companies see that evolution going very slowly due to technical challenges in the various updates (Da Silva et al., 2020). Digital transformation takes time. The ecosystems need to see incremental technological changes, and fill the gaps on the way. Proof-of-concepts give the best results, and experimentations are usual steps towards its completion (Tulip, 2020).

Getting pushed, or forced to make the shift in a small amount of time can make organizations invest without fully thinking things through or understanding the implications on the operations. Considering the wide array of possibilities in the implementation, investing in the more relevant technology or idea takes time, as does the preparation to such an undertaking. For the Engineering Employers' Federation (EEF), there are three stages to the journey that is Industry 4.0: the conception, the evolution and the revolution. Organizations should focus on one step at the time, and move forward realistically (Jarret, 2020).

Moving towards Industry 4.0 can be done in many different ways, and some require less investment than others. On the one hand, advanced engineering technologies are longer to implement, showing slow adoption for every project, as does advanced robotic automation. The digital operations on the other hand, with the exception of blockchain, seems to be easier and faster to adopt, requiring few to none previous technology infrastructures. It is also the case for

some human-machine interface technologies, like basic automation or Augmented Reality. Other technologies' implementation speed is more related to the previous disposition of the organization (Agrawal et al., 2020).

3.7.1.4. *When to implement?*

Because a high fixed cost is generally associated with the introduction of new technologies, and the operating costs are planned to decrease, there are times better than others for the implementation. The time when the introduction of the concept starts will influence the timing of the implementation of further technologies (Klincewicz & Luss, 1985).

3.7.2. Success factors and favorable conditions

The basic internal capabilities of an organization will have an important influence on Industry 4.0 projects.

Along with training and formation, which have already been discussed as barrier to Industry 4.0, acceptance from a social point of view is needed. A common understanding of the changes to come will help employees to accept and adopt rapidly the transformation as the new normal (Horváth & Szabó, 2019). Everyone's engagements will be a contribution in the vision, speeding up the adoption and ensuring to take full advantage of the benefits. Taking into account every level, from top and middle management to production floor, will favor the adoption (Sepasgozar, 2020). Training and top-down strategy helps with engagement, as does pilot projects. Assembling a team which will champion the implementation will ensure seriousness about the technology, and guaranty the resources for the success of the project are in place (Kerl, 2020).

The previous level of ICT infrastructure is a factor in the adoption of Industry 4.0 (Sony, 2020). The presence of a well-functioning IT infrastructure, as well as data use and other tools already being part of the regular activities, are an advantage (Moeuf et al., 2020). Uniformity of digitalization in existing structures will also profit the organization (Pessl et al., 2017).

Projects are facilitated when a good preparation has been done beforehand, and Industry 4.0 benefits from a continuous improvement strategy (Moeuf et al., 2020). A lack of digital strategy, or plans about the actions to conduct is a major setback (Raj et al., 2020). The capacity that the technologies bring needs to be supported by an appropriate approach, in order to deal with the complexity of the systems and manage it efficiently (Oztemel & Gursev, 2020). Agility

in strategy should become the norm with the emergence of these technologies, a consequence of the changing environment. (Horváth & Szabó, 2019).

Another requirement for an effective transition is stability. Having processes that are well established and in place allows one to build on good foundations. *“It can be expected that most of the enterprises will introduce the Industry 4.0 elements gradually and by building on already existing equipment and software solutions, thus not endangering the stability of their production.”* (Rojko, 2017).

In order to build or increase these internal capabilities, consulting firms are often called upon (Sepasgozar, 2020). External expertise, in the case it cannot be found internally, is confirmed to be usually requested in Moeuf et al. (2020).

Berman and Bell (2011) emphasized that *“the challenge for business is how fast and how far to go on their path to digital transformation”*. In order to carry out the projects, communication is key, and needs to be intensive. If there is a lack of coordination between the different units of the organization, the introduction may be more challenging (Horváth & Szabó, 2019).

Kerl (2020) indicates the importance of the goal behind the implementation. The technology in which the organization invests should be needed and solve existing problems. Wanting to go for Industry 4.0 without having an underlying need for it is not a judicious idea.

3.7.3. Challenges and implications for organizations

The implementation of Industry 4.0 has major implications and challenges for an organization, and can have effects on strategy, talent, business model and organization for the company. That undertaking has to be made carefully, as it can impact the core of the organization (Cotteleer et al., 2019).

3.7.3.1. Technical aspects

Because of the characteristics of Industry 4.0, the regulations are required to be respected in order to transform an organization (Ebert & Duarte, 2018). Political, technical and infrastructure regulations, issues by governments, need to be complied with, and companies that are under legislation of countries that put stricter conditions on the implementation of new technologies or the features they bring, will have more difficulties to transition. Some standards regarding connectivity devices, data sharing, privacy and so on could hinder the implementation (Da Silva et al., 2020).

One of the difficulties that presents itself for the implementation of new technologies is the lack of standardized approach, which is due to the difficulty of the task (Butt, 2020). The implementation could also be hurt by a lack of standardization overall (Horváth & Szabó, 2019). When wanting to create, develop or join a network, common standards are needed (Raj et al., 2020), and a lack thereof hamper successful implementation.

Another issue encountered for the implementation of the new technologies is the lack of knowledge about the execution, where to start and how it will work. Executives know the possibilities, but are unsure about how they can actually benefit from them (Cotteleer et al., 2019). A good know-how is one of the conditions for the introduction of the concept (Rojko, 2017). Due to its novelty, there is still a gap in the procedure and theoretic model (Da Silva et al., 2020). However the fact is that successfully implementing Industry 4.0 will be the result of different things depending on many variables. *“There is no one-size-fits-all strategy for a successful Industry 4.0 transformation”* (Tulip, 2020).

The most common approach is thus to retrofit on established systems and processes, as already mentioned. Retrofitting is however said to prevent the completion of Industry 4.0, comforting organizations in small investments and engagement, and making them miss out on many benefits. What they obtain with small or isolated projects does not ensure sustainable results, which only a “total implementation” can do. But due to the variable structures and sizes of the company, undertaking a complete transition is very complex (Sony, 2020). Scaling the benefits requires even more investment for each type of organization (Tulip, 2020).

In addition, changes that were before transactional are now transformational, due to the continuity, openness and overall complexity caused by technologies. Conducting change successfully is not an easy task (Raj et al., 2020). Because it is a response to an evolving complex environment, the concept and its implementation are very technical. The integration can be difficult, and requires a fit on an organizational and operation point of view. More rigid companies can be blocked out in this respect (Müller et al., 2018).

With the vision needed to be on such a long term, complexity will be met at every level (Schumacher et al., 2016). Continuous innovation is a new norm in manufacturing, and organizations feel obligated to put it as a priority (Oztemel & Gursev, 2020). The uncertainties and lack of comprehension of Industry 4.0 can be put it on the back burner.

3.7.3.2. *Workers*

Human work will not be the same, as already touched upon. The increase in reliance on machines does not mean a decrease in reliance on people, but it does imply a change in activities. Indeed, transition or loss of job is to be expected for those whose activities are being replaced by machines, and the qualifications in high demand will be different for workers (Da Silva et al., 2020). There should be a decrease in the number of jobs that demand lower qualifications, and an increase in those that involve higher levels of skills, such as data scientist and engineers, changing the labor market landscape. The management functions are also transformed. Leaders are demanded to be more creative and open-minded under Industry 4.0, and need to consider the other players of the network as well in their decisions (Horváth & Szabó, 2019). Robots becoming more predominant, 3D printing and cooperative machines, ... the production landscape will change, as will skills and knowledge to operate them (Oztemel & Gursev, 2020).

3.7.3.3. *Partners and first move implications*

There are some influences for other members of the network, especially suppliers who are essential for the chain to work (Da Silva et al., 2020). The efforts of the other members of the chain mainly concern infrastructure and skills. Organizations shifting will encourage changes in business models and economics, and may have macro effects on the other organizations (Rüßmann et al., 2015). Adopting Industry 4.0 may oblige them to follow to some degree, or implies to find new bonds (Da Silva et al., 2020).

As can be seen in 3.3., technology calls for more technologies, as they enable each other and allow for more implementation because of synergies and complementarity. This could also become problematic, in the sense that making the shift towards Industry 4.0 might imply more than just implementing one technology if the companies want it to be a success. Implementation in an isolated manner is complicated and has significant cost, therefore starting the change implies larger operations in the future, whether because the opportunities will present themselves, or because more support will be needed to what is present. “*for the success of Industry 4.0, there should be a total implementation*”, and that is quite an engagement (Sony, 2020). Mutual enhancement is part of the concept. Each of the technologies enable, empower and make more relevant the implementation of the others (Tulip, 2020).

3.8. Situation before Covid-19

With the objective to understand the impacts on Industry 4.0, this section gives a picture of the situation of the concept before Covid-19 happens and where it is found. It also looks into the differences between companies regarding the implementation of new technologies. A few features are explored, with the goal to grasp the characteristics that make Industry 4.0 more or less expected in an organization. Small and middle enterprises will first be confronted to large ones, followed by locals versus multinational companies, before looking at the condition of the market and in the countries of the organization.

3.8.1. State of the concept

There is some contradictions with regards to the state of development of Industry 4.0. But although some present the revolution as mostly theoretical and not happening practically (Jarret, 2020), many sources declare the concept well ongoing, but still in its early phases.

Cotteleer et al. (2019) indicates that the transformation has started to take place in almost every industry, the focus for now being on improving existing operations, balanced with opportunities offered by Industry 4.0. The concept is promising, leaders believe in it and want to be prepared for the digital future. It is now well established in many organizations and can no longer be considered a “*future trend*”, as many have it as the core of their business.

Many companies are already moving towards the vision that is Industry 4.0. For others, because truly revolutionizing an industry implies a lot of changes and work, it is not expected to happen quickly (Riberio, 2021). If the will to adopt new technologies is well established, many still think the change is going slowly. Reasons for that being poor integration of the technologies, insufficient training, and lack of support from employees (Kerl, 2020).

Overall, in pre-covid times, a lot of work still needs to happen in order for the revolution to actually take place, studies showing that only 14% of executives thinks their organization is prepared for the changes, and that only four out of ten organizations are satisfied of their progresses with the concept (Raj et al., 2020).

Components of Industry 4.0 are already present in industries, but the transformation will be achieved when integration, automation, decentralization and optimization of the flow will be attained (Rüßmann et al., 2015). Yet it is not developed extensively, the advanced and newer technologies being absent from many Industry 4.0 implementations (Xu et al., 2018).

3.8.2. Where can it be found?

The areas with the highest levels of maturity regarding Industry 4.0 are the supply chain, sales, planning and marketing, and at the other end, the less mature areas are shop floor production, product design, and customer asset support (Cotteleer et al., 2019).

The automotive and manufacturing sectors are said to be way ahead of construction in that regard (Sepasgozar, 2020). In manufacturing, more than half are considering the matter a priority, and in the industries that are more price-sensitive, that number goes to 80% for immediate priority (Tulip, 2020). Tulip (2020) provides some statistics on the state of Industry 4.0 in 2018. 64% of manufacturing organizations had launched a program with the goal to add or develop connectivity, and 23% more were about to. Intelligence programs were present in 70% of the respondent companies, and flexible automation programs in 61%. The steps to start the implementation are present, yet only 30% overall admit to results at scale for the program. Of the existing machines, close to 50% have at least some kind of digital link to infrastructure.

From Rüßmann et al. (2015) the most implemented components are BDA and Cybersecurity, along with Cloud Computing. At the other end, Additive Manufacturing, Augmented Reality and Autonomous Robots are less present (Tulip, 2020). Frank et al. (2019) also gives cloud services as the most accessible solution, used as a base technology by the companies. Contrarily, it reveals that IoT but also BDA have low levels of adoption, differing from Rüßmann et al. (2015) regarding BDA. According to Babiceanu & Seker (2016), applications of Big Data are lagging in the manufacturing environment compared to other such as business processes, in terms of the implementation and diversity. This may be due to a challenging implementation of this base technology (Frank et al., 2019).

Regarding the organization, a greater variability in products is related with higher presence of the technologies, as they look to increase their flexibility. Places where quality is a must, like pharmaceutical firm, seek to limit errors, and also are keen to Industry 4.0 (Smit et al., 2016). With the disruptive nature of the concept, the approach to digital technologies is often led by fresh and innovative views. Older organizations anchored in their ways have more chances to be left behind (Cotteleer et al., 2019).

3.8.3. SMEs vs large enterprises

The size is an important differentiator for this context. On the one hand, companies of a smaller size invest less often than larger groups in those technologies, in which there is more interest.

SMEs are said to struggle with the adoption of the technologies, and are limited by less important financial resources (Szász et al., 2020). The high investment required to implement and the uncertainty about returns and implications for the organization seem to be more challenging for SMEs as well (Schumacher et al., 2016).

On the other hand, large companies are most of the time more prepared for the transformation. Indeed, investing in process and innovating with product are features more present in that type of companies, as they have the resources and the knowledge to do so (Frank et al., 2019). They will profit more from the technologies, which will more likely have a higher utilization rate than in SMEs, making the payoff more interesting (Szász et al., 2020).

Additionally, the processes and costs related to Industry 4.0 implementation being more difficult to handle for the smaller organizations, they may find it harder to synchronize the new technologies with their existing ones (Schumacher et al., 2016). Among the stakeholders of the supply chain involved, the processes need to be standardized for the integration. That aspect may be more challenging for SMEs, which are originally less standardized and automated and have less resources, even though they are more flexible (Müller et al., 2018).

The larger companies also present the advantages of having a longer term view than SMEs, making them more able regarding strategy (Müller et al., 2018). Smaller organizations often have a shorter-term strategy, which is a major risk (Moeuf et al., 2020). Sepasgozar (2020) reveals that the most prominent issues for SMEs are their lack of knowledge about Industry 4.0 and strategic importance and the focus of their expenses.

More daring experimentations with new technologies are present in large companies (Szász et al., 2020), they therefore have the possibilities to go further into the concept (Frank et al., 2019). The incentives to continue implementing are larger, and the common barriers affect them less than small and medium size organizations (Horváth & Szabó, 2019).

Regulation has been given as a barrier, and it is even more the case for SMEs, which also have poor access to funding overall (Ebert & Duarte, 2018). They often lack the necessary standards for technological advances, which raise problems when joining networks or initiating collaboration. The requirements regarding availability and flow of data are often not matched (Raj et al., 2020).

The organizational factors of smaller corporations present a few positive points in the context of Industry 4.0 implementation. They first have smaller profit expectations, and are less

complex to manage when implementing new ideas or innovate, having simpler processes and systems. SMEs have also the advantage of being less dependent on technologies, and more flexible in that regard as well, and can cooperate easily (Horváth & Szabó, 2019). Their small size can also allow them to be extensively more agile, and bring the possibility to involve employees more and more easily. Some opportunities offered by new technologies are more accessible to SMEs as well, as redesigning their processes, or changing their business model requires less changes (Moeuf et al., 2020). With their flatter hierarchy, overall flexibility and short term decision making capabilities, they present some advantages (Müller et al., 2018).

3.8.4. MNC and locals

Szász et al. (2020) indicates that being a multinational or a local firm has no impact, and none is advantaged compared to the other. No difference is seen in the transformation efforts, and the level of adoption is equally average after a certain level of maturity. The MNCs seem not to be ahead of the locals, at least yet.

But whether a company has an international reach will also make it more or less likely to be active in the fourth industrial revolution (Szász et al., 2020). Because multinational companies may be more in a position to feel the VUCA world, great benefit should result from an implementation of Industry 4.0. Growing uncertainties will definitely benefit from an optimization of the processes (Telukdarie et al., 2018). Technological (or market) projects have therefore more chances to be carried out by MNCs (Horváth & Szabó, 2019).

3.8.5. Countries features

Finally, the country in which the companies operate has also an influence (Szász et al., 2020). The level of competitiveness, as well as the economic and political situation, may play a role (Sony, 2020). Regarding competition, Szász et al. (2020) advances that in more competitive countries, less effort is put into Industry 4.0, especially because the multinational would have no advantage over the local firm in that regard, and efforts in countries with less competition, like in the south-East Asian region, are significantly more important. Studies show that high competition is correlated with lower resources allocation in technological advances (RodríguezArdura & Meseguer-Artola, 2010), and it is less the case for lower competitive markets (Sony, 2020).

National policies and coordination between governments and running behind in developing countries, which results in a low diffusion of the concept there (Raj et al., 2020). Without

standards, regulation and certification, development is more difficult, an important issue in those countries. Governments have had major influence in the development of the vision, putting in place policy and regulation in order to favor it, and giving economic incentives to organizations. If today the incentives are less pushed by governments than in the beginning, being in a country where the conditions are favorable regarding regulations and installation procedures is a definite benefit when it comes to implementation (Da Silva et al., 2020).

In developed economies, the barriers to implementation are different. Technology is the factor that can slow down the implementation, and companies rely on themselves to solve that issue. They need to develop the technology and the support in order to adopt (Sepasgozar, 2020).

3.9. Impacts of COVID-19

This section is dedicated to finding first leads of answers regarding the impacts of the pandemic on the concept.

3.9.1. Digital

Covid-19 encourages digitalization in companies. Information products and services have not been negatively impacted during the crisis, continuing to function, contrary to physical product or manufacturing, for which operations have been disturbed and have shut down in some cases. Industries such as media and banking, being early adopters of technologies, have encountered less issues. Because they have a high intensity of product and process information, an increase of their digitalization was easier, and has occurred and accelerated during the crisis, something that, in the case of banks, they were previously reluctant to do (Seetharaman, 2020)

Craven et al. (2021) reports that the companies with higher implementation degree of Industry 4.0 showed greater reactivity and endured the pandemic better. Companies where digital technologies were already present saw that initiative pay-off, gaining fast revenue growth, and reducing costs.

Many firms which possessed a solid digital infrastructure have decided to implement digital transformation technologies, being in a good situation and having the incentives to do so. Among the technologies implemented are CC, IoT, Blockchain, AI and ML (Pandey & Pal, 2020). Blackburn et al. (2020) indicates that companies which already had invested in new technologies, such as AI, were advantaged in their transformation.

The increased use of digital technology in everyday life has triggered the transformation of industrial processes (Rojko, 2017). Covid-19 digitized the world, leading firms and schools shifting to remote due to lockdowns. Internet presence and performance have become more central issues as reliance on them increased (Pandey et al, 2020)

Even in businesses, digital solutions were essential in order to interact, conduct operation, but also reach out to clients (Angevine et al., 2021). Pandey & Pal (2020) supports that this shift will be impacting “*all aspects of work and life*”. Internet and internet-based services have been, more than ever, at the core of most activities. Compared to pre-lockdowns, usage of the internet has plummeted from 40 to 100%.

From Blackburn et al. (2020): “*The COVID-19 crisis seemingly provides a sudden glimpse into a future world, one in which digital has become central to every interaction, forcing both organizations and individuals further up the adoption curve almost overnight.*”.

3.9.2. Physical interactions

Work being done remotely, an increasing need for capacity of telecommunication technologies has emerged overall. Remote interactions are required, creating challenges regarding exchange of information and communication (Kumar et al., 2020), like the need for rapid and secure communication and digital transfer of huge amounts of data (Czifra & Molnár, 2020).

One of the most important consequences of Covid-19 has been the social distancing and national lockdowns that have taken place (Pandey & Pal, 2020). Integrating digital, or digital components in replacement or as a way to minimize physical contact is therefore something that has been considered by organizations (Seetharaman, 2020). Manual material transfer is an issue that has been revealed, and its role should decrease in the future, replaced by automated transfer of material requiring no contact. Because of that, transparency also gained importance (Czifra & Molnár, 2020).

The labor market was disrupted during the Covid-19. Suddenly, losses and adjustment of job occurred by millions, and for those keeping it, restrictions were installed. The physical dimension of work was put at the center of the disruption (Lund et al., 2021a). Retailers in the US cope with physicality constraints by using automation, AI and other digital tools, to pick, sort and track products, as well as selling them (Lund et al., 2021b).

3.9.3. Economy and performances

GDPs have declined during the pandemics, and the world's economy has suffered (Czifra & Molnár, 2020). Covid-19 had impacts on the economy, consequences of lockdown regulations. These impacts decrease revenues for corporations, one of the reasons for the decrease in performance.

Corporate performance overall has also decreased since the beginning of 2020. This is due to the negative impact on production, operation and sales (Shen et al., 2020). Issues such as stoppage and transport delaying responses made some production capacity unusable (Czifra & Molnár, 2020), diminishing revenues. With the implementation of quarantine measures, productivity and revenue decreased again, worsening performance further (Shen et al., 2020). Busellato et al. (2021) estimates the reduction of overall profit around 55%.

Highly affected areas are more impacted in that aspect, and companies having financial constraints have a harder time to conduct operations. The same can be said for firms having small amounts of sales and small investment scale. Having higher incomes and investments is given as a lead in order to diminish that effect (Shen et al., 2020).

3.9.4. Supply chain disruption

The supply chain has been heavily disrupted, especially when a part of it is located in an area affected by the virus. Because of the uncertainty surrounding the issue and the rapidity of the spread, moving operations is complicated (Czifra & Molnár, 2020).

As with any pandemic outbreak, the supply chain faced challenges regarding flexibility, being slow to respond to the changes in supply and demand. Uncertainties and changes come from the change in consumer behavior. Supply chains for necessary items saw huge increases in demand as people stockpiled (Kumar et al., 2020), but for other products people have greatly reduced their consumption and investment, reducing demand (Seetharaman, 2020).

Against the fluctuation in demand, supply has sometimes been completely stopped with the shutdown of businesses, and if not it was delayed due to long lead times. The delay in procurement of essentials is also synonymous with lockdown and increased control, suppliers having issues with highly demanded items (Kumar et al., 2020). The lack of real-time transparency has been felt due to these issues.

Covid-19 has revealed the vulnerability and rigidity of some parts of the supply chain, some processes and systems. Retailers lacked responsiveness and flexibility to meet those demands. In addition, distribution center became inaccessible because of the lockdown and distancing measures. Manufacturers could operate from home, an issue in that situation (Czifra & Molnár, 2020). The impacts vary depending on sectors, some seeing their demand being completely lost, like tourism or aviation, and others only delayed (Craven et al., 2021).

Due to lockdowns consequences, risks were raised among the whole supply chain, as reported by 94% of the Fortune 1000 companies. Those disruptions resulted in huge costs that damaged financial situations in the long term. Additionally, global supply chain productivity has significantly decreased. Depending on the time and duration, the scale of the propagation and the facilities availability, performances of supply chains are more or less impacted, and can be an indicator for its resilience and viability. Infrastructure readiness and availability are challenging during epidemics, as capacity and access are often limited, causing transportation and distribution problems.

Due to the difficult conditions, a shortage of workers is also observed during pandemics. Trust between the players of the chain is always an issue on those conditions, integrity and competency having an impact that are dearer when there is a lack of visibility and information excess (Kumar et al., 2020).

Another consequence of the pandemic is regionalization, with the border closing and organizations wanting to protect their supply chains. That trend was already underway before, but has accelerated since the beginning of the crisis, the goal of the organization being to integrate suppliers in the sequencing of their operations. In the light of this trend, trust gains importance to allow faster decision-making and maintain activities (Busellato et al., 2021). Following the crisis, the expectation is that supply chains will be shorter, and more fragmented, changing the landscape and the core of many operations (Choong et al., 2020).

3.9.5. Call for flexibility

From the point of view of renowned experts, one of the main Covid-19 pandemics impact is an uncertainty regarding forecasts that will be higher than normal. That uncertainty comes from the unreliable forecasts and last-minutes changes that occurred, which are related to the customers. Problems with material transportation, lead-times and unplanned issues at the borders are more related to the supply chain. Other sources of uncertainty are machines or

resource failures, capacity or technology constraint, poor communication between silos or data issues. Because of the uncertainty the organization faces, quick adaptation and reaction to the demand is an important goal. As explained in the presentation, flexibility is one of the focuses of a transition to digital, and in order to be enabled, it needs to be surrounded by a flexible environment (Czifra & Molnár, 2020).

The dynamic nature of the disruption that is Covid-19 can make less advanced solutions insufficient to support decisions, and push for the upgrade to Industry 4.0 technologies such as simulations. Advanced analyzing, planning and scheduling capabilities are now needed in order to make the right decision (Kumar et al., 2020).

The new ecosystem that is a result of the pandemic encourages firms to be agile and dynamic, in order to adapt and rapidly be able to make changes in how they operate. This would not only contribute to their continuity and make survival to a crisis situation more likely, but could also allow them to seize the opportunities that could present themselves (Ivanov & Dolgui, 2020). Working in agile ways has also become the norm in order to match the daily changes in consumer habits. The disruption felt in the supply chain pushed the need for flexibility to mitigate the effects (Blackburn et al., 2020).

3.9.6. Short time to react

Another point raised is the short-time in which the spread has occurred, and the “ferocity” and speed with which the world has been impacted. That has specific consequences on businesses (Seetharaman, 2020). The changes occurred suddenly, giving the organizations little time to react and organize a response to an issue that required new solutions. It prevented them from taking the time to plan, and made them make decisions quickly and experiment, to then correct and adjust along the way (Pandey & Pal, 2020).

Conducting new initiatives during these times, with that enforced speed and at that scale, is difficult for most organizations, and very different than in a normal situation. The rapidity demanded to shift to digital may reveal issues in the technological resources or skills of companies. In general, due to the slow adoption speed to changes from customers, companies match their experimentation of new strategies to their environment's willingness to accept it. They do not push the learning curve and satisfy themselves to keep up. Daring to make quick changes is not the norm as it generally does not result in success. Changing how things work is a risk in normal times, but *“The COVID-19 crisis [...] has made experimentation both a*

necessity and an expectation”, and experimentation is needed to make changes as learning results from it (Blackburn et al., 2020).

3.9.7. Resilience

Czifra & Molnár (2020) predicts that following the pandemic, there will be an increase in smart city investment in order to mitigate its effects, to support everyday operations, and prevent the kind of damages that occurred along the whole supply chain. The resilience of operations has been at the center of many debates following the crisis, and is now a priority for most organizations (McKendrick, 2020). Transparency is increasingly required, into all parts of the supply chain, as proactivity and real-time reaction is part of the new normal (Busellato et al., 2021). Strategic considerations regarding the supply chain resilience have been accelerated by the crisis (Craven et al., 2021).

The fluctuations of demand and supply require agility, if not organizations risk losses in cost efficiency and resilience. And a demand for connection between operations and commercial functions has been noted to increase visibility, be more informed and mitigate potential risks. Increasing their digital solutions should put companies into good and resilient positions.

Efficiency, resilience and agility, are therefore all features that the implementation of Industry 4.0 can provide to companies. Integration of the stakeholders, from end-to-end, is a foundation of resilience, leading to a more collaborative, trusting and transparent approach. Whether for survival or growth in the aftermath, operation functions have evolved during the Covid-19 pandemic, as daily operations depend on it and need to be worked on in order to solve the new challenges (Busellato et al., 2021).

3.9.8. Technological solutions

The solutions and features provided by Industry 4.0 technologies fit the bill when considering the challenges arising. Virtual Reality is a judicious option for organizations in Covid-19 period, as it allows to not interrupt work, share complex ideas more effectively, or create realistic training conditions when needed. A response to flexibility issues could be 3D printing, and simulation is a lead in order to reduce uncertainties (Czifra & Molnár, 2020). The trust issue can be solved with the implementation of Blockchain technology and the integration of systems. The retailers faced major issues, issues that may find solutions in Industry 4.0, by increasing trust and transparency for some products (Kumar et al., 2020). Productivity and

revenue, problems discussed before, can be boosted by more than 10% through the use of digital and analytics tools (Craven et al., 2021).

Manufacturing procedures by example are likely to see more partnerships in a shared digital environment, using Additive Manufacturing. The attributes of 3D printing make it a perfect solution for the context, and they could become the key machines in the post-pandemic era of manufacturing. The mass customization capability, convenience of digital file use, opportunities for sustainability it present, among others, could very well make it “the new normal” (Choong et al., 2020).

3.9.9. Survive and recover

During the crisis, the focus was more on survival and less on gaining competitive advantage over the competition or improving working processes. (Czifra & Molnár, 2020) proposes three phases for organizations. The first one is survival, the second is recovery, and the third is life post-crisis, the goal being to reach that third phase with the least damage possible regarding finances, reason for which non-essential expenditure had to be cut.

With Covid-19, viability is a challenge, and the demand for the resilience, survival, adaptability and recovery capability are high (Kumar et al., 2020). That situation plays well in the development of the concept of Industry 4.0, as it can help them survive, shorten the phase of recovery, and has the tools to build a resilient business (Czifra & Molnár, 2020).

The initiatives taken by organizations were thus mostly directed to survival, when it used to be the long-term competitive advantage that attracted the moves (Leinwand & Mani, 2021). Once the survival part of the crisis has passed, the recovery will occur. However it is also facilitated by new technologies (Lund et al., 2021b).

3.9.10. Opportunities and innovations

As with all crises, opportunities reveal themselves. The constraint of Covid-19 has pushed organizations to be innovative, in their products and services in the form of new (digital) design, new delivery channels or mechanisms, and in their environment, creating new partnerships and ecosystems in order to mitigate the effects (Seetharaman, 2020).

By using applications of digital technology in every aspect of life, the move towards Industry 4.0 is accelerated. The need to be able to collaborate, communicate or co-create instantaneously

without being physically close forced advances in the domain (McKendrick, 2020). Like other crises, Covid-19 may have accelerated innovations by forcing it.

A crisis is the perfect time to make or advance your move to digital technologies for (Blackburn et al., 2020). New ecosystems facilitating implementations are set in place, supporting new ways of providing customer services or products to relation across the supply chain. The restriction of physical contacts made organizations look for new solutions, resulting in new partnerships and fast emergence of digital platforms. New business models have also emerged as a consequence of the situation, as an attempt for companies to survive (Seetharaman, 2020).

3.9.11. Increasing applications

The different technologies are not only favored by the context of the crisis, but are also a direct solution for the management of the crisis, whether for the tracking of the disease or in the medical area, where they are used to perform services (Ting et al., 2020). It emerges as a way to conform to new rules and demand, or just the situation. Health concerns and tracking, safe distancing and homeworking can be seen as temporary, and implementing digital technology could solve these issues (McKendrick, 2020).

That could be another aspect that increased the implementation of Industry 4.0 in other organizations, via the influences of those applications, or thanks to the knowledge and experience that have been gained on the subject. The use of the technologies in other fields would increase competence in it overall, contributing to the diffusion of the concept.

3.9.12. Other impacts

Safety and the health of employees was another factor to consider, sanitary measures and sometimes medical attention being needed. Trust is also complicated in those times, and in the case of the coronavirus particularly regarding virus propagation, “no-touch deliveries” becoming the norm (Kumar et al., 2020).

Shortage of workers has also been a consequence of the situation. It is a reason for automation programs, and attempts to increase end-to-end visibility. Overall, the supply chain and manufacturing should justifiably become digital (McKendrick, 2020).

3.9.13. Future trends

For Lund et al. (2021a), work will be reshaped in the after-crisis following three trends: First, if it will not be to the degree of the pandemic, remote work and the virtual meeting should

continue. Second, online activities and commerce have increased at a large rate, and it will stay that way. Third, AI and automation adoption will be sped up and increased. Whether in warehouses, stores, plants or call centers, the increase in demand and requirement for less workers have led companies to deploy these capabilities. The research shows that the workplace with the most physical proximity will see the fastest adoption.

The fact that many basic activities moved online accelerated the technological transformation, in order to adapt to the new demand (Leinwand & Mani, 2021). Digital has become the only channel in order to engage with customers. Productivity was driven by automated processes, as the supply chain was required to be stable, flexible and transparent, features found in the new technologies (Blackburn et al., 2020). During the pandemic, digital tools have allowed faster and more efficient reaction to market changes (Korbel et al., 2019). Their implementation should be accelerated by the situation, due to the suddenness of the event and the quick reaction required (Busellato et al., 2021).

From a survey in Europe, 70% of executives asked on the matter believed that digital transformation will be accelerated because of Covid-19, and it has already been shown evidently across various sectors and regions (Blackburn et al., 2020). Ongoing Industry 4.0 efforts were sometimes stopped during the pandemic, due to cash concerns. But overall, the implementations were accelerated, as a way to support business continuity, through automation, digital home working and performance management, allowing organizations to keep going with limited physical interactions (McKendrick, 2020).

4. Results and answers

In this section, the elements of answers relevant for the analysis are reported for each interview conducted. The interviews are taken individually, summarized and every contribution related to the questions is presented.

4.1. Interview 1

Respondent 1 (R1) explains Industry 4.0 (I4.0) as “the new evolution that integrates operational excellence and new technologies” and defines three steps for it: connectivity, intelligence and automation. It can be noted that Additive Manufacturing (AM) is not considered part of I4.0 for R1.

The natural evolution or “next level” approach to I4.0 is the more structured, following and building on previous improvement steps such as “Lean”, which is advised in order to get results. R1 reveals an additional reason why organizations move towards I4.0: the fashion effect. The “fashionistas” often lack the right process.

The barriers given by R1 for the implementation of I4.0 are the lack of knowledge, the fear of the implications of the transformation and the lack of clarity on returns, which may push organizations to keep a traditional improvement approach. These barriers may contribute to companies not moving towards I4.0, or moving erroneously.

The impacts of Covid-19 on operations, manufacturing and supply chains are not significant for R1. Factories that needed to produce, produced, and (large) companies kept their activities running. What has been the most impacted for R1 is innovation through collaboration, which is complicated by the lack of proximity of people working together, lack of travel and overall distancing. Innovation for operational excellence and I4.0 was consequently slowed down. Additionally, companies having to deal with the administrative and control aspects raised by Covid-19 means that less time is available for innovation.

The connectivity aspect of I4.0, and the technologies offering it, is interesting in order to remedy issues such as travelling. Tools such as remote expertise, communication platform and connective glasses are solutions, and data from machines have been more extensively used in order to allow analysis and maintenance remotely. Augmented Reality (AR), Internet of Things (IoT) and integrations are some of the components of the I4.0 that are relevant with the Covid-19, all because of their connectivity feature. Companies that already possessed that connectivity aspect, in equipment or integration, are favored and less affected by the crisis. In these companies, acceleration (in terms of Artificial Intelligence (AI)) is even possible.

According to R1, the root reasons for which organizations implement I4.0 do not change with the crisis. Efficiency, quality, and other traditional desires for improvement are still the main intention. However, the pandemic may have raised complementary logic for the decision, which is to add connectivity to the machines in order to facilitate remote work.

Covid-19 may accentuate the transition to I4.0 in the sense that technologies could be a solution to the problem they had, but change is never easy, especially when it happens quickly. Although urgency should be positive for increases and development, the focus of organization is also more on mitigating the crisis rather than improvement in these times. This is even more true for

SMEs who are more quickly affected and lack experience in handling these issues, where large organizations have obligations regarding advancement, in the opinion of R1. It is confirmed that all large organizations are already involved with I4.0, and the increase in SMEs is seen as a natural continuity and not necessarily linked to the pandemic.

Belgium is said to not be cutting edge regarding I4.0, especially when compared to other countries such as Germany or the USA. This would be due to the fact that I4.0 is mostly present in manufacturing, not a dominating sector in Belgium, where it is mostly found in biotech and logistics.

Speaking of how to implement, R1 mentions the steps that are traditionally used. The first one is the “proof of concept” (POC), which has been followed by “used case”, and calls companies to add a third one, “capabilities”. The importance of forming people to the technologies and continuous improvement, in order for everyone to contribute to it, will be key in the future for R1. It is already the case in more mature organizations, and should be propagated for success. In times of Covid-19, the fact that people are not on site is a difficulty when dealing with I4.0 implementation.

Finally, R1 believes I4.0 will be increasingly adopted, still for traditional reasons, everyone filling its own needs using it. It means that every sector will adopt it for different reasons, and approach it differently. In healthcare for example, the customer experience has the potential to be greatly improved with these technologies. Overall, that increase in applications is positive for the concept, and can be as well for other sectors.

4.2. Interview 2

The combined use of mature technologies that allows industries to improve internal efficacy or generate business models is the definition given by Respondent 2 (R2). I4.0 is given mainly as a productivity factor, in the continuity of Lean and operational excellence, and that should not change according to R2, who also notes that going digital without having a good basis in terms of process is useless.

If connectivity and collaboration may be more relevant than before in the decision to implement I4.0, it is an additional aspect that companies may consider following the pandemic. The changes occurring are not specific to I4.0, but are more general to the way people work (together).

It is given that Belgium is not at the forefront of I4.0 in Europe, even though there are activities. The difference regarding I4.0 between sectors is noticed, with telecom being more digitally advanced than manufacturing, which is more traditional and requires more manual labor for example. A cultural barrier is mentioned for the traditional sectors, which may experience more controlled transitions, requiring more stability. Awareness was raised over many issues that organizations could face, such as those related to the supply chain. Some aspects may have been revealed partly because of the speed and urgency of the situation, but not specifically I4.0.

R2 states that what has been implemented would have been done without the crisis, but the Covid-19 accelerates transformation. Savings and travelling limitations from companies have been increased due to remote, and accelerated digitalization. The acceleration is positive overall for R2, and should occur at every level of I4.0. In R2's opinion, many firms were under pressure during the pandemic, and therefore careful with investments, which may have prevented the increase in I4.0 projects.

For R2, one of the effects of the crisis is that the usefulness of the I4.0 solutions is more acknowledged, the business case being made more obvious, and a cultural component may be at play, facilitating transition and acceptance. The way to implement the technologies has not been affected by the pandemic. Most projects are part of a transformation, and the approach to a transformation will stay the same and is different from a creation from scratch. The problems related to the implementation are not affected either.

Large projects involving travels had to be carried remotely, and tools such as connected glasses, which are part of AR, have been increasingly used as a solution, in order to do training, support, audits,... remotely. Covid-19 has increased the presence of technologies that allow remote collaboration, according to R2.

Digitalization of processes to increase connectivity facilitated information exchange, which has been helpful during lockdowns and sickness waves, and permitted the monitoring of factories at a distance for example. However, R2 believes that remote collaboration presents some issues, being less effective in some instances, and not being a good solution for everyone. Some losses and sacrifices of some aspects come along with the increasing digitalization. On the other hand, maintenance capabilities and 3D printing technologies are said to be less relevant for the crisis.

The Covid-19 effects are mainly the drop in demand, but factories have continued to run, demand went back up and the incomes for the first year of the crisis are not bad for all

organizations. However, a consequence of the crisis occurring now is raw material procurement issues, which impact hardware or computer supply. The IT equipment supply chain is really disrupted today. The increase in digital solution still relies on physical objects and machines, and has created these procurement issues that are hampering I4.0 in a sense.

4.3. Interview 3

I4.0 is all about the intelligence of people, the use of technologies and bringing value to everybody for Respondent 3 (R3) He has a broad view on the impact of the Covid-19 on I4.0, having experience in various sectors, and provides an overview of the subject across sectors.

R3 states that, before the crisis, many sectors started to work hard on I4.0 projects, with the exception of healthcare which was lagging behind. But with Covid-19, I4.0 has considerably accelerated in healthcare. I4.0 initiatives in the food sector have not been impacted, and stoppages of projects have not been observed. That is also the case in the utility sector, but more so for reasons of necessity. In fact, I4.0 demand coming from this sector could even not be followed in some case. On the contrary, projects in discrete manufacturing have seen interruptions and cancelations after the first increase of cases. The reasons are the following: business not working properly due to low demand or issue linked to restrictions, but also the lack of people to work on these projects. With people on temporary leave due to production not running, these people could not work on the I4.0 projects. In the “Horeca” and “event” sector, due to the lack of activities, the initiatives were stopped.

The point is made that sectors heavily impacted, due to financial issues, were compelled to stop any I4.0 initiatives. But they are not as much stopped as they are delayed, even though the timeline is not certain. The value and interest for I4.0 is still present, but the capacity to go through with the projects was just not there. The situation now is different, and the delayed initiatives are restarting.

Providers of 3D printing have had a lot of work in healthcare, with an increase in the use for medical equipment, because of the capacity of that technology to make products quickly. These features existed before Covid-19, but the crisis made them more in demand. With the crisis, there has been more focus on AM, but also on AR, with its use in maintenance and usefulness to provide remote assistance, the numbers of POCs increasing. Another notable increase reported regards Apps, which allowed users to have data available directly on their smartphone,

and thus more visibility. The technologies that have accelerated are said to be already proven before.

Related to apps, cybersecurity is mentioned, as is the idea that companies, in the urgency to make data visible, may have gone too fast, and the question of whether they have considered everything regarding data security is raised. R3 says Covid-19 may have made people more aware that security requires large investments. Cloud providers may benefit from the crisis as a consequence, companies being more inclined to use them to have more data availability, the providers being already secured. Again it depends on sectors, some kinds of data not being trusted in Clouds, like in the case of healthcare. Overall, there is a realization about I4.0. Companies want to combine data, but realize the barriers that exist to do so. Innovation is said to be pushed in the future, due to that understanding raised by Covid-19. That has been especially the case in healthcare, where Apps have been developed to parry the fact that travelling to get healthcare was no longer safe, and where “mobile health” was accelerated to allow people to use their smartphone to monitor or receive medical treatments or instructions from home.

R3 points out that I4.0 takes time and is an evolutionary process. Companies that have focused on practices such as Lean management and continuous improvement are at an advantage regarding I4.0. The technologies represent an important investment, which is used to optimize a few percent of the processes in the organization. Considering it has a return on investment that usually takes a few years, and compared to other investments like buying a new machine, which present a shorter return on investment, it may be seen as too long.

In term of type of organizations, overall large organizations are more relevant to look at regarding I4.0 because they are the ones involved with it. R3 has not seen smaller companies being affected in that aspect, because there are not a lot of projects going on with them. They will tackle it in the future, but still need to work on things such as upgrading their ERP systems and stabilizing their platforms.

In Belgium, the larger, “stronger” companies are said to have always worked quickly on I4.0, due to the relations with German countries, one of the initiators of the concept. With the Covid-19, reactivity has been important, and the reliance on importation from countries like China has been highlighted. A reallocation of production, which could already be perceived beforehand,

could be accelerated by the crisis, increasing the number of production facilities in Belgium. I4.0, with again its ability to produce very quickly, is a solution in that aspect.

Finally, the consequence of remote work has impacted communication, and more specifically has increased digital communications. R3 informs that work on the I4.0 projects can be done easier, and faster, due to the fact that people are more accustomed to these tools and that it is more convenient.

4.4. Interview 4

For Respondent 4 (R4), I4.0 is a topic that has increased significantly over the past years, and continued to do so during the pandemic, even though there could have been some barriers to that, an example given being the fact that people could not go on site. He defines the concept as “the way industrial companies embrace the opportunities provided by new technologies”, and how technologies are adopted to digitally transform companies, an idea that is not yet at the top-level in every manufacturing site in the last decade.

Regarding Covid-19, two main challenges are given. The first one is the supply chain disruption, and the consequences of restriction in supply, with ripple down effects ending in costs for companies, not able to match demands. The vulnerability of systems has been highlighted, making companies consider diminishing their reliance on others. The pandemic made the reasons for which manufacturing capabilities were put into others hand, e.g. the cost, less relevant, sometimes erasing it. The solution could be to manufacture in Belgium, which has its own advantages, such as the access to talent, freedom of design, closeness and short lead times. And that is where I4.0, with simulation related technologies, can be helpful to support the setup, and where 3D printing should in theory be valuable. R4 explains that, in the case of 3D printing, many companies’ products are not designed in order for them to profit from the advantages it offers, which ends up with costs too high, and should be considered during the design phase of whatever it will be used to produce for the technology to be capitalized on. So I4.0 is not the direct solution to that problem, but could facilitate or help the alternatives.

Secondly, the ability to work remotely was questioned, due to restriction of travelling. For that aspect, I4.0 is a solution on the same level as all technologies, and one of the consequences of the crisis is the acceptance of these technologies, like collaboration tools, which are part of Industry 3.0 for R4, a step not attained by every company. The I4.0 technologies involved are the ones that help with remote assistance, like AR and the use of smart glasses for example.

Covid-19 reinforced that we live in a dynamic world, and I4.0 has been seen to be relevant for that world. In management consulting, the numbers are the best ever, mainly because of business linked to I4.0. Companies want to be prepared for the future in more than one way. Because of the detachment from mass production and the increase in customization, the competitiveness increases, smaller organizations being more able to answer to that demand. Flexibility is a growing need to match the individualization of the demand. And therefore, an acceleration seen by R4 during the last year and a half concerns “strategic reflection” from organizations.

The number of I4.0 implementations is at the same level as before, but the first phases, the strategical parts of those projects, are more numerous, and implementations should increase in the future as a result of that augmentation. It could therefore be said the number of projects has increase because of the pandemic.

That acceleration is all good for the concept, as the fact that more companies think of it means that more solutions will be developed, which creates more adoption of the solutions, increasing the market and making solutions cheaper, which finally increases implementations. R4 evokes a reinforcing cycle in that regard, that helps to tackle one of the barriers of implementation, which concerns the fact that companies usually don’t want to be first mover even if they are interested, and wait for technology to be tested before going with it, a process that accelerates as well. With more people being “equipped” with I4.0, sharing and exchanges are keys to make the industry evolves.

Another point mentioned by R4 is the change in consumer behavior. Covid-19 has clearly changed how people consume, and how they interact in everyday life. The increase in digital use, which has increased with the pandemic, can be a push for organizations to integrate the digital in the workplace, to match that change of mindset from both customers and employees. The main impact of the Covid-19 on I4.0 for R4 is on the people component. The changes that are synonyms with I4.0 are more accepted by people, who are more involved and willing to support it.

R4 gives insights on the top three barriers for I4.0. First is the lack of knowledge and vision on digital matters. That has been affected and diminished over the past years, companies looking more and more into it. The second one is the budget. With the crisis, companies had more financial difficulties and revenues decreased, although R4 notifies that today these issues are

resolved and numbers are better than before the start of the pandemic for most sectors. That barrier has therefore been increased during the pandemic. And lastly, the lack of adoption. For adoptions to be higher, impacts need to be shown, and the fact that fewer people were in factories during the crisis did not help.

If companies from every sector can benefit from I4.0 in some way, it is to a different degree. It is the personal opinion of R4 that “smaller companies can benefit the most”, even though it is not in their priority. That may be a plus for Belgium where the SMEs proportion is important. Regarding large companies, they benefit more from I4.0 because they have more activities in it. Benefitting from I4.0 means at least one of the three following for R4: an optimization of internal processes, the addition of smart products, or a new business model.

I4.0 accelerated in the sense that its adoption curve was slower before the pandemic, and the various stages, the “typical journey”, organizations go through to have it is now quicker. Convincing people of I4.0 is easier now, and going with it is done more rapidly. And if it continues, the world in the next few years will be transformed.

4.5. Interview 5

I4.0 is the gathering of all applications of new technologies in an industrial environment for Respondent 5 (R5), going to the “next step” after automating.

Companies have been increasingly interested in I4.0 in the past two years, and more tempted to try technologies, such as smart glasses for remote assistance to give an example. It was sometimes the only way to be able to interact with the sites, and as a consequence the adoption was easier. That increase concerns the number of companies and number of technologies, reports R5. Providers of these technologies have seen a significant increase in their revenue, a testament to the growing interest, their business accelerating.

I4.0 can resolve part of the issues occurring with Covid-19. The restrictions on travelling create issues in knowledge transfer and application, which can be solved with I4.0, by helping to replicate knowledge without people being present. But communication tools, which are part of I4.0 for R5, also help in the case of the crisis. Collaboration and connecting are made easier and done more often. In addition, the obligation to use these tools has made people more capable and willing to use them.

The supply chain problems created by Covid-19, the main one being the disruption of too long supply chains, can be alleviated by tracing technologies, but the solutions to resolve it are not found in I4.0. “Local for local” production and closer critical points of the supply chain, are directions that could be taken as a solution for the future.

Solutions that allow people to “be there” without being physically present are the most involved in the context of the Covid-19. IoT is also mentioned along with collaboration and remote assistance, bringing in the ability of tracing from location and gaining more visibility of the whole processes.

Transparency in operations has revealed itself to be of major importance. The bullwhip effect in the supply chain is important when members stop producing, for example, due to Covid-19. Therefore, companies find it more important to be informed and have visibility on the chain, which can be done with new technologies. This is a case where the organization has been made aware of that necessity by the crisis.

Some personal “positives” of the pandemic are related by R5. If the first reactions were to issue a crisis and do what was necessary to deal with the urgent issue, things have not been that way since then. When only the workers were left on site due to restrictions, they were obliged to do things themselves, meaning that they followed more training and used virtual assistance, which may have increased their capabilities. The management teams on the other hand had more time and reflected on how to improve things in operations, which involves new technologies. So barriers like the lack of use of technology, and the fear of using it, have been greatly lifted in that process, because Covid-19 made it a necessity to do so.

If the number of projects increased during the time of the pandemic, it remains on track with what was happening before. I4.0 was already growing heavily in the last four years. What may have been impacted by Covid is the acceptance of the new technologies and the willingness to try them, which has made I4.0 becoming more of the norm and created new ways of working.

An acceleration of I4.0 will have a role in competitiveness, those not investing or jumping on the train will be further behind and not able to answer to the increasing trends that made it emerge. That fear of lagging is an important reason for a move toward I4.0, along with taking advances on the others. That acceleration is not an acceleration in terms of speeding off initiations or ongoing projects. In the beginning companies just wanted to survive the crisis and did savings. After that they recovered, and looked to improve on aspects such as I4.0.

Finally, R5 explains that, looking at Covid-19, organizations have been impacted differently by the crisis, mainly depending on the sectors they are in. Some of them, such as life science, did very well, while others, like aviation, were quite poor, and for some others it depended on other variables, like the size available for manufacturing companies. These effects have been felt similarly all around the world.

5. Analysis

5.1. Does the pandemic accelerated Industry 4.0?

This question, on which this whole work revolves, is answered positively by all respondents. However, more precisions about that acceleration are brought. There has been an acceleration in the sense that the vision of Industry 4.0 has been propagated more widely. More companies, more sectors are now involved, or are more advanced in it than they were before. The concept of Industry 4.0 overall is more advanced at this point in time than it would have been if the crisis did not happened, in terms of its presence in organizations, its use and even in terms of its development, as there is a mention of an increase in technology, but mostly in terms of reflections and awareness about it. The fact that Industry 4.0 providers and consulting firms associated with Industry 4.0 have had a very good year and a half in terms of revenues is evidence of that acceleration.

From the interviews, it can be gathered that the acceleration does not refer to a speeding up of implementation processes in any way. It also does not correspond to a boom of these implementations, as the initiatives have not been more numerous than they were before, but that should change in the future, project reflections being indeed more important than they were before. How Industry 4.0 is implemented is not subjected to a change, except the fact that people were not on site during that implementation, and therefore no significant change linked to that aspect can be pointed out as reason for the acceleration.

If the perspective of the Engineering Employers' Federation mentioned in the literature review is taken, it could be said that the first two phases of Industry 4.0, which are conception and evolution, are the parts that are accelerated, and bring industries closer to the third one, revolution. It is possible that the reason why the following phase, which would correspond to a significant increase in actual implementations, did not take place, is related to the slowness of the process. Leads indicating that implementations will increase in the future have been gathered.

It comes out of the interviews that the urgency of the crisis is not directly linked to the acceleration of Industry 4.0. However, it might have an impact regarding a lack of considerations of companies on some issues related to Industry 4.0 implementations, a respondent stating that they may have gone too fast with processes because of that. But the crisis will pass, and the issues encountered, such as travelling reduction, are temporary. Still, what it revealed may stay, and many of the changes in directions taken by organizations following the pandemic will continue in the future.

5.2. How does it accelerate Industry 4.0?

First of all, that acceleration wasn't a shock, and the directions in which things are going regarding Industry 4.0 were foreseen, only it happened sooner than it would have without the pandemic. What comes out of the interviews is that the increasing presence and applications of Industry 4.0 are in the continuity of what was already going on before Covid-19 even existed. Indeed, the fact that Industry 4.0 accelerates is true since the apparition of the idea of Industry 4.0, and it had been observed in the years before the pandemic as well. The growth of the digital transformation would and will have happened anyway, it just took the next steps sooner.

As will be explained further, that continuity is specific to organizations and sectors. The speeding up of the processes is also different depending on some characteristics of the company. There is again continuity in the reasons for which companies went with Industry 4.0 during the pandemic. Traditional motivations, mainly part of a continuous improvement vision, are recurring elements in conversations with experts.

Companies want to reach the “next step” of their development, higher their productivity, improve their efficiency, their quality and so on, and that is Industry 4.0. Companies that had already started their transformations, or were working with continuous improvement practices, found themselves at an advantage during the crisis, being closer to that “next step” and could benefit more from it. The areas in which Industry 4.0 has flourished during the pandemic present many of the various success factors and favorable conditions presented in the literature. Stability and connectivity are observed as the features that are key in order to benefit most of the potential of the crisis. The technologies that were subject to the greatest acceleration were considered to be already proven before as well.

Trends that have been said to be influenced by the crisis, like the regionalization of supply chains, are still in the continuity of pre-Covid-19 times. They were boosted during that time,

but already going on before the events of the last year and a half. The reduction of travels was also occurring before the crisis, but the reasons were more financial than related to restrictions.

5.3. Why did it accelerate?

The main consequences of the pandemic that had impacts on Industry 4.0 are the travelling and lockdown restrictions. The disruption of the supply chain plays a role in its increase, but indirectly. These are the important points that have part in Industry 4.0 acceleration. Some triggers were indeed switched on by Covid-19. If the main reasons to move towards it haven't changed, additional ones are at play.

A first trigger relates to the characteristics of Industry 4.0, which were more researched than before. Three have been identified in the interviews.

The first one is the connectivity of the technologies, which is reported by all respondents to have been a valuable asset to have. Communication tools are being massively used in companies since the beginning of the pandemic. People being unable to travel and working from home enabled digital communications through platforms such as Zoom. Another technology linked to connectivity that has been discussed by all respondents is Augmented Reality (AR), with the use of connective glasses, which have seen a significant increase in use in the last year and a half. The possibility to provide expertise and assistance more effectively from a distance is greatly appreciated, as a way to interact on site. AR has been identified as part of the technologies to not require a lot of infrastructure or conditions in order to be implemented, and using it is easy and quick. That may be an additional reason why it is the most mentioned “new” technology in the interviews. Along with communication platforms, they allow for collaboration to happen during the crisis. Internet of Things (IoT), Apps and integrations are also mentioned, all bringing that connectivity feature. The communication and connectivity features are important elements of the fourth industrial revolution, and the literature review shows that it is present in most of the technologies that characterize it. These features were increasingly looked after by companies before the crisis, and will surely increase in presence after it.

But IoT and Apps were most appreciated for the visibility they bring, the second characteristic of Industry 4.0 that has been referred to multiple times in the interviews. IoT has been extensively used by companies in order to help with remote maintenance, but also in order to gain more transparency on the supply chain. Tracing ability is increasingly wanted by

organizations in order to have more information about what is going on with the other members. They want to be informed on what is happening in their process as well, and IoT and Apps are effective ways to have that.

Thirdly, the flexibility, or ability to adapt and react to issues quickly, is pointed out by two respondents. The world has become, or reveals itself, even more dynamic than it used to be, and responding to these changes is primordial. Additive Manufacturing (AM) has been proved useful when relying on other countries for productions was an issue, and is increasingly considered by companies for its ability to produce quickly. 3D printing could also benefit from the regionalization trend that is touched upon below. 3D printing is however said to not be relevant as a solution during the pandemic by one respondent, and often executed badly by another.

Some other leads gathered in interviews regarding more prominent benefits are the following.

The transfer of intelligence and information has been seen to be problematic during the pandemic, and Industry 4.0 presents many technologies that can be solutions for that issue. Artificial Intelligence and Big Data are used to generate that intelligence, and storage capacities have been observed in many technologies such as Cloud Computing. Industry 4.0 is a solution in the sense that it provides a way to replace the lack of expertise on site by automation, or could be a support for the people to access that intelligence.

As explained, continuity has been observed in many tendencies, but a trend that did change with the Covid-19 pandemic, is globalization. The disruption created reversed the trend, and regionalization, and even “local for local “ production, may be on the horizon. If globalization helped the emergence of Industry 4.0, regionalization may be useful to make it flourish, and possess arguments for organizations which want to be established more locally in their impact. 3D printing for instance has been given as a solution for producing quickly, and regionalization may push the utilization of that technology, as it is more appropriate to integrate it in the design of a production site or a product.

If Industry 4.0 cannot solve all issues that arise during the crisis, it can still be accelerated by the fact that what it offers can support other options or trends that have occurred during the pandemic and may shape the future landscape. More local productions for example can benefit from the adoption and use of the ways of the fourth industrial revolution, and new ways of working, or new business models, are more accessible with the implementation of Industry 4.0.

A second trigger is linked to the impacts on some barriers of Industry 4.0.

What has been undoubtedly observed from the crisis is a change in mindset and in the perception companies and employees have of Industry 4.0. If they were sometimes forced to have recourse to the technology, there was also more considerations to what it could bring to organizations. Realizing that some issues could occur, and that it could be prevented by using Industry 4.0, realizing the usefulness and convenience of some of the technologies, or realizing what is needed in order to implement or benefit from Industry 4.0, are consequences of the Covid-19 crisis. Respondents talk about “cultural change”, “realizations”, increase in “strategic reflection”, and overall companies being made aware of Industry 4.0. The fact that they consider it more seriously than before means that they can be more prepared, and understand more of the various barriers that could present themselves. Security concerns for example seem to be more in the mind of companies. If that change is true for Industry 4.0, it needs to be noted that it is also the case for most, if not all, technologies, and not only the specific case that is the fourth industrial revolution.

An hypothesis for the push or forcing of Industry 4.0, which would have led to a lack of consideration, is explored in the literature review, but the field shows that it is indeed the inverse that happened, awareness being raised about the concept. It is advanced by a respondent that the short-time allowed for reaction might be a reason why only the first “reflection” part of Industry 4.0 has been accelerated.

There is definitely an increase in digital technologies, in companies but also in everyday life. That increase is a clear effect of the restrictions related to the Covid-19. The point is made several times that it improves workers and employee capabilities to work with these technologies, makes them more willing to accept them, and pushes organizations to experiment with them. Companies have gained experience working with technology, and that experience leads to learning and improvement opportunities. In some cases, going with Industry 4.0 was not only a solution, it was the only solution, as interacting was not possible any other way, which shows the direct connection with the pandemic.

Although being obliged to do things differently, organizations benefited from the crisis in that regard, as they may have found that things worked better that way. Moreover, a respondent issued the idea that the obligation for management teams to be at home actually freed up time for them to think about how to improve things, and compelled workers to form themselves more

and increase their capabilities and scope of action. That mindset and capability changes benefit the implementation of Industry 4.0, as it corresponds to a barrier being diminished.

The literature review revealed that many consider that there is still work to do in order to achieve Industry 4.0, or to capitalize on what it can bring an organization. The lack of business cases that partly caused the uncertainty about the return on investment of the Industry 4.0 project is considered a barrier for the concept, as is referred to in the literature review. Today that barrier may also start to be lifted with the increase of cases revealed in the interview. More examples of Industry 4.0 should also appear following the crisis, further diminishing that barrier.

5.4. Nuancing the acceleration

Nuance can be brought to the acceleration. First of all in the sense that part of the development of Industry 4.0 actually slowed down with the Covid-19 crisis, at least for a moment. As it is seen in the literature, the crisis gave companies financial troubles. Moreover, when Covid-19 emerged, companies were in a crisis mode and focused on handling administrative and operational issues, thus work on Industry 4.0 was scarce during that period. Without the time, the people or the money to conduct Industry 4.0 initiatives, many of them stopped, or at least were delayed. Innovation in operations, which may lead to the “next step” and to Industry 4.0, suffered from an initial lack of collaboration related to the situation. However, another respondent states that innovation is pushed by the coronavirus, so no conclusions can be made about that.

The impacts of the crisis are thus not all unidirectional and positive. A barrier that has not been affected in only one way by restrictions is the adoption of technologies, people not being able to work with, or see the impact of the implementation. If technologies overall are more accepted overall, the fact that people were not on site created issues in order to show the actual impacts post-implementation.

However, that crisis period only lasted a time for most organizations. The finances of companies are said to be back and higher than before the crisis, therefore the budget barrier is no longer impacted, although savings and changes in priorities did negatively impacted Industry 4.0 initiatives for a time. It can indeed be gathered from the interviews that the crisis stage passed quickly enough, many examples being given of companies actually doing quite well

after an initial slump, or even not being impacted at all by the crisis regarding business operations.

The acceleration can also be nuanced by how Industry 4.0 is defined. As it has been seen in the literature, the concept is defined in many different ways, people focusing on different aspects of it, not agreeing on what it represents or what can be considered to be part of Industry 4.0. However, whether or not someone encompasses a technology into the concept can change the degree to which the acceleration occurs for that person. In only five interviews, differences have been observed on whether digital communications tools or AM was part of it. Considering they are involved in some of the main points made by the contributors, one could see how describing the impact of Covid-19 on Industry 4.0 may depend on perspectives. Innovation is also a key element of one of the respondent's definitions, and that aspect being hampered by the Covid-19, the acceleration is less marked than for others who consider it a less important feature. In order to evaluate more precisely the impacts, an universal definition should be provided, the acceleration depending on how it is defined.

5.5. Where did it happen?

As already touched upon, the impact of the crisis was different depending on the sectors, and therefore how it influences Industry 4.0 varies as well. The more impacted sectors, such as event and Horeca, suffered more on every level, and as a consequence Industry 4.0 projects related to these sectors have been completely stopped.

Some sectors are said to not have been impacted, such as the food and utility sector. These sectors answer primary needs, and therefore activities seem to mainly have kept going as usual. The manufacturing sector has been mostly affected during the first phase of the pandemic. Because of the restrictions, manufacturing, which requires people to be on site to work on Industry 4.0, was in a difficult situation at first. As already explained, they have then recovered, and most respondents testify that the sector was doing well thereafter.

Healthcare on the other hand, is a sector that completely boomed during the pandemic, due to its direct relation with it. If it was lagging behind regarding some technologies such as AM before the pandemic, the activities related to Industry 4.0 are more numerous than in other places. The sector is doing well and the acceleration could be said to be the most important there, as it is where the most development has occurred since the apparition of the Covid-19.

The benefits regarding Industry 4.0 mentioned above are therefore different depending on the sector. Manufacturing, which is more traditional, may have profited from a mindset shift to a greater extent than others. On the other hand, sectors which are more naturally advanced in the characteristics of Industry 4.0, like telecommunications and utility, would have had more opportunities to grow further, having the setups to do so. Even more, some demand from that sector, in terms of implementation of Industry 4.0, was too important and could not be matched.

Although there are some beliefs that the smaller organizations can gain more than larger one, it cannot be generalized, nor said that they did. In fact, the lack of experience of these companies, not only regarding Industry 4.0, as pointed out in the literature review, but also in terms of handling the crisis overall, put them in more difficulties than their counterparts. The fact that they are not on the same level of advancement as larger organizations and the lack of initiatives started before the crisis increase that last point. They do have more potential, and are interested in Industry 4.0 for the future, but have not been significantly impacted by the Covid-19 in that regard.

It is thus more relevant to look at large organizations for the theme of this study. They are usually more mature, and more keen to have people with the necessary competencies to deal with the technologies, which is always a key element for its development, and is also the case during the crisis. These features of larger organizations, e.g. more maturity and competencies on Industry 4.0, are the ones that would favor a company to do well during the pandemic.

5.6. The case of Belgium

If this study focuses on the case of Belgium, the results can be generalized. No particularities have been found for the acceleration specifically in Belgium. What could be seen as different from other countries is related to the type of companies present in the country, and their link to other countries. Belgium could benefit from their relation with Germany regarding manufacturing, but overall the manufacturing activities in Belgium are not important, and Industry 4.0 is mostly found in logistics and biotech. Only the more important companies are more advanced in terms of Industry 4.0, as there are expectations on them to do so, and those expectations did not go away during the pandemic.

The “acceleration” looks to have happened quite similarly if compared with other countries, countries that were ahead before should still be ahead now, everyone is just further into Industry

4.0. However, if some features regarding countries are touched upon in the literature review, they were not confirmed by the empiric.

6. Conclusion

The Covid-19 and its consequences are definitely impacting Industry 4.0. The most tangible way it plays into the acceleration is by increasing Industry 4.0 considerations in organizations, a necessary step on the way to be present everywhere. But the acceleration is only in the continuity of how the development of the concept was happening before the crisis. It has been seen throughout the work that few major changes have occurred, but mostly that many processes underway have been “pushed” by the situation created by the Covid-19. Good foundations are therefore needed in order to be involved in the acceleration.

The advantages of Industry 4.0 and their relevance to the context of the pandemic played a role in the acceleration. Connectivity, transparency and traceability, and flexibility or responsiveness are the characteristics that help in that regard, adding on top of traditional reasons which are still the main goal.

In addition, some barriers were equally lifted as a consequence of the pandemic. The lack of knowledge and the lack of capabilities that are cited extensively in the literature have been impacted. Companies and people are now more aware about the concept, what it can bring and what it implies to work with it, and people overall gained knowledge on digital communication from the situation.

The sectors most involved in those accelerations are directly related to their level of activities during the crisis. Healthcare has seen the best year of all sectors, and the acceleration can be said to be the most present there. Sectors with no activity, have not been part of the acceleration, but could benefit from it, through the development of the concept overall.

Following up the continuity aspects identified, larger organizations are also more involved with Industry 4.0 and feel the acceleration more significantly, while SMEs continue to be prospects for the future of the concept. It has been insinuated that these smaller organizations have more opportunities to widen their Industry 4.0 activities during the pandemic, and this is also the perspective of one of the respondent. It is also observed that the conclusions given above about how the acceleration happened in Belgium can be expanded to other countries overall.

Nuances and discussions are provided on this acceleration. Although the overall effect is the acceleration of the fourth industrial revolution, some aspects of the pandemic in fact created or raised difficulties for the development or the implementation of Industry 4.0. Financial difficulties, practical issues and lack of focus are discussed here.

The point has been made and confirmed that there is a lack of consensus on what Industry 4.0 precisely is, which has consequences on how the acceleration is understood. Finding a definition on which everyone could agree on looks to be a difficult task, but would greatly help further research.

The main elements that could be gathered at this point in time are presented in this work. New arguments not met on the literature review have been encountered, some quite significant, while others have been confirmed, turned down or never mentioned in the empirical part. New inputs could be form the further overtime, and with them new elements of answers to the research question.

It should be pointed out that, the fact that the respondents all have experience in consulting may give a “strategic” perspective on the matter, and different points may be more pressed on with different profiles of respondents.

Many opportunities for further research have been revealed in this work. This is partly due to the fact that the phenomenon treated is occurring at the time this paper is handed in. Looking back on the results when the crisis will be passed, or attenuated, with the numbers to back up the claims, is a first follow up that could be conducted. Many precisions could also be brought to this work, by focusing on a particular sector or a particular technology. Each part of the literature review could be a focus for another work that could bring more precisions to the subject. More interviews could be conducted on the questions answered in this work, in order to bring more answer elements to generalize.

7. Bibliography

- Agrawal, M., Eloot, K., Mancini, M., & Patel, A. (2020, July 29). *Industry 4.0: Reimagining manufacturing operations after COVID-19*. McKinsey & Company. <https://www.mckinsey.com/business-functions/operations/our-insights/industry-40-reimagining-manufacturing-operations-after-covid-19>
- Alcácer, V., & Cruz-Machado, V. (2019). Scanning the industry 4.0: A literature review on technologies for manufacturing systems. *Engineering Science and Technology, an International Journal*, 22(3), 899-919. <https://doi.org/10.1016/j.jestch.2019.01.006>
- Alladi, T., Chamola, V., Parizi, R. M., & Choo, K. K. R. (2019). Blockchain Applications for industry 4.0 and industrial IoT: A Review. *IEEE Access*, 7, 176935-176951. <https://doi.org/10.1109/ACCESS.2019.2956748>
- Angevine, C., Keomany, J., Thomsen, J., & Zimmel, R., (2021, May 27). *Implementing a digital transformation at industrial companies*. McKinsey & Company. <https://www.mckinsey.com/industries/advanced-electronics/our-insights/implementing-a-digital-transformation-at-industrial-companies?cid=other-eml-alt-mip-mck&hdpid=7bea6051-9ba8-488c-8b11-d870c5dd974b&hctky=11899817&hlkid=4c3d7ac67e124cc7a36540e38b840966>
- Babiceanu, R. F., & Seker, R. (2016). Big data and virtualization for manufacturing cyber-physical systems: A survey of the current status and future outlook. *Computers in Industry*, 81, 128-137. <https://doi.org/10.1016/j.compind.2016.02.004>
- Bécue, A., Praça, I., & Gama, J. (2021). Artificial intelligence, cyber-threats and industry 4.0: Challenges and opportunities. *Artificial Intelligence Review*, 54(5), 3849-3886. <https://doi.org/10.1007/s10462-020-09942-2>
- Blackburn, S., LaBerge, L., O'Toole, C., & Schneider, J. (2020, April 22). *Digital strategy in a time of crisis*. McKinsey & Company. <https://kolnegar.ir/wp-content/uploads/2020/07/Digital-strategy-in-a-time-of-crisis.pdf>
- Brous, P., Janssen, M., & Herder, P. (2020) The dual effects of the internet of things (IoT): A systematic review of the benefits and risks of IoT adoption by organizations. *International Journal of Information Management*, 51, 101952, ISSN 0268-4012. <https://doi.org/10.1016/j.ijinfomgt.2019.05.008> .
- Busellato, N., Drentin, R., Nair, S., Schlichter, M., Kishore, S., & Singh, A., (2021, April 12). *Rethinking operations in the next normal*. McKinsey & Company. <https://www.mckinsey.com/business-functions/operations/our-insights/rethinking-operations-in-the-next-normal?cid=other-eml-alt-mip-mck&hdpid=464abdba-f104-4ad7-ad75-02fa61682b21&hctky=11899817&hlkid=89beb5ca71a746a0b2f3782025a8b19e>
- Butt, J. (2020). A strategic roadmap for the manufacturing industry to implement industry 4.0. *Designs*, 4(2), 11. <https://doi.org/10.3390/designs4020011>
- Choong, Y. Y. C., Tan, H. W., Patel, D. C., Choong, W. T. N., Chen, C. H., Low, H. Y., ... & Chua, C. K. (2020). The global rise of 3D printing during the COVID-19 pandemic. *Nature Reviews Materials*, 5(9), 637-639. <https://doi.org/10.1016/j.dsx.2020.07.010>
- Cognizant (2020, April 24). *COVID-19: Accelerating Industry 4.0: A good prescription for surviving today's pandemic and mitigating the next one*. Perspective. <https://www.cognizant.com/perspectives/covid-19-accelerating-industry-4-0-a-good-prescription-for-surviving-todays-pandemic-and-mitigating-the-next-one>
- Cotteleer, M., Daecher, A., Hanley, T., Holdowsky, J., Mahto, M., Murphy, T., Rutgers, V., & Sniderman, B. (2019). *The Industry 4.0 paradox. Overcoming disconnects on the path to digital transformation*. Deloitte. <https://www2.deloitte.com/global/en/pages/energy-and-resources/articles/the-industry-4-0-paradox.html>

- Craven, M., Liu, L., Mysore, M., & Wilson, M. (2021, August 04). *COVID-19: Implications for business*. McKinsey & Company. <https://www.mckinsey.com/business-functions/risk/our-insights/covid-19-implications-for-business>
- Czifra, G., & Molnár, Z. (2020). Covid-19 and industry 4.0. *Res. Pap. Fac. Mater. Sci. Technol. Slovak Univ. Technol*, 28(46), 36-45. <https://doi.org/10.2478/rput-2020-0005>
- Da Silva, V. L., Kovalski, J. L., Pagani, R. N., Silva, J. D. M., & Corsi, A. (2020). Implementation of Industry 4.0 concept in companies: Empirical evidences. *International Journal of Computer Integrated Manufacturing*, 33(4), 325-342. <https://doi.org/10.1080/0951192X.2019.1699258>
- Ebert, C., & Duarte, C. H. C. (2018). Digital transformation. *IEEE Softw.*, 35(4), 16-21. <https://www.chcduarte.com/dx2018.pdf>
- Fitzgerald, J., & Quasney, E. (2017). *Using autonomous robots to drive supply chain innovation*. Deloitte. <https://www2.deloitte.com/us/en/pages/manufacturing/articles/autonomous-robots-supply-chain-innovation.html>
- Frank, A. G., Dalenogare, L. S., & Ayala, N. F. (2019). Industry 4.0 technologies: Implementation patterns in manufacturing companies. *International Journal of Production Economics*, 210, 15-26. <https://doi.org/10.1016/j.ijpe.2019.01.004>
- Frankenfield, F. (2021). *Artificial intelligence (AI)*. Investopedia. <https://www.investopedia.com/terms/a/artificial-intelligence-ai.asp>
- Ghadge, A., Kara, M. E., Moradlou, H., & Goswami, M. (2020). The impact of industry 4.0 implementation on supply chains. *Journal of Manufacturing Technology Management*, 31(4), 669-686. <https://doi.org/10.1108/JMTM-10-2019-0368>
- Gubán, M., & Kovács, G. (2017). Industry 4.0 conception. *Acta Technica Corviniensis-Bulletin of Engineering*, 10(1), 22-25. <https://web.a.ebscohost.com/abstract?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=20673809&asa=Y&AN=121771778&h=fOXtVNQ1LjzQPSCvS41dnvMrZWDtDRzQl%2b%2bTAVxwXi0WKuL9FVaZ%2f2KPk9zs16e7GxEIV%2bZuhTGHA4%2fxSDusrw%3d%3d&crl=c&resultNs=A dminWebAuth&resultLocal=ErrCrlNotAuth&crlhashurl=login.aspx%3fdirect%3dtrue%26profile%3dehost%26scope%3dsite%26authtype%3dcrawler%26jrnl%3d20673809%26asa%3dY%26AN%3d121771778>
- Gupta, P., Seetharaman, A., & Raj, J. R. (2013). The usage and adoption of cloud computing by small and medium businesses. *International journal of information management*, 33(5), 861-874. <https://doi.org/10.1016/j.ijinfomgt.2013.07.001>
- Horváth, D., & Szabó, R. Z. (2019). Driving forces and barriers of industry 4.0: Do multinational and small and medium-sized companies have equal opportunities?. *Technological Forecasting and Social Change*, 146, 119-132. <https://doi.org/10.1016/j.techfore.2019.05.021>
- Identity. (n.d.). *In Dico en ligne Le Robert*. <https://dictionnaire.lerobert.com/definition/blockchain>
- Industry Today. (2020, October 02). *Impact of globalization on industrial relations*. <https://industrytoday.com/impact-of-globalization-on-industrial-relations/>
- Info-Coronavirus Belgique. (2021, June 04). *What is the government doing?* <https://www.info-coronavirus.be/en/what-is-the-government-doing-about-it/>
- Ivanov, D., & Dolgui, A. (2020). Viability of intertwined supply networks: extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak. *International Journal of Production Research*, 58(10), 2904-2915. <https://doi.org/10.1080/00207543.2020.1750727>

- Ivanov, D., Dolgui, A., & Sokolov, B. (2019). The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics. *International Journal of Production Research*, 57(3), 829-846. <https://doi.org/10.1080/00207543.2018.1488086>
- Jarret, C. (2020, June 19). Incremental steps can yield industry 4.0 benefits. *Embedded*. <https://www.embedded.com/incremental-steps-can-yield-industry-4-0-benefits/>
- Kerl, K. (2020, February 25). *5 Steps to successfully implementing new technology in the workplace*. SelectOne. <https://www.selectonellc.com/blog/introducing-new-technology-to-your-organization>
- Kern, J., (n.d.). *Covid-19*. Futura Santé. <https://www.futura-sciences.com/sante/definitions/coronavirus-covid-19-18585/>
- Klincewicz, J. G., & Luss, H. (1985). Optimal timing decisions for the introduction of new technologies. *European Journal of Operational Research*, 20(2), 211-220. [https://doi.org/10.1016/0377-2217\(85\)90062-1](https://doi.org/10.1016/0377-2217(85)90062-1)
- Korbel, K. M., Sim, S., & Niel, J. V. (2019, December 19). *Enabling a digital and analytics transformation in heavy-industry manufacturing*. McKinsey & Company. <https://www.mckinsey.com/business-functions/operations/our-insights/enabling-a-digital-and-analytics-transformation-in-heavy-industry-manufacturing>
- Kuka. (n.d.). *Global megatrends shaping the future of production: Demographic change*. <https://www.kuka.com/en-be/future-production/sfpl/megatrends/demographic-change>
- Kumar, M. S., Raut, R. D., Narwane, V. S., & Narkhede, B. E. (2020). Applications of industry 4.0 to overcome the COVID-19 operational challenges. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, 14(5), 1283-1289. <https://doi.org/10.1016/j.dsx.2020.07.010>
- Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & information systems engineering*, 6(4), 239-242. <https://doi.org/10.1007/s12599-014-0334-4>
- Leinwand, P., & Mani, M. M. (2021, March 26). Digitizing isn't the same as digital transformation. *Harvard Business Review*. <https://hbr.org/2021/03/digitizing-isnt-the-same-as-digital-transformation>
- Liao, Y., Deschamps, F., Loures, E. D. F. R., & Ramos, L. F. P. (2017). Past, present and future of industry 4.0- a systematic literature review and research agenda proposal. *International Journal of Production Research*, 55(12), 3609-3629. <https://doi.org/10.1080/00207543.2017.1308576>
- Lund, S., Madgavkar, A., Manyika, J., Smit, S., Ellingrud, K., Meaney, M., & Robinson, O. (2021, February 18). *The future of work after COVID-19*. McKinsey & Company. <https://www.mckinsey.com/featured-insights/future-of-work/the-future-of-work-after-covid-19>
- Lund, S., Madgavkar, A., Mischle, J., Remes, J., (2021, May 18). *What's next for consumers, workers, and companies in the post-COVID-19 recovery*. McKinsey & Company. <https://www.mckinsey.com/featured-insights/future-of-work/whats-next-for-consumers-workers-and-companies-in-the-post-covid-19-recovery>
- Matt, C., Hess, T., & Benlian, A. (2015). Digital transformation strategies. *Business & Information Systems Engineering*, 57, 339-343. <https://doi.org/10.1007/s12599-015-0401-5>
- McKendrick, J., (2020, September 15). *The covid crisis has dramatically accelerated the transition to industry 4.0*. Real Time Business Insights. <https://www.rtinsights.com/the-covid-crisis-has-dramatically-accelerated-the-transition-to-industry-4-0/>
- McMahon, C., (2020). *How COVID-19 is Accelerating Industry 4.0*. WhatTheyThink. <https://whattheythink.com/articles/100405-how-covid-19-accelerating-industry-40/>

- Moeuf, A., Lamouri, S., Pellerin, R., Tamayo-Giraldo, S., Tobon-Valencia, E., & Eburdy, R. (2020). Identification of critical success factors, risks and opportunities of industry 4.0 in SMEs. *International Journal of Production Research*, 58(5), 1384-1400. <https://doi.org/10.1080/00207543.2019.1636323>
- Müller, J. M., Kiel, D., & Voigt, K. I. (2018). What drives the implementation of industry 4.0? The role of opportunities and challenges in the context of sustainability. *Sustainability*, 10(1), 247. <https://doi.org/10.3390/su10010247>
- Ortt, R., Stolwijk, C., & Punter, M. (2020). Implementing industry 4.0: assessing the current state. *Journal of Manufacturing Technology Management*, 31(5), 825-836. <https://doi.org/10.1108/JMTM-07-2020-0284>
- Oztemel, E., & Gursev, S. (2020). Literature review of industry 4.0 and related technologies. *Journal of Intelligent Manufacturing*, 31(1), 127-182. <https://doi.org/10.1007/s10845-018-1433-8>
- Pacchini, A. P. T., Lucato, W. C., Facchini, F., & Mummolo, G. (2019). The degree of readiness for the implementation of industry 4.0. *Computers in Industry*, 113, 103125. <https://doi.org/10.1016/j.compind.2019.103125>
- Pandey, N., & Pal, A. (2020). Impact of digital surge during Covid-19 pandemic: A viewpoint on research and practice. *International journal of information management*, 55, 102171. <https://doi.org/10.1016/j.ijinfomgt.2020.102171>
- Pessl, E., Sorko, S. R., & Mayer, B. (2017). Roadmap industry 4.0—implementation guideline for enterprises. *International Journal of Science, Technology and Society*, 5(6), 193-202. <https://doi.org/10.11648/j.ijsts.20170506.14>
- Piccarozzi, M., Aquilani, B., & Gatti, C. (2018). Industry 4.0 in management studies: A systematic literature review. *Sustainability*, 10(10), 3821. <https://doi.org/10.3390/su10103821>
- Prause, M., & Weigand, J. (2016). Industry 4.0 and object-oriented development: incremental and architectural change. *Journal of Technology Management & Innovation*, 11(2), 104-110. <http://dx.doi.org/10.4067/S0718-27242016000200010>
- Qin, J., Liu, Y., & Grosvenor, R. (2016). A categorical framework of manufacturing for industry 4.0 and beyond. *Procedia CIRP*, 52, 173-178. <https://doi.org/10.1016/j.procir.2016.08.005>
- Raj, A., Dwivedi, G., Sharma, A., de Sousa Jabbour, A. B. L., & Rajak, S. (2020). Barriers to the adoption of industry 4.0 technologies in the manufacturing sector: An inter-country comparative perspective. *International Journal of Production Economics*, 224, 107546. <https://doi.org/10.1016/j.ijpe.2019.107546>
- Ribeiro, J. (2021, February 02). A (very) brief introduction to AI in the industry 4.0. Towards Data Science. <https://towardsdatascience.com/a-very-brief-introduction-to-ai-in-the-industry-4-0-14e6f4b46cd1>
- Roblek, V., Meško, M., & Krapež, A. (2016). A complex view of industry 4.0. *Sage Open*. <https://doi.org/10.1177/2158244016653987>
- Rojko, A. (2017). Industry 4.0 concept: Background and overview. *International Journal of Interactive Mobile Technologies*, 11(5), 77-90. <https://doi.org/10.3991/ijim.v11i5.7072>
- Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., & Harnisch, M. (2015, April 09). *Industry 4.0: The future of productivity and growth in manufacturing industries*. Boston Consulting Group. <https://www.bcg.com/en-be/publications/2015/engineered-products-project-business-industry-4-future-productivity-growth-manufacturing-industries>
- Schumacher, A., Erol, S., & Sihni, W. (2016). A maturity model for assessing industry 4.0 readiness and maturity of manufacturing enterprises. *Procedia CIRP*, 52, 161-166. <https://doi.org/10.1016/j.procir.2016.07.040>

- Seetharaman, P. (2020). Business models shifts: Impact of Covid-19. *International Journal of Information Management*, 54, 102173. <https://doi.org/10.1016/j.ijinfomgt.2020.102173>
- Sepasgozar, S. M. (2020). Digital technology utilisation decisions for facilitating the implementation of industry 4.0 technologies. *Construction Innovation*, 21(3), 476-479. <https://doi.org/10.1108/CI-02-2020-0020>
- Shen, H., Fu, M., Pan, H., Yu, Z., & Chen, Y. (2020). The impact of the COVID-19 pandemic on firm performance. *Emerging Markets Finance and Trade*, 56(10), 2213-2230. <https://doi.org/10.1080/1540496X.2020.1785863>
- Smit, J., Kreutzer, S., Moeller, C., & Arlberg, M. (2016). Industry 4.0. European Parliament. *Directorate general for internal policies*. [https://www.europarl.europa.eu/RegData/etudes/STUD/2016/570007/IPOL_STU\(2016\)570007_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/STUD/2016/570007/IPOL_STU(2016)570007_EN.pdf)
- Sony, M. (2020). Pros and cons of implementing industry 4.0 for the organizations: a review and synthesis of evidence. *Production & Manufacturing Research*, 8(1), 244-272. <https://doi.org/10.1080/21693277.2020.1781705>
- Sorokač, A., & Mišota, B. (2017). Incremental innovation and implementation of concept industry 4.0. In *New Trends in Process Control and Production Management*. <https://doi.org/10.1201/9781315163963-87>
- Subic, A., Xiang, Y., Pai, S., & de La Serve, E. (2018, October 5). *Blockchain and industry 4.0: Why blockchain is at the heart of the fourth industrial revolution and digital economy?*. Capgemini. <https://www.capgemini.com/au-en/resources/blockchain-and-industry-4-0/>
- Szász, L., Demeter, K., Rácz, B. G., & Losonci, D. (2020). Industry 4.0: a review and analysis of contingency and performance effects. *Journal of Manufacturing Technology Management*, 32(3), 667-694. <https://doi.org/10.1108/JMTM-10-2019-0371>
- Tay, S. I., Lee, T. C., Hamid, N. Z. A., & Ahmad, A. N. A. (2018). An overview of industry 4.0: Definition, components, and government initiatives. *Journal of Advanced Research in Dynamical and Control Systems*, 10(14), 1379-1387. https://www.researchgate.net/publication/332440369_An_Overview_of_Industry_40_Definition_Components_and_Government_Initiatives
- Telukdarie, A., Buhulaiga, E., Bag, S., Gupta, S., & Luo, Z. (2018). Industry 4.0 implementation for multinationals. *Process Safety and Environmental Protection*, 118, 316-329. <https://doi.org/10.1016/j.psep.2018.06.030>
- Ting, D. S. W., Carin, L., Dzau, V., & Wong, T. Y. (2020). Digital technology and COVID-19. *Nature medicine*, 26(4), 459-461. <https://doi.org/10.1038/s41591-020-0824-5>
- Tulip. (2020). *The manufacturer's guide to industry 4.0*. https://cdn.brandfolder.io/GDDASP4K/as/63x27bt5wjn54kbcnjin2v4/LM-0018_Industry_4_0_Ebook.pdf
- Tupa, J., Simota, J., & Steiner, F. (2017). Aspects of risk management implementation for industry 4.0. *Procedia manufacturing*, 11, 1223-1230. <https://doi.org/10.1016/j.promfg.2017.07.248>
- Xu, L. D., Xu, E. L., & Li, L. (2018). Industry 4.0: state of the art and future trends. *International Journal of Production Research*, 56(8), 2941-2962. <https://doi.org/10.1080/00207543.2018.1444806>
- Yeeply (2020, April 30). *What is Industry 4.0? A simple definition, trends & technologies*. Yeeply. <https://en.yeeply.com/blog/what-is-industry-4-0/>
- Yue, X., Cai, H., Yan, H., Zou, C., & Zhou, K. (2015). Cloud-assisted industrial cyber-physical systems: An insight. *Microprocessors and Microsystems*, 39(8), 1262-1270. <https://doi.org/10.1016/j.micpro.2015.08.013>

8. Appendices

APPENDIX 1: Interview guide

1. Can you present yourself in a few words?
2. What is your experience with Industry 4.0?
3. How do you define Industry 4.0 in your own words?
4. How would you characterize the level of Industry 4.0 in Belgium? Compared to other countries?
5. How would you describe the impacts of Covid-19 on industries and operations?
6. To what extent is Industry 4.0 a solution to the issues raised by the crisis?
7. What are the most interesting technologies and/or characteristics of the concept in the context of the pandemic?
8. To what extent did the Covid-19 pandemics had an impact on Industry 4.0 implementation?
9. What stimulates organizations to implement or advance toward Industry 4.0? To what extent has it changed with the Covid-19 crisis?
10. To what extent have the traditional barriers of the implementation of Industry 4.0 been affected by the Covid-19 pandemic?
11. In what sense do you think there was an acceleration of Industry 4.0?
12. To what extent did the number of Industry 4.0 projects increased since the beginning of the pandemics?
13. To what extent do you think speed is relevant regarding the subject?
14. To what extent do you think there was an acceleration in the implementation of Industry 4.0 since the beginning of the pandemics, whether in initiation of projects or acceleration of ongoing projects? What are the reasons for it?
15. What may be the consequences related to an acceleration of implementation? Regarding the implementation, but also the performances and result of an initiative?
16. To what extent has the way to implement Industry 4.0 changed? Is a “slow” and incremental process still the norm?
17. What type of organizations/What are the characteristics of the organizations that have/should have been the most impacted by the pandemics regarding the (acceleration of) implementation of Industry 4.0? The less impacted?
18. What do you see for the future of Industry 4.0? What do your opinion on the concept?
19. Do you have anything to add?

APPENDIX 2: Interview 1 – Matthieu Oliviers

Pierrick De Bock: PDB

Matthieu Oliviers: MO

PDB – Est-ce que vous pouvez vous présenter en quelques mots ?

MO – Bien en général quand je me présente, je parle de trois choses qui me caractérisent. Je dirais la première chose, c'est le plaisir de l'amélioration continue, que je fais depuis que je suis tout jeune en fait et que j'ai appris à faire de façon plus structurée quand j'ai commencé à travailler dans l'industrie, c'est-à-dire avec des méthodologies de type TPM, excellence opérationnelle, Lean Management. La deuxième chose qui me caractérise, c'est l'automation. J'ai toujours adoré l'informatique. En fait, je suis né dedans. A 11 ans, je programmais sur mon Premier Apple 2. Et puis l'automation, c'est devenu aussi la robotique puisque je suis ingénieur en mécanique, robotique, mécatronique. J'ai fait de la recherche en robotique et dans toute ma carrière, j'ai travaillé soit dans l'automation, l'automation industrielle ou ses applications dans le MES, et cetera, à la fois software et hardware. Et la 3e chose qui le caractérise, c'est que je suis depuis quelques années maintenant, avec un focus plutôt Healthcare, Live Science, Medical Devices, et c'est comme ça que ces dernières années, j'ai travaillé dans le Pharma pour GSK. J'ai travaillé aussi leurs medical devices pour BD, Philips. J'ai travaillé pour Universal Technology également dans les biotech et maintenant je suis 100 pourcent focus sur une start-up qui a comme objectif d'adresser les besoins de la transformation digitale dans les hôpitaux et le Healthcare en général qui s'appelle Procaryote.

PDB – Est-ce que vous pourriez me donner votre définition de l'Industry 4.0 ?

MO – Souvent, je fais référence à des aspects politiques avec l'usine du futur, avec l'envie des politiciens européens et américains de faire revenir l'industrie en Europe et en Occident grâce à l'utilisation de technologies nouvelles. Mais moi qui connais l'automation et l'utilisation des données depuis plus de 20 ans, moi j'aime bien définir l'Industry 4.0 comme, euh, l'évolution nouvelle, qui consiste à intégrer à la fois l'excellence opérationnelle et les dernières technologies. Et je le défini en 3 étapes, la connectivité, l'intelligence et l'automation.

PDB – Quelle est votre expérience donc plus concrètement avec l'Industry 4.0 ?

MO – Écoutez, j'ai fait, j'ai fait des diagnostics ces derniers temps pour pas mal d'industries, à la fois sur des applications de type process que des applications de type produit. Donc la différence, je sais pas si vous voyez bien la différence, mais typiquement le process c'est quand on va dans une industrie, voir la façon dont la supply chain, dont le manufacturing est géré et là des applications process, ce serait la mise en place d'un MES, la mise en place d'utilisation de données pour faire de la maintenance prédictive des choses comme ça. Donc ça c'est vraiment le process. Et le produit, bah, j'ai travaillé pour une société comme CMI, pour les, les aider à voir comment un drone, comment l'utilisation d'un cloud, du data analytics pour les aider à créer des produits plus complets. Ils travaillent par exemple dans la tourelle de chars, et bien : “Comment on peut utiliser un drone pour en faire des jumelles en fait ?”. Donc c'est à la fois process et produits et j'ai à la fois travaillé dans le diagnostic, ces derniers temps on a fait pas mal de diagnostic pour voir où en étaient les sociétés dans lesquels j'ai travaillé ou pour lesquels j'ai travaillé. Mais j'ai travaillé aussi dans l'implémentation, depuis longtemps, j'implémente des robots, des systèmes, donc du software et du hardware dans l'Industry 4.0 pour améliorer la connectivité des machines, pour améliorer avec une couche d'intelligence ou pour automatiser les processus.

PDB – Quelles sont, selon vous, les raisons principales pour lesquelles les entreprises décident d'aller avec Industry 4.0 ?

MO – Bah ils ont besoin d'aller en général au “next level”. Vous voyez, c'est comme un jeu d'ordinateur, le next level quand on a implémenté le Lean, pour faire des steppes d'amélioration. Bah c'est souvent d'utiliser les dernières technologies qui sont le digital. Quand on n'a pas implémenté le Lean où l'excellence opérationnelle, il y en a certains qui veulent aussi parce que des questions de parce qu'ils sont fashionistas, comme on dit. Ils trouvent que c'est fashion et ils pensent qu'ils vont tout révolutionner avec des technologies, souvent ils se plantent parce que justement ils n'ont pas les bons processus. Il y a des articles là-dessus où, si vous tapez fashionistas Capgemini, vous verrez, qui classent un petit peu les différentes sociétés, ceux qui, justement vont dans le digital parce que c'est fashion et d'autres qui le font de façon structurelle. D'ailleurs, c'est ce qu'on conseille, c'est de le faire de façon plus structurée, pour avoir de vrais résultats.

PDB – Quelles sont les principales barrières à l'implémentation de l'Industry 4.0 pour une entreprise ?

MO – Oh y'en a plein en fait. J'ai déjà fait une présentation là-dessus, euh, à un certain moment donné. Alors il y a soit les barrières à démarrer, soit les barrières aux succès. Ici, ce que je comprends, c'est que votre question, c'est plutôt les barrières à démarrer. Bah en première barrière, c'est la non-connaissance. On ne sait pas ce que ce sont ces technologies ou le l'Industry 4.0 en tant que telle. La 2e barrière, c'est euh... la peur en fait. La peur de ce que vous risquez de perdre. Il y a des entreprises qui étaient assez avancée dans le Lean, dans l'excellence opérationnelle et qui se disait : “Si j'ajoute du digital, je vais mettre une barrière entre les opérateurs et la réalité concrète de terrain”. Ce qui est exactement l'inverse de ce qu'on veut avoir dans le Lean, puisque ce qu'on veut dans le Lean, de faire des feedbacks, et que les gens et les managers soient acteurs de terrain. Si on ajoute une couche de l'informatique, on a peur que l'opérateur bah quelque part puisqu'il ne note plus sur un tableau blanc, ce qui se passe, on a peur qu'il ne soit plus dans l'amélioration continue mais qui considère que c'est l'ordinateur qui doit améliorer et pas lui, donc c'est la perte de tout ce qu'on a implémenté dans le passé, la responsabilisation des gens de terrains, ça, c'est une 2e raison. La 3e raison, c'est la peur en fait que justement soit c'est trop, c'est fashion, et ça va rien rapporter, soit c'est trop compliqué parce que y a tellement de technologie à faire, il y a et donc l'envie plutôt de rester dans un ... une idée d'amélioration comme on le fait je dirais traditionnellement qui est : t'as une idée d'amélioration, tu imagines les différentes technologies que tu pourrais faire, et puis tu le fais, donc tu te lances pas directement dans un vrai projet de transformation digitale de l'entreprise. Et c'est un gros problème en fait. Enfin, ces trois aspects sont des gros problèmes parce que ça peut faire que certaines personnes où certaines sociétés, soit ne se lancent pas du tout, soit se lancent erronément.

PDB – Comment caractériseriez-vous le niveau d'implémentation de l'Industry 4.0 en Belgique ?

MO – La première caractérisation qu'il faut faire, c'est une caractérisation par secteur en fait, et ça, ça explique beaucoup de où en est la Belgique. En fait, la Belgique n'est pas une terre de manufacturing. Elle l'a été quand moi, j'étais jeune, euh... essentiellement dans l'automobile, parce qu'on avait favorisé l'arrivée de du secteur automobile et de la manufacture. Et petit à petit, on a eu de moins en moins, comme partout en Europe. Mais en Belgique, on n'a jamais fait revenir ça en fait. Dans d'autres pays d'Europe comme l'Allemagne, même s'ils ont perdu le manufacturing, ils ont par contre garder tous les aspects “mechanical engineering”, “electrical engineering”, ils sont très forts là-dedans. Et donc ils font de l'Industry 4.0, je dirais pour leurs clients, dans le monde entier et donc beaucoup de constructeurs de machines allemands font de l'Industry 4.0 pour leurs produits. Et donc, comme nous, on a plus de manufacture automobile en Belgique puisqu'on a on a perdu Renault, Audi, c'est devenu tout petit, Ford Genk aussi. Enfin, on a perdu beaucoup. Toyota bien a choisi la France... Ce sur quoi la Belgique a mis je dirais sa préférence, c'est un la logistique. En logistique y a pas énormément de choses à faire en en automation. Enfin, y en a un mais ... Ouais, enfin en tout cas pas c'est pas comme dans le manufacturing. Et puis dans la biotech. Dans les biotech, en fait c'est très peu mature, et dans le Pharma par exemple y a pas énormément de choses à faire. Donc c'est ce qui fait que la Belgique, en fait, n'est vraiment pas, euh, à la pointe par rapport aux autres pays, en fait. Par exemple, si vous regardez, Obama avait fait tout un discours - lui, il appelle ça “Internet Factory”, Macron, quand il était encore ministre de l'économie, il appelait ça “l'usine du futur”, chacun un peu sa terminologie. Mais du temps d'Obama, en fait, parce que c'est à ce moment-là que ça a vraiment commencé à grandir. Il a lancé des centres, je crois qu'il s'appelait “MII”, centre de Manufacturing ... Institute ? Je sais plus quel était le deuxième “i”, mais donc c'est ou “Advanced manufacturing institute”, AMI... donc c'est des grands centres aux États-Unis justement pour promouvoir l'industrie du futur. A Eindhoven il y en a un aussi. Mais en Belgique, en fait, il y en a pas vraiment, alors il y a “technifutur”, “technocampus”, qui essaient de faire quelque chose et en particulier, sont en train de lancer un Industry 4.0. Mais ils sont très en retard par rapport à ce que Obama a annoncé il y a des années et à ce que, par exemple, ce qui a été lancé en Allemagne.

PDB – Comment est-ce que vous décririez, de manière générale, l'impact du Covid-19 sur les opérations en Belgique ?

MO – Par rapport au manufacturing et la supply chain, il y a pas eu beaucoup d'impact, je pense. Mais par contre, enfin, je veux dire les opérations en tant que tel, l'exécution, parce que à partir du moment où on devait produire, on devait vendre et on devait distribuer, bah on l'a fait en fait. Dans les meilleures entreprises ont de toute façon décidé que un site de production... quand j'ai travaillé chez Philippe, par exemple, le site de production, il était complet. La décision, c'est “business critical”, et donc tous les gens qui travaillent dans les usines, travaillent. Je connais même des gens dans d'autres pays en Roumanie, qui ont été isolé parce que ils devaient rester, ils étaient quelque part en quarantaine dans l'usine même. Ça c'est pour les opérations. Par contre, et là on rejoint l'Industry 4.0, ce qui a pâti, c'est toute l'innovation, et en particulier l'innovation qui peut se faire par la collaboration, les workshops. Et donc moi ce que j'ai vu beaucoup c'est en effet et je pense certainement en Belgique... Mais même chez Philips par exemple, on a eu un grand projet de d'Industry 4.0 sur trois sites de production, on a créé en fait ce qu'on appelle des “lighthouses”, mais c'était très compliqué parce que il y avait un site à Singapour, un site à en Inde et un site au Costa Rica. Et donc on devait tout faire par vidéo-conférence avec quelqu'un qui se baladait dans

l'usine avec un projecteur ou son ordinateur pour faire les vidéos. Enfin clairement, c'était beaucoup plus compliqué à organiser. Et donc l'innovation en termes d'excellence opérationnelle et en terme de d'Industry 4.0, a été très fort ralenti.

PDB – Dans quelle mesure pensez-vous que l'Industry 4.0 est une solution aux problèmes qui ont été soulevés par le Covid-19 ?

MO – Ben je vais vous donner un exemple. A cause du COVID, on ne pouvait plus voyager, du coup, on a fait beaucoup plus de ce qu'on appelle de la télé-expertise, donc on a utilisé ben, vous le savez bien, Zoom, MS Teams, mais aussi des lunettes connectées. On a utilisé plus utilisé les données qu'on avait des machines pour faire des analyses à distance ou de la maintenance prédictive à distance. C'est surtout la connectivité, en fait. L'aspect connectivité a permis de faire ... de pallier le fait qu'on pouvait plus être sur place.

PDB – L'Industry 4.0 est soit caractérisée par des caractéristiques comme vous l'avez fait, soit par les différentes technologies comme les imprimante 3D, l'Internet of Things et cetera. Est-ce que vous pensez qu'il y a une technologie spécifique qui est plus intéressante par rapport à la situation du Covid ?

MO – Bah déjà, pour moi l'impression 3D et l'additive manufacturing, pour moi c'est pas exactement la même chose. Enfin, c'est très loin de l'Industry 4.0. Et comme je vous disais, moi je classe en trois niveaux : connectivité, intelligence et automation. Pour le Covid pour moi, tout ce qui est connectivité, et dans connectivité, il y a l'Internet of Things, mais il y a aussi les Software integration, verticale ou horizontale integration. Donc tout ça, ça a bénéficié. Enfin, ça a été très utile lors du Covid. Et par exemple la réalité augmentée. C'est quelque chose qui est aussi pour moi classé dans l'aspect connectivité.

PDB – Quelles étaient les difficultés par rapport à l'implémentation de l'industrie 4.0 dans le contexte du Covid-19 ?

MO – C'est tout le fait que on n'est pas sur place. Le diagnostic est plus compliqué puisque il faut le faire à distance. C'est ce que je disais sur l'innovation, en fait, on ne sait plus aussi bien innover que on le faisait avant. Mais par contre, si on est déjà avancé sur l'aspect connectivité, donc si on a déjà les machines connectées, si on a déjà les softwares intégrés, dans ce cas-là, en fait, le Covid ou pas Covid c'est pas très déranger et au contraire on aurait pu peut être même accélérer tout ce qui est intelligence artificielle. Euh, puisque à partir du moment où les machines sont connectées, en faire de la maintenance prédictive par exemple, on a le temps de le faire.

PDB – Y a-t-il eu des changements dans la façon dont l'implémentation de l'Industry 4.0 s'est effectuée ?

MO – Euh oui. Oui, parce qu'on pouvait plus se rendre sur place.

PDB – Dans quelle mesure est ce que le type d'organisation voulant implémenter l'Industry 4.0 a été modifié avec le Covid-19 ?

MO – Oui, je pense pas que c'est dû au Covid en tout cas. Toutes les grandes entreprises ont déjà mis le doigt dedans. Et donc maintenant, les petites entreprises suivent, mais de manière assez naturel. Ouais je sais pas si c'est lié spécialement au Covid en fait.

PDB – Dans quelle mesure est-ce que les raisons pour lesquelles une entreprise déciderait d'implémenter l'industrie 4.0 ont changé depuis qu'il a eu la crise du Covid ?

MO – Euh, peut-être que les raisons sont différentes, dans le sens que anciennement, les raisons étaient plus traditionnelles. C'était de gagner en efficacité, c'était de gagner en qualité, c'était les nécessité traditionnels de s'améliorer. Aujourd'hui, il y a peut-être une raison complémentaire qui est de se dire que parce que les gens veulent travailler de plus en plus de façon remote, et doivent travailler de façon de plus en plus remote, ou on s'aperçoit que le travail est en remote peut avoir des effets bénéfiques, bah de ce fait là, ça peut être une raison complémentaire pour lequel on a envie d'ajouter plus de connectivités aux machines.

PDB – Dans quelle mesure est-ce que vous pensez que la vitesse à laquelle la pandémie du Covid s'est produite est pertinentes par rapport à l'implémentation de nouvelles technologies ?

MO – Bah l'impact pour moi, il est clair, c'est le fait que ça a été soudain. Bah toutes les forces ont été mises sur des choses très, je dirais administrative, comment est-ce qu'on gère le fait qu'il y ait du social distancing et cetera. Euh donc y'a eu un ralentissement donc comme je disais tout ce qui est innovation ? Je ne sais pas si le fait que ça a été soudain... peut être que parce que la chose se passe soudainement, il y a un effet de choc un peu plus important donc peut être que ce choc a fait que les dirigeants de sociétés se sont peut-être plus demandé comment ils pourraient réagir ou utiliser toute sorte d'idées comme les technologies pour s'améliorer. C'est toujours bien, quelque chose se passe vite pour accentuer le choc de transition et le changement, c'est vrai. Bon, maintenant je

sais, je crois que ça a eu aussi un effet... Il y a beaucoup de gens qui ont été aussi groggy. Bon, y a peu de gens qui aiment le changement, qui peuvent changer facilement et le fait que ça a été un choc assez rapide. Je pense que beaucoup de gens se sont concentrés, là-dessus plutôt que de l'amélioration continue. Et donc on... Je pense que ça a eu un effet aussi sur la capacité d'innover et les gens étaient tellement occupés à dire : "Oui mais il y a le Covid, j'ai pas le temps de faire ceci, j'ai pas le temps de faire cela donc... Et là probablement encore plus les petites entreprises. Je pense que les petites entreprises je pense, mais j'ai pas de chiffres mais je pense que les grandes entreprises avaient de toute façon des obligations de s'améliorer. Et donc, enfin, la machine était lancée, tandis que dans les petites entreprises, elles sont peut-être plus rapidement affectées par ce genre de choc et savent pas comment gérer et donc on ralentit beaucoup de choses. Je peux vous le dire, pour avoir travaillé dans une petite entreprise aussi euh je sais, avant le Covid il y avait pas mal de gens qui voulaient faire du 4.0 et en gros t'es le seul à continuer à le faire. Parce que les autres avaient d'autres choses, ils savent pas comment donc voilà.

PDB – Dans quel mesure y a-t-il eu un changement dans la façon dont l'Industry 4.0 est implémentée ?

MO – Je pense que ce qui se passe souvent, c'est que on fait ce qu'on appelle des proof-of-concept. En fait, je suis dans l'industrie 4.0 depuis longtemps et quand on a commencé, c'est-à-dire... avec ce genre de concept, on a commencé dans les années 2000... Juste après la crise, en fait, ça va faire 2010. On était très fort "Proof-of-Concept". On faisait des POCs, des POCs, des POCs, des POCs, ... on avait une idée avec ... ça a commencé, entre autres, avec les lunettes de Google. Et on s'est dit, voilà, on va faire un Proof of Concept de ce truc là et comme c'était après la crise de 2008, justement, c'était à ce moment-là où on s'est dit, il faut ramener un petit peu de manufacture, et puis les coûts des Chinois devenaient de plus en plus élevé, donc c'est qu'il y avait des opportunités. On a commencé avec des proof-of-concept et puis en fait, ça a coûté très cher et ça marchait pas toujours et c'était plus du gadget. Du coup, on a basculé dans ce qu'on appelle les "used cases", ou les cas d'usage en français, c'est à dire que dans toutes les directions, on a : "Arrêtez vos proof of Concept", "Arrêté d'essayer des technologies", "Faites-moi une liste de cas d'usage où vous allez pouvoir utiliser cette technologie avec des business cases". Et là aussi, en fait ... enfin, beaucoup de sociétés sont encore dans cet état de niveau de maturité là, mais en fait on s'aperçoit que ça aussi c'est pas efficace. Parce qu'en fait, on regarde ... mais je l'ai moi-même fait aussi hein... En 2015, c'est encore des choses que j'ai faites, je dirais même, je dirais jusqu'en 2018. C'est ce qu'on faisait, c'est à dire des listes de "used cases" et "Voilà toutes les technologies, où est ce qu'on peut les utiliser ?". On faisait des brainstorming, des workshops, et cetera. Et j'en fais encore. Mais j'ai ajouté une 3e couche, qui est la couche que toutes les sociétés devraient ajouter aujourd'hui. C'est les "capabilities". En fait, ce qu'on doit faire aujourd'hui, c'est s'assurer qu'on forme les gens à ces technologies. Qu'on les forme à qu'est-ce que celle du Data Analytics, qu'on les forme à qu'est-ce que c'est que de la robotique, de l'automation, et cetera, pour que eux-mêmes aient les idées. Exactement comme on a fait dans le Lean, en fait. Au départ, dans le Lean, dans le début du siècle, quand Ford a fait cette première ligne de production de Ford T, Bah c'était très top down, on dit : "Voilà, on va améliorer, on va faire une ligne de production en pull", et cetera. Petit à petit, on est rentré dans un mode de réflexion où on se dit bah en fait on va avoir beaucoup plus d'amélioration si on propose à tout le monde d'améliorer. Et pour que tout le monde participe à l'amélioration continue, bah il a fallu commencer à expliquer, à former, avoir des bureaux de méthodes, et cetera, pour que tous les opérateurs, même l'ouvrier sur la chaîne de production, puisse participer. Il fallait qu'ils comprennent pourquoi on travaille en pull, qu'est-ce que c'est qu'un workshop, qu'est-ce que c'est qu'un groupe de travail, et cetera. Et ça, c'est ce qu'on a fait à partir des années 50, 60 jusque dans les années 80, 90 pour les grosses entreprises, et les petites entreprises, elles, sont encore à faire ça. Ça, exactement ce qu'on doit faire pour l'industrie 4.0 en fait. On a commencé par dire : "Voilà on va tester les technologies". La 2e phase c'était : "Non, on veut faire sérieusement, on fait, on fait des cas d'usage pour ne pas dépenser de l'argent dans tous les sens". Ce qu'on doit faire maintenant, c'est mettre en place un data lake, par exemple. Enfin, si je prends l'exemple du data analytics, mettre en place un data lake donc ... Je sais pas un azur par exemple, de telle manière à ce que tout le monde puisse avoir accès aux données et que tout le monde puisse commencer à faire son petit dashboard dans son coin pour améliorer le processus qu'il connaît bien, exactement comme l'opérateur qui était sur la ligne de production, il connaissait bien ce que lui il faisait et du coup il avait des idées. Ah mais si je mettais un élastique là où si je me bougeais autrement, ce serait beaucoup plus efficace serait plus de qualité, plus de sécurité, et cetera. De la même manière pour l'industrie 4.0 ou pour le digital. Il faut que les gens aient de plus en plus de formation, sur les outils, les systèmes, la collectivité et cetera, l'automation. Et sache ce qu'un robot sait faire, ce qu'un robot collaboratif sait faire, de telle manière à ce que eux-mêmes se disent : "Ah ouais mais si je travaillais avec un robot collaboratif, lui il pourrait tenir ça pendant que moi je fais ça". Et c'est là que ... les entreprises les plus matures, c'est ce qu'elles font. Et pour l'instant, c'est encore un peu épare, mais si vous allez voir GE par exemple, Général Electric, et bien, ils ont mis des data lake en place, et ils ont donné énormément de formation en Power BI ou en Excel, pour que les gens fassent eux-mêmes en fait des améliorations à l'aide du digital.

PDB – Quelle est votre opinion sur l'Industry 4.0 ?

MO – Regarde en fait, si on regarde l'angle politique, parce que le mot Industry 4.0 c'est, c'est du marketing politique en fait, donc regarde l'angle politique, je pense qu'on en est qu'à ses prémices. C'est à dire que j'ai pas encore vu beaucoup de manufactures revenir en Europe, mais je pense que le fait que maintenant on ajoute des tarifs douaniers dans ce qui vient de la Chine va permettre de faire revenir et en combinaison avec la robotisation, on va pouvoir atteindre plus rapidement des niveaux... enfin, compenser en fait, la différence de productivité qu'on a encore, pour la manufacture. Les salaires des Chinois ont encore augmenté mais pas encore suffisamment et puis maintenant toute la manufacture est là-bas donc pour la faire revenir quelque part ça a un coût et donc on la fera revenir que si on ajoute encore des tarifs douaniers. On n'a pas les ... Ils sont encore trop bon marché, en gros. Ça c'est le point de vue politique. Si on regarde des perspectives industrielles. Je pense que les technologies vont clairement être de plus en plus adoptées, mais pas forcément pour faire revenir de la manufacture, mais plus déjà pour améliorer la productivité de manière générale en fait, et petit à petit, chacun dans son coin, chacun dans son usine, dans son secteur, pour ses besoins propres. Si on regarde par exemple le secteur ... dans certains secteurs, ça sert très fort à augmenter la qualité, éviter l'erreur humaine, et cetera. Dans d'autres secteurs, ça va servir à augmenter l'efficacité. Et dans le secteur qui moi m'intéresse beaucoup en ce moment, qui sont les hôpitaux, le 4.0 ou l'utilisation de la connectivité, de l'intelligence, et de l'automation, ça permet d'abord d'améliorer l'expérience patient. Parce que le patient et dans le retail là on pourrait dire aussi dans l'industrie, c'est un peu moins le cas, mais parce que c'est du B2B souvent, mais dans l'industrie qu'est le Healthcare, le client final, c'est l'utilisateur qui lui-même va vouloir être connecté. En fait, le patient, parce qu'il a de plus en plus d'informations, il a de plus en plus envie d'agir sur sa santé et donc il a pour ça, il a besoin d'être connecté, c'est à dire d'avoir les données. Et il a besoin de la deuxième couche qui est l'intelligence. Par exemple, avec des applications comme la détection des points de beauté, voir s'ils ont un problème ou pas, ça la couche intelligence, que lui, il peut utiliser directement lui-même, et ça aide quelque part, le médecin à donner un meilleur diagnostic. Puis l'automation, ça, ce sera plutôt pour ... enfin, si on te parle en terme de software, bah c'est pour lui permettre d'avoir une plus rapide revalidation par exemple ou à un rendez-vous plus rapide. Le fait qui qui qu'on automatise les processus de suivi de thérapie ou de prise de rendez-vous, tout ça permet aux patients en fait d'être mieux soignés ou d'avoir une période de revalidation plus court, d'être plus ambulatoire. Et donc quelque part dans le secteur Healthcare, je crois que ça va continuer, mais c'est pas pour ramener de la manufacture, c'est plus pour améliorer. En fait, améliorer les soins et la santé des gens.

PDB – Est-ce que vous pensez que justement cette amélioration et cette augmentation d'applications dans le domaine Healthcare, peut avoir une influence positive sur d'autres secteurs ?

MO – Oui, certainement. Tout a une influence positive. Le monde va vers le plus positif de toute façon.

APPENDIX 3: Interview 2 – Philippe Huberts

Pierrick De Bock: PDB

Philippe Huberts: PH

PDB – Pouvez-vous vous présenter en quelques mots ?

PH – Je m'appelle Phillippe Huberts, je suis en charge de digital automation technologies pour ce qu'on appelle "integrated supply chain" chez AkzoNobel. Donc integrated Supply Chain ça englobe manufacturing, logistics et supply planning. Donc typiquement quand on parle d'Industry 4.0, c'est plus sur la partie manufacturing, mais tu as aussi le lien avec les sujets logistiques, tout ça qui sont intéressants. Euh... Donc voilà AkzoNobel, c'est une entreprise qui fait des "painted coating", donc c'est tout ce qui est peinture, revêtement qu'on va retrouver dans tout un tas de secteurs. Tous les avions qui volent actuellement dans le ciel ont des coating AkzoNobel, donc les Boeing, Airbus, ce sont vraiment des clients de Akzo par exemple. Et on va retrouver des coating dans le bâtiment, sur du mobiliers, ... McLaren est un grand client emblématique aussi de chez AkzoNobel, donc sur les voitures, tout ça. Et puis l'aspect peinture, bah c'est à la fois des peintures solvant de base, ou à base d'eau. Donc c'est un grand leader dans le secteur, vraiment sur peinture et coating. Avant il y avait la partie chimie qui maintenant une autre entreprise totalement. Et c'est une entreprise d'environ 35 000 personnes dont le siège se trouve à Amsterdam. Donc moi j'ai un rôle globale, je regarde vraiment tout ce qui est digitale au globale, même si je suis basé en Belgique. Et au niveau globale, on a environ 125 sites de production.

PDB – Comment définissez-vous l'industrie 4.0 dans vos propres mots ?

PH – Alors pour moi l'Industry 4.0 c'est un ensemble de technologies. On parlerait de IoT, de Big Data, de Cloud, Augmented Reality, 3D printing, ... combinés ensemble. D'accord donc c'est pas une technologie c'est vraiment la combinaison ensemble de ces techno. Et qui atteint un niveau de maturité qui permet à l'industrie qui l'applique, soit d'améliorer son efficacité en interne, soit de générer des nouveaux business modèles. Donc voilà je pense qu'il y a vraiment les deux aspects, soit tu améliores l'efficacité interne, soit tu génères de nouveaux services, de nouveaux business modèles. Et donc c'est pas une techno c'est vraiment la combinaison des technologies, ce n'est pas non plus des trucs de R&D ou des trucs qui ne sont pas à maturité, c'est vraiment des trucs qui deviennent aujourd'hui à maturité.

PDB – Quelle est votre expérience avec l'Industry 4.0 ?

PH – Moi ça fait une dizaine d'années je pense que je travaille autour des sujets Industry 4.0, digital. À l'époque, on ne parlait pas vraiment d'Industry 4.0. J'ai commencé ma carrière dans l'IT, puis je suis passé plus côté techno pour le business, toujours dans les ressources naturelles, la chimie, et aujourd'hui Akzo qui est plus manufacturing FMCG. Avant on parlait plus d'application de métiers ou autres chose, et puis maintenant on parle plus de transformation digital et d'Industry 4.0, et que c'est parce que justement on a toutes ces techno qui arrivent à maturité qui fait que l'on sent qu'il y a un côté disruptif, et c'est pour ça qu'on parle d'Industry 4.0. Donc moi aujourd'hui je fais ça chez AkzoNobel, avant ça je travaillais chez Yara, qui est une entreprise chimique donc qui fait des engrais. Chez Yara je faisais en fait le digital manufacturing. Et avant j'étais chez Accenture, dans la consultance, à l'époque on parlait pas d'Industry 4.0, mais voilà c'était des applications, des solutions, qui étaient pas de l'IT pour de l'IT, qui étaient pas de l'infrastructure, mais qui étaient rarement orienté métier et business quoi.

PDB – Quelles ont été les raisons du développement du concept ?

PH – Ah c'est un facteur de productivité. On dit souvent que l'Industry 4.0 va permettre d'accroître la productivité, la fiabilité, la qualité et la sécurité des usines. Mais voilà je pense qu'avant tout c'est une affaire de productivité. Il y a eu des gains de productivité dans les révolutions industrielles précédentes. Je pense que ce qui est important c'est que récemment, donc on va dire fin vingtième siècle, on parlait d'excellence opérationnelle, de Lean manufacturing, de six sigma, tu vois toutes ces méthodes qui sont arrivées mais que ça n'a pas su ... Et aujourd'hui voilà c'est un peu devenu un standard, et cela s'est développé dans l'industrie. Et puis l'Industry 4.0 finalement c'est un nouveau plateau, c'est la continuité techno quelque part de tout ce qui est Lean, opération excellence. Donc moi partout où je suis passé je repositionnais l'Industry 4.0 le digital pour le manufacturing comme vraiment le "next horizon". D'ailleurs ça sert à rien de faire du digital si on a pas les bases en termes de process, donc avant de parler de ... je sais pas de productive maintenance, bah si tu as pas des bons process de maintenance, si tu fais pas ta maintenance correctement, si tu as pas un bon planning de maintenance bah ça sert à rien. Donc c'est vraiment le "next horizon" en matière de productivité.

PDB – Quelles sont les principales barrières à l’implémentation de l’Industry 4.0 ?

PH – Bah si tu prends le manufacturing, comme Akzo, c’est quand même un secteur qui est assez euh .. traditionnelle si je puis dire, donc si tu compares, par rapport à la télécom par exemple, ils sont bien plus en avance d’un point de vue digital. Voilà parce que c’est plus traditionnelle, il y a encore beaucoup plus d’activité manuelle aussi. Au niveau automatisation, je suis parfois étonné en Belgique par exemple chez Akzo, il y a encore des gens qui mettent les étiquettes à la main sur les pots de peintures, ce qui est... bon voilà. Et donc je pense qu’il y a eu un frein culturelle, il y a une question de maturité, et aussi le fait que c’est ... oui c’est des secteurs qui sont traditionnelles, mais aussi plus stables, sur lesquelles tu as besoin d’une certaine prévisibilité et tout ça, donc typiquement dans le manufacturing, les changements doivent se faire de manière très contrôlée. Et donc il y a parfois une certaine résistance, une certaine réticence avec les nouvelles technos, ... qui sont pas suffisamment prouvées, qui ne sont pas suffisamment matures, tout ça. Donc il fallait atteindre un certain degré de maturité. Donc ça change mais ça change parfois un peu en dessous quoi.

PDB – Comment caractériseriez-vous le niveau d’implémentation de l’Industrie 4.0 en Belgique ? Par rapport à d’autres pays ?

PH – Bah je crois qu’on est pas les plus avancé en Europe, ça c’est clair. Le terme Industry 4.0 historiquement vient d’Allemagne. Donc je pense que l’Allemagne particulièrement est nettement plus avancée. Je pense qu’en matière de techno, ... oui, il y a des boîtes, il y a des start-ups, il y a un écosystème, pareil c’est pas le plus avancé d’Europe. Mais voilà je dirais qu’on doit être dans la moyenne.

PDB – Dans quelle mesure existe-t-il des particularités concernant l’Industrie 4.0 en Belgique ?

PH – Je ne pense pas. En tout cas, nous chez AkzoNobel, comme j’ai expliqué en introduction moi j’ai un rôle globale, j’habite juste à Bruxelles pour des raisons personnelles, on a une usine en fait à Machelen en Belgique, qui est la seule usine AkzoNobel en Belgique. Il y a rien de spécifique par rapport au reste de l’Europe, par rapport au reste du monde. Je pense que ce qui est important c’est que culturellement, je vois d’énorme différence entre l’Europe et l’Asie, donc l’Asie est beaucoup plus volontaire, a beaucoup plus oui cette volonté d’adopter de nouvelles technos par rapport à l’Europe. C’est clair d’un point de vue perso, donc ça tu pourrais dire l’utilisation du smartphone, les gens dans leur vie perso, mais c’est aussi clair dans un terrain professionnel.

PDB – Comment décririez-vous l’impact de la pandémie du Covid-19 sur les opérations ?

PH – Je pense que beaucoup de gens vont dire que c’est un accélérateur de transformation, voilà. Je pense qu’il y a pas vraiment de chose qu’on a mis en place qu’on aurait pas mis en place si il y avait pas eu le Covid. Mais voilà c’est un accélérateur, donc l’impact du Covid c’est que par exemple... Déjà avant le Covid tu sentais certaines restrictions au niveau des voyages, voilà toutes les boîtes cherches à faire de plus en plus d’économie, limiter les voyages limiter les déplacements professionnels ça fait des économie et puis là bah voilà ça a été très loin avec le Covid. Après pour limiter les déplacements professionnels, il faut digitaliser les process, il faut faire les choses des plus en plus “remote”, comme on est en train de le faire, comme cette interview finalement. Moi aujourd’hui je travaille depuis la maison, voilà. Donc ça a été un accélérateur pour le digital, ça c’est clair. Après d’un point de vue pratique, j’ai partagé avec toi un article d’AkzoNobel qui expliquait un peu l’Augmented Reality, et c’est vrai que vraiment d’un point de vue très pratique, on avait un grand projet par exemple sur le digital manufacturing, où en fait on implémente des solutions digitales, d’IoT pour monitorer les sites les machines tout ça bon peu importe. Et le fait est que c’est des solutions qu’on implémentait à grande échelle, donc sur une trentaine de sites actuellement, donc c’est des grands programmes de déploiement sauf qu’avec le Covid du jour au lendemain on ne pouvait plus voyager sur les sites. Et donc normalement quand on fait ce genre de déploiement pour un site, on va aller sur le site, on va discuter du design, dire “Okay c’est telle machine, on va connecter ceci comme-ça, on va déployer tel type de serveur, on va le faire comme ça, ...” et là on ne pouvait plus le faire, et donc on a fait ça à distance, avec Teams, mais c’est là aussi qu’on a introduit la réalité augmentée donc les lunettes connectées, l’Augmented Reality, ce qui servait, par exemple, moi si j’étais à Amsterdam, avec une équipe pour faire le design, tu implémentes ça, je sais pas eu Etats-Unis, à Nashville, bah les gens à Nashville avait les lunettes, nous montrait les machines, et en fait on interagissait, on leur montrait un peu le câblage là-bas comment c’est tac tac tac, on pouvait zoomer à distance, donc ça a été vraiment un outil qu’on a utilisé pour faire de la collaboration. Et c’est un truc qu’on a commencé à faire je pense au mois d’avril-mai 2020, et qui a vraiment pris grâce au Covid. Donc aujourd’hui AkzoNobel c’est 125 sites de productions, et donc sur 125, il y a environ un tiers, quarante, qui ont des lunettes de réalité augmentée, donc qu’on utilise pour faire du training à distance, du support à distance, des audits à distance, voilà, et ça je suis sûr que ça aurait pas été si vite si il y avait pas eu le Covid, très clairement.

PDB – Selon vous, quelle(s) industrie(s) est (sont) la (les) plus touchée(s) et pourquoi ?

PH – Oui ça c’est clair que le tourisme, tout ce qui est transport aérien, tout ça, souffre beaucoup, mais c’est pas... c’est plus lié à la demande quoi, c’est pas les opérations, c’est le fait qu’il y a la demande qui drop complètement. Je pense que la question est plus, si je comprends bien “Quelles sont les industries, qui en interne et dans l’opérationnelle, souffre et ont souffert le plus par rapport au Covid”. Nous par exemple, AkzoNobel a pas énormément souffert, le truc c’est qu’il a eu une baisse de la demande comme je disais. Après c’est remonté pas mal et il y a même eu un effet contraire parce que justement comme les gens étaient très fort chez eux bah ils voulaient refaire leur peinture, leur déco tout ça, donc finalement on a eu des chiffres en 2020 qui étaient pas mauvais. Et on a continué à faire tourner les usines et voilà. Mais aujourd’hui, en 2021, on a plus des problèmes d’approvisionnement, donc qui sont dues aux matières premières, et ça c’est intéressant pour le digital, d’approvisionnement aussi en hardware, donc tout ce qui est ordinateur, serveur, machin tout ça, ou équipement, par exemple on utilise ce qu’on appelle un data concentrateur, donc c’est ce qu’on déploie dans les usines pour concentrer le flux de données avant de les envoyer dans le cloud. C’est vraiment une galère incroyable parce que l’on met aujourd’hui six mois à avoir ces équipements quoi, les faire livrer, alors qu’avant on aurait eu le truc qui arrivait en un mois. Donc ce qui est sûr c’est que toute la supply chain comprenant l’électronique a vraiment été fortement perturbé, et ça nous a impacté, nous comme d’autres.

PDB – Dans quelle mesure l’industrie 4.0 est-elle une solution aux problèmes soulevés par la crise ?

PH – Tout ce qui est technologies de collaboration à distance, tout ça ça a vraiment apporter une solution. Donc lunettes connectées, tout ça. Je pense la digitalisation des process en générale parce que voilà en mettant les données, en partageant les données en les stockant, et puis en les ouvrant à distance au sein de l’entreprise, bah voilà on peut faire quelque part la supervision d’une usine à distance. Pareil en digitalisant les process, plutôt que de tout avoir sur papier, ça a facilité la transmission d’informations, donc si moi je suis pas là, et que c’est toi qui prends le relais parce que moi je suis malade, je suis absent ou whatever, bah le fait d’avoir la traçabilité intra-système ça aide beaucoup. Donc oui ça renforce les opérations, ça les rends plus fiable quelque part.

PDB – Quelles sont les technologies et/ou les caractéristiques les plus intéressantes du concept dans le contexte de la pandémie ?

PH – Augmented Reality, tout ce qui est connected worker, process digitalisation, IoT, ... Tout ce qui apporte de la connectivité, du collaboratif, voilà. À l’inverse qu’est-ce qui n’aide pas ? Bah tous les trucs de maintenance, predictive maintenance, peu importe, impression 3D peu importe.

PDB – Dans quelle mesure la pandémie du Covid-19 a-t-elle eu un impact sur la mise en œuvre de l’industrie 4.0 ?

PH – Bah comme je l’expliquais ça a à la fois un côté accélérateur, on se rend compte de l’importance et des solutions que ça apporte, de comment ça facilite la vie. Donc d’un côté il y a le côté vraiment bah oui le business case est plus évident que jamais. Mais c’est à double tranchant il y a comme je l’expliquais le côté approvisionnement hardware que je trouve fascinant, même si maintenant on dit “Okay, on va y aller, on va investir beaucoup, plus vite, au lieu de déployer je sais pas la techno sur 30 sites on va le faire sur 60 sites”, great ! Mais après derrière la chaîne d’approvisionnement... en tout cas, la situation dans laquelle elle a été en 2021 ne suit pas, donc ça c’est assez incroyable, donc après il faut voir en 2022 si ça sera encore le cas, mais c’est assez cocasse que maintenant que le business case est plus démontré que jamais, avec ces problèmes d’approvisionnement, on reste quand même limité physiquement. C’est intéressant de se dire que tout ce qui est ... tu peux parler de dématérialisation, de trucs dans le cloud et tout ça, okay, mais derrière il y a des machines et des vrais trucs physiques, donc tout n’est pas dématérialisé, donc ces vrais machines et trucs physiques il faut il faut encore les produire, et on est dépendant de tout ça.

PDB – Que pensez-vous des effets de cette accélération de l’Industry 4.0 ?

PH – Je pense que ce n’est que du positif, donc que ça soit une accélération c’est que du positif. Après, euh, donc on parle vraiment de l’accélération de l’Industry 4.0, après, si tu sors du cadre pure digital Industry 4.0, moi je pense qu’en terme de collaboration, on est quand même moins effectif en remote. Peut-être que l’idéal, c’est un “way of working hybrid”, où les gens seraient, je sais pas moi, deux jours semaine à la maison et trois jours semaine sur site. Toute cette période on était plutôt dans du cinq jours semaine à la maison, je pense que ça avait un effet négatif sur la collaboration, sur la connectivité. Après on peut dire c’est contrebalancé parce que les gens font des grosses journées tout ça machin, bah certes mais moi personnellement, j’ai trouvé que c’était plus dur de travailler complètement en remote parce qu’on reste des animaux sociaux, parce que l’on reste ... les décisions se prennent parfois près de la machine à café, parce que parfois tu vas prendre rendez-vous en permanence avec les gens, bah comme on le fait maintenant “est-ce que tu es dispo à 5 heures ?” tac... au lieu d’aller trouver les gens. Donc en terme d’efficacité, moi je pense pas que quand on est toujours à la maison ça aide, mais bon ça c’est en

générale. Après dans le manufacturing les gens allaient quand même sur site quand ils travaillent sur des sites de production tout ça donc c'est différent quoi.

PDB – Dans quelle mesure les raisons sous-jacentes à la mise en œuvre de l'industrie 4.0 ont-elles changé avec la pandémie de covid-19 ?

PH – Je ne pense pas que ça va changer. Peut-être qu'il y a un focus plus sur l'aspect... peut-être que ... comme je disais au tout début, c'est surtout une affaire de productivité l'Industry 4.0. Peut-être que là il y a aussi un shift qui se fait par rapport aux aspects plus collaboratifs, connectivité, ... ouais donc je sais pas le fait de faciliter le fait que des usines par exemple puissent s'aider à distance. Que si deux usines utilisent les même équipement peut-être que l'ingénieur d'un site pourra aider un ingénieur d'un autre site qui a des problèmes, ça c'est des cas d'usage qui avant étaient peut-être moins populaire ou qui passaient au second plan par rapport à ce pur "productivity", et qui là reviennent un peu devant parce qu'on se rend compte de toute la valeur de cette collaboration.

PDB – Donc cela serait plus de manière complémentaire, et la base des raisons d'implémentation resterait les même de manière générale ?

PH – Oui je crois.

PDB – Dans quelle mesure le nombre de projets de l'industrie 4.0 a-t-il augmenté due au Covid ?

PH – Je ne suis pas sûr qu'il ait augmenté parce que même si on voit mieux le business case parce que beaucoup de boîte restent encore sous pression et sont assez prudente par rapport aux investissements, donc je ne pense pas en fait. Je pense que ça serait intéressant d'en discuter avec des consultants ou quoi, mais j'ai pas l'impression. Voilà je pense qu'on voit mieux l'intérêt, je pense que culturellement ça va être mieux accepté, mais pour une accélération des projets je ne pense pas. Moi si je regarde chez Akzo par exemple les investissements qu'on a fait dans l'Industry 4.0, en 2021 c'est le même ordre de grandeur qu'en 2020, voilà donc c'est peut-être culturellement plus accepté, mais c'est pas l'e-commerce, où par exemple on peut dire aujourd'hui il y a plein de gens qui ont utilisé l'e-commerce pour la première fois de leur vie lors de la ... lors du confinement, et du coup t'as un boom de l'e-commerce. Mais je pense pas que c'est le cas sur l'Industry 4.0.

PDB – Dans quelle mesure pensez-vous que la vitesse à laquelle la crise s'est produite est pertinente pour la mise en œuvre des technologies de l'industrie 4.0 ?

PH – Je ne sais pas. Oui bah ça a été très vite, donc ça a pris les gens par surprise, maintenant si ça avait été deux fois plus lentement, ça aurait pas forcément... Fin je pense que culturellement ça a vraiment amené une certaine prise de conscience, mais c'est pas forcément lié à l'urgence, enfin je ne pense pas. Non je pense que la vitesse c'est plus ce qui impact aujourd'hui la supply chain niveau mondiale, les problèmes quant à l'approvisionnement de matériel, tout ça effectivement c'est parce que ça a été tellement vite que ça n'a pas pu être anticipé. Mais sur le case de l'Industry 4.0, je ne pense pas.

PDB – Dans quelle mesure la manière de mettre en œuvre l'industrie 4.0 a-t-elle changé ?

PH – Je pense que les changements de la façon dont les choses sont implémentées c'est pas propre à l'Industry 4.0. Si on fait un workshop pour les besoins d'une telle solution ... Avant par défaut on aurait fait ce workshop inside donc en présentielle avec des gens du monde entier. Aujourd'hui eh bien ça va se faire de façon beaucoup plus remote. L'implémentation va se faire beaucoup plus à distance.

PDB – Et si l'on considère qu'une attitude incrémentale et de mise à niveau était la norme avant la crise ?

PH – Ça je pense ça a pas changé. Je pense qu'on fera toujours ... non les activités la façon de faire, enfin non ça n'a pas changé l'approche. Nous l'approche on commence toujours par faire des pilotes, ensuite on passe dans des phases de scale-up, où donc typiquement on commence sur un ou deux sites, puis on va maturer tout ça sur peut-être cinq sites. Et puis aujourd'hui on a des grands projets qui touchent je disais environ une trentaine de site, et donc voilà c'est beaucoup plus gros tout ça. Mais donc voilà, toutes les problématiques de rétrofit, les problématiques d'un contexte existant, d'une dette technologique comme on dit, ça ça n'a pas changé. C'est ce qui... ça fait partie des fins d'adoption de l'Industry 4.0. Donc voilà, la différence entre une boîte où l'on part de zéro, on crée des usines, ça sera totalement différent.

PDB – Quelle est votre opinion sur le concept d'industrie 4.0 ? Prudent, optimiste, pourquoi ? Dans quelle mesure a-t-il changé avec la crise ?

PH – Moi je pense que j'ai beaucoup de chance de travailler sur ce sujet, je suis très content. Je pense que c'est vraiment très chouette de travailler à la croisée du business et de la technologie comme ça, de travailler avec des techno qui ont un impact concret sur le travail des gens, en usine, sur le shop-floor tout ça, donc c'est super. Et

euh je vois un grand avenir pour l'Industry 4.0 puisque ... on en parle beaucoup, on en parle de plus en plus, qui font partie de stratégie d'entreprise. Aujourd'hui Accenture par exemple ils parlent d'Industry X.0, il y en a qui parlent de 5.0, donc voilà je suis pas inquiet par rapport à l'avenir. On est dans un monde de plus en plus techno, et ça se reflète sur l'industrie. Donc je ne suis pas inquiet, je vois une accélération, comme tout le monde, à tous les niveaux.

PDB – Y a-t-il quelque chose que vous aimeriez ajouter ? Un point important ou un détail qui n'a pas été abordé ?

PH – Non mais voilà l'impact... fin je pense que l'Industry 4.0 c'est vraiment un cas particulier. C'est vraiment le Covid qui a changé la façon dont les gens travaillent, la collaboration en général. Industry 4.0 ou pas Industry 4.0, finalement ça va pas se refléter dans un plan d'Industry 4.0 mais ça va se refléter dans un plan générale. Par exemple aujourd'hui je travaillais ... donc voilà en septembre on va avoir une conférence en interne AkzoNobel, avec tous les sites et c'est un truc il y a deux ans qu'on l'avait fait. Et il y a deux ans on avait fait cette conférence avec les trois régions, donc un espèce de up comme ça, et donc on en avait en Amérique, en Europe et en Asie, tous les directeurs d'usine et les gens dans la région se réunissaient. Et en septembre cette conférence elle va être complètement remote. Donc ça sera pas la même chose, je pense qu'on y perdra au change sur certains aspects. Par ailleurs, on va y gagner aussi, bah ça va être beaucoup moins chère, ça va être plus facile d'avoir plus de gens en fait, puisqu'on va étendre le nombre de participants, mais voilà ça amène d'autres bénéfices. En tout cas c'est faire les choses différemment et dans le contenu de la conférence et dans la façon de faire certaines sessions et tout ça, bah voilà ça change l'approche. Mais pas forcément lié à l'Industry 4.0.

APPENDIX 4: Interview 3 – Francis Masscho

Pierrick De Bock: PDB

Francis Masscho: FM

FM – The last 10 years I have been working at Delaware, mainly in the manufacturing sector. However I also have some relation with the healthcare sector, and with some... let's say heu hospitals. I have a very good relation with the hospital university of.. How do you call it, ja the Hospital University of Gent. UZ Gent, it is a competitor, a little bit of a competitor with UZ Leuven I think, but I have a very good relation with it and also a lot of projects. So I have seen in the last two years what happened with Industry 4.0 in different sectors hey, we talk about the manufacturing sector then we talk about the food sector for example also. Looking at the food sector, I have projects in discrete manufacturing sector, in the health sector, heu .. I have also projects in the apparel sector, apparel, you know, clothing, technical clothing. So I have a rather broad view of different industry sectors.

And before Covid, I recognized that, not the healthcare but the other sectors, they were working quite heavily, quite heavily yes they started working on Industry 4.0 projects because they recognized these projects, long term projects. So it is not a revolution hey Industry 4.0, it is an evolution, as you know. It is not for one year, but it is an evolution where people, where companies they know that there are different technologies, different ways of capturing data, different ways of doing something with data, of learning out of that data, there are different ways to connect to systems which gather data, so ... And we have seen two years ago that ja the discrete, food, apparel sector and other sectors, they were quite well concentrated on everything regarding Industry 4.0. Like for example in the healthcare sector and the hospital sector, there I saw a little bit, except from 3D, you know 3D printing?

PDB – Yes.

FM – That they were lacking somewhat behind in specific areas, and ... I you look to the healthcare, because of the Covid, that Industry 4.0 accelerated in the healthcare. Because I have seen per example projects with the ... for the ... you know when you have to give air to the people, to propel air through tube hey, that particular machine for example, or components, some of them are printed by 3D printing, and companies like Materialize, close to Leuven, do you know about the company, Materialize?

PDB – I think I read about It yes.

FM – Ja, but you have to look at it at the end of this, it is quite a good example for Industry 4.0 sector, or Industry 4.0 technology. They had much more work, even more work in the healthcare sector, to print to make machine quite fast or to make the components available in the healthcare quite fast, by using 3D printing. It was already a proven technology and this accelerated it in this area.

If you look in the food sector, there, as the business was not hampered by Covid, there was... we have not seen heu some impact of the Covid on the Industry 4.0 initiatives. So this projects, let's say, came heu let's say.. they did not stop, while in discrete manufacturing, I will not tell you the name of the companies but I can tell you the name of the companies we are.. I received a phone call from two three weeks after let's say the increase of Covid and the whole let's say.. I don't say the panic but anyway, that we had to stop our projects. That's mainly because: one, they did not sell, they wanted to pay attention to their spending, so some projects were of course delayed, but on the other hand, second reasons why projects were delayed it is because some people were not available. So if production is not running, you need the people of production to work on Industry 4.0 projects. Some people were obliged to take heu.. How do you call it? Not a holiday but to take temporary leave, you understand hey? They were not able anymore to work. So there we have definitely seen that the focus on Industry 4.0 initiatives was not high, even it stopped.

If you look also, so that's a summary, the discrete manufacturing stopped, the healthcare they increased, but if we talk about the technology, what kind of technology, the impacts on technology, of Covid, then as I said 3D has become of bigger importance, then there is definitely also more and more interests in POCs, I don't say the big projects hey, but in "proof-of-Concepts" related to Augmented Reality. There I see that people are looking how Augmented reality in maintenance hey, can be helpful to help, to support people from remote site. So you can more and more work remotely, or guide people remotely using Augmented Reality, so this has become of larger importance.

Then Industry 4.0 relates also to make data available to people, and also to understand what the relations are within that data. First of all you have to make it available, that's hey... And then you have to use the technology to learn from your data to see some relations between those data using different kind of technology, heu let's say software,

AI technologies. And what we have seen is that just to make the data available, visible that ... we have seen an increase of Apps, so Apps on your smartphone so that the data is directly available hey not on your PC, but on your App, on your smartphone.

Bringing in fact another problem related to security of the data of course. Did some companies not go too fast? Did they take everything into account related to security? You can also say, that's maybe an impact of Covid, making data available through Apps, but what is the level of security underneath it. And if you then look into making data available, a lot of data, if you talk about ... tons of data, companies also think about ... Is that now a result of Covid I do not know, but more and more people understand that to be in line with everything regarding security, they have to invest a lot, so these people these companies have to invest a lot, in people, in trainings, in software, in everything. But hey also recognize that some Cloud providers already available with all the security levels and they maintain it and it is much easier for these big players like Microsoft, Amazon, Azure or Google, they have these platform already available. And I think there is also a tendency, that's also a kind of ... let's say, it's a consequence of Covid, that, probably, as they understand these companies that security is very important, to make that data available, that they go quicker to a Cloud, they are more open to Cloud solutions than others, than in the past. But there again, there is a difference between the different sectors, within the industries. If you look again within the healthcare sectors, which is trying to find relation between all the different data, or personal data hey, of laboratory, radio test of lots of examples, of other information about us. This is data which they do not trust to put in a Cloud solution. So there they are reluctant and they stay on premises data models. Even if it takes five or ten times more efforts to develop a data platform compare to the availability of data platforms in Azure, they stay to... on premise location, for the moment. They also think about Industry 4.0, they also know that it is not realistic to stay on premise.

So Industry 4.0, again, it is everything related, it that now through Covid hey, everything, especially in the healthcare, relates to combining data and to learn out of it. And the more they want to combine data, they see that it is not possible, allez, it costs a lot of money, a lot of time to install this kind of platform, then they also think: "Oh, we are at the borders of our capacities", so in the longer terms, they will think faster about Cloud solutions, because of Covid, because they understand much more that they have to do something with data platforms to combine all that different methodo data they have, to understand how to do it, to ja to help people at the end, at the end it is all about finding the best way how to help how to find the best message hey. So this is definitely an area which has pushed forward ja the innovation.

If you also look in the healthcare what happened now, before Covid, we all went to a doctor hey. But now, because we couldn't go to a doctor because of the fact that hey, meeting a doctor hey, it was a risk, for the doctor to become ill of for us I don't know. But what I called the "mobile health", is accelerated, so everything regarding mobile health, which is also a topic related to Industry 4.0 of course, is this has been .. this has grown in importance hey. If you now already, if you verify with Louvain, the University of Leuven, they make all kinds of Apps, to make data available for you. And if you then look to data, if you look into the specialized companies, they find for example solutions that you have, some people will have some illness and have to put heu, who are working here with a needle, who is constant you know. And they have to give themselves, once a week, some kind of ...hey. This is also controlled by an app. These are things which are coming, instead of going to a doctor, because Covid, you didn't go... You did go before Covid, you went to a doctor, but now, they are looking for "Ok, how can we maybe guide somebody at home, using his smartphone" and that what the person is doing, that in a way it is monitored, you can see "Ok, he has done it in a right way, press the button" "Press the button when you stop, when you start when you stop" that there is some kind of control over what the person is doing. So that mobile health is, because of Covid, has become much more important, also.

There are definitely, and that's maybe a kind of industry, beside discrete manufacturing, who also suffered from Covid, is per example all these companies who are related to the Horeca sector. All these companies to the "evenement" sector, with all the fairs. You know, industries fairs. Normally you have different kind of industries, having once a year, or every two years, a fair, everybody is coming together, there a different stands and things like that. But imagine what kind of industry is that. There are companies that are only related to these kind of customers working in that area, so all these companies, they had to stop hey, and of course they are not interested anymore, they have no money anymore, they could not, did not work further anymore on their initiatives to Industry 4.0. But again, Industry 4.0. is not ... some kind of projects, you can say it has delayed their implementations, the implementation. Is that now for half year, for one year for some companies, or even longer. But it has not stopped, the interest, and ... So the companies, they are still convinced about the value of Industry 4.0, about ... let's say, in a realistic way, because, you really have to be pragmatic about Industry 4.0 I think. Learn the small concepts to understand the benefits of, before investing about it. And that's how our customers are working with POCs, all these POCs have been delayed, but they are starting again. And we are trying now, to

penetrate much more in the healthcare sector, with everything related to data platform, combining the data and the apps, all kind of Apps, which have to be developed, but there we are focusing on... But ok, that's from a Delaware point of view.

For the rest it were interesting times for us, to understand also how Covid impacted all of our projects, not only the Industry 4.0 projects, but all our projects. And if you look into the utility sector, electricity, gaz, ... of course these people have never stopped working on Industry 4.0. They continued, we are working also on that sector, for example, we could not follow the development needs of all the Apps they needed. That's all I have to say.

PDB – What do you see for the future of Industry 4.0?

PM – The future? Industry 4.0 is a very general term, it is a very general term. The future of Industry 4.0 is trying to select within a company the right level of technology. That's one. The second is to be able to coop with the challenges of integration, within different systems, platforms, who have the data available, to make them available in one centrale place, and to use the different let's say.. The future for me, the future? Ok. There I think that companies have to understand how companies like per example Microsoft, Azure, or SAP with their "Leonardo" concept, how these companies are already in fact ready to help people out with some, ... to combine data, to try to find the value out of that data. That is the future of Industry 4.0. At the end, what is the purpose, to really be able to produce with a higher quality, to have less waste, to be able to give a better service to the customers, and a better product, more reliable product. And if you look at the companies who already, who are concentrating on Lean manufacturing in the past, elimination of waste and so on, all the things to optimize production processes, for these companies, there is still an advantage of Industry 4.0. However I must say, it is high hanging fruit, it is more difficult to find the right business case, or the right technology, in Industry 4.0. And you have to install Robovision, you know Robovision? It is about cameras you install on your production line, and you can identify bad quality, or predict, try to be proactive that you will not have that kind of bad quality. That is something, if you look at these investments, in Industry 4.0 technologies, that they have already worked in the past without Industry 4.0, to optimize their production processes and to have the lowest level of quality errors, hey the lowest level of waste, and then you have to invest 100 000 euros or even more to further optimize the two or three percent bad quality but at the end you have a return on investment of three or four years, that for a company is quite long, compared to other investments, where you can optimize your labor forces. I don't say that you have to withdraw people hey, but that you can optimize your labor forces, you are growing but with the same people, you buy another machine, a new machine, and the return on investment of this machine is for example less than one year hey. And if you have limited amount of money you choose to buy another machine hey, and not to work on "Industry 4.0 Robovision technology" to increase the quality.

PDB – You talked about the various sectors and how Covid impact them differently. To what extent do you think different type of organization are impact by Covid in the context of Industry 4.0?

FM – The difference to see is that the large organizations they started the first part of Industry 4.0 initiatives. When for example the smaller organization have still to work on stable platform. Like for example they still not have a stable ERP or they still have to upgrade their ERP systems, that's not Industry 4.0 but they still have to invest a lot of money in those objects. So I did not see the small companies suffering in their Industry 4.0 projects because they did not have a lot. They are interested hey, they are interested, but that is for them further away on the horizon.

PDB – And what that delayed because of Covid?

FM – No.

PDB – Is there some specificities about Industry 4.0 in Belgium?

FM – I think that the Belgium companies, the concept Industry 4.0 it comes more from, it originated from Germany. We have a lot of manufacturing companies that relate somewhat to Germany, a supplier, a costumers, ... there is a lot of relations. The strong Belgium companies, they worked really quite fast on Industry 4.0, I must say. And I think that ... But, the Flemish companies, they are doing it also in a pragmatic way, and it has to bring the value to them. That is something I always see in the Belgium companies, they take their time to invest and really spend their money in the best way.

PDB – I think I almost all that I need, let me see...

FM – Ok, I look at my notes... Ha yeah, what the impact could also be of Covid but, somewhat related to Industry 4.0 also, is the throughput time. If you look into what companies do produce, as let's say components in China, they import these components. You understand that the reactivity to be able to support problems, challenges in Belgium, you have to be very reactive. We have seen it hey with the masks, we had to wear, that it was rather

difficult, we did not have any production machines, we could not do it. Just as an example, we probably will have, and it was already coming on, reallocation of some production brands, offshore, back to, near shore, or local. I think that is accelerated by Covid, and this will also, of course, ja the impact of Industry 4.0 I don't know, but everything again as to be aligned and maybe there will be an increase in some production facilities here in Belgium again. But the reallocation was already going on. Keep in mind that, also in China, the costs of the raw materials are high. So the percentage of the labor cost is ... is you compare that percentage a higher percentage of cost salary cost here in Europe, it is compensate by the lower costs of transportation. There is a cost of transportation from China to here, and as the loons in China are also increasing, probably we will have some companies in the East I don't know, which probably can produce quite low prices. But there is definitely an effect of reallocation, because of the fast reactivity companies have to... You cannot be proactive you don't know at the moment, what kind of machine do we need, to produce what? What will we need on two or three years hey? And this years it was the machines to give air to the people, there was a shortage of these kind of machines. People had to look around. Then we have the relation with Industry 4.0 that we have to produce some kind of things very quickly and things like that, you fall back again on 3D, hey; 3D printing.

Ha ja, and the last point, related to Industry 4.0 is everything related to communication. You can say that Industry 4.0 project "Ok, everybody is working now remote", but as you know this has a very high impact on what we are doing here, Teams. And I think that, because we, and that's the last thing of Covid, that it is much easier to work now with customers, we can... we don't have to drive now in our car, so within five minutes I have another call, with another company, and they are used to it. Of course, I have seen these people before, but it is much easier to work together with them, on Industry 4.0 projects. In that way, because we accepted of these kind of communication tools, it is good that we can work faster, and definitely we can also... it is much more easier to combine people from different or the same industry sector, in the same, in one conference call, to align, to meet, to share ideas about Industry 4.0. It is very easy for us to have one meeting with 40 companies, talking about Industry 4.0.

PDB – In your own word, what do you think Industry 4.0 is, and what aspect of your definition is the most relevant regarding the Covid-19?

FM – For me, working on Industry 4.0, it is definitely not technology. It is about ... Again I would like to put people in front. Cause we are working with different people and the intelligence of the people. Having a certain call, and definitely also technology, because in a kind of way, the technologies you have, they can see the relations between different, between the data which is not possible for us to recognize. And third concept related to Industry 4.0 for me is bringing value. And then I would say, bringing value in different kinds of way. Value for the companies itself, because everybody wants to make money, is It about the reduction of the cost, providing additional models to the customers, that's also value for a customers, for the company. But it is also about value, for healthcare, value for us, the people, for community as a whole. And then I would ... Now for me Industry 4.0 at the end, it's about bringing value to everybody, I would call it like that.

APPENDIX 5: Interview 4 – Johan Van der Straeten

Pierrick De Bock: PDB

Johan Van der Straeten: JVDS

JVDS – Ok, so let me also briefly introduce myself and see if I can provide my perspectives on yours thesis questions. So my name is Johan and I'm currently working, it has been eight years for PwC. Before that I worked in industry myself at Phillips for seven years, and I'm an engineer, a mechanical engineer by background and in PwC Belgium, I'm responsible for our manufacturing practice, which is basically a group of 35 people that do management consulting projects in industries. And of course Industry 4.0 or digital operations as we refer to it. That is a hot topic, and it has increased significantly in the past years, past year even, despite the pandemic, and let's say the challenges that are imposed by it, especially when you are in management consulting and are not allowed to enter manufacturing sites. So yeah, we can cover that more in depth and details, but I think for the past five years I have been involved in Industry 4.0 in Belgium. I also conducted studies together with “FlandersMAKE”. I don't know if you will speak to them, but that's a Research Institute, regarding Industry 4.0 in the Flemish part of Belgium, of course, and that maybe also can provide a bit of the expected, more technically speaking.

PDB – Ok, great thanks. So should I ask you the question I sent you, and maybe a few more?

JVDS – Yeah, we can start with those and if you have follow up questions or if you want to elaborate a bit more, just interrupt me because I have put the list in front of me, the different questions.

PDB - Ok, great. So first, I would like to ask you how you define, with your own words, Industry 4.0.

JVDS - Ok, yeah, for me industry 4.0 is ... the way industrial companies embrace the opportunities provided by new technologies and new technologies can be really new technologies, and people refers to AI Artificial Intelligence, ... But for me it's a lot more on, sometimes less new technologies but how they are adopted to really transform the company into a digitally enabled company, and especially in manufacturing. There is a lot of history and not every manufacturing site is already top notch and using technology of the last 10 to 20 years. So for me, Industry 4.0 is really the transition from the old way of working to the new way of working and all of that enabled by new technologies. And I think the new technologies part is of course the big accelerator because now a lot more is possible at lower costs with bigger impact, but at the end of the day you can still achieve a lot, also sometimes with more standardized technology. That's a bit my personal opinion.

PDB – Ok, great. To what extent is industry 4.0 a solution to the issue raised by the crisis in your opinion?

JVDS – Yeah, I think when you in ask the question you also have to say and you have to make explicit what are now the issues raised by the crisis is. From my perspective there are some, yeah, concrete issues that have popped up or have become a lot more visible due to the pandemic and I think you can categorize them in two different categories. On the one hand, there is the whole supply chain disruption. A lot of companies have seen the last year that kind of disruption in their supply chain and they were dependent on certain suppliers in another country where there were restrictions where there was not the output expected and that whole effect ripple down to the supply chain and costs companies to not being able to fulfil customer needs. And it is a bit like avalanche, it starts small and then that supplies pops, but then everything starts to... the whole system, how it is said that, is becoming very vulnerable and from that perspective, that is a new ... that is an issue that has become more expected. So lot of companies today are looking into how can we be more or how can we reduce our dependencies on other companies. And that's why it's a dual sourcing or internal manufacturing, and so on. So I think that is the first part of the first category.

The second category is, and that is more human oriented, because people have to work from home and there are restrictions that have come to the side, companies have also realized that they are not ready yet works remotely. And I think that ... , for instance, having an expert on your manufacturing site that has to fly in is no longer an option. So a lot of companies realized: “Ok, how should we deal with this in the future?” Those for me are two specific issues.

An the second part of your question, to what extent is Industry 4.0 a solution? Well, I think there we have to see Industry 4.0 is not only a solution to the issues raised by the crisis. I think what Industry 4.0 offers, it's a lot of technologies, so all technologies that for instance, solve issues on remote working. And think about the rise of of Zoom. You cannot, in order the rise of all these hangout meetings, and I am just giving a personal experience: before the pandemic, you had to write to whatever clients wherever to have a meeting of one hour to get introduced.

That is no longer required. Companies have accepted that you can have a zoom meeting or whatever to get to know each other, and I hope it will stay the same, but it goes a lot further.

It also when for instance you are, you can speak about the remote assistance. So today if I am an expert in a certain machine and I need to provide specific maintenance, I have to fly in the expert that typically has a lead time, high cost. That person executes the job, has to fly back, ... When there is a lot of technologies available then it's very simple. If you put on the smart glasses that has real time video, you add Augmented Reality and you demonstrate as an expert from wherever you are in the world, you demonstrate how you have to do, conduct the maintenance and somebody that is actually on the ground has to execute alone. So these are Industry 4.0 tools, technologies that are available and that I also see arrive in there, in their revenue and then in the way they are growing. It's about software that support execution of procedures. It's about software that supports collaboration, working together on documents, chat function and so on, I think, and that's what I don't call Industry 4.0. In the normal definition, for instance, collaborating, chat function on the document is not Industry 4.0, this industry 3.0 technology and from Microsoft Teams. But for industrial companies, even that step still has to be made and what our clients sometimes say that they are still in industry 2.0 and when we come with our story of Industry 4.0 they say they're first goal to industry 3.0. And to avoid that discussion, we would rather use that terminology digital operations, because then you... yeah, it doesn't make that value to talk about 3.0, 4.0. And you probably, when you speak to other people there is a more dogmatic definition of Industry 4.0. And so yeah, okay, I'm a bit more pragmatic. I'll leave it up to you to see how you want to incorporate this thing in the ...

And the second part is the supply chain. That's all the second category or issues raised by the pandemic, getting there it is, again, a bit of a very high level problem. Why did we shift certain manufacturing capabilities to other countries? It is cost driven and it is because we have accepted that you get a lower cost. We take the lead times or six weeks that coming from China, for instance, that's acceptable, it is high volume. If you have a certain flow that is all acceptable, but what happens if suddenly there is a hiccup in that whole system? The costs are... the lower costs are totally covered by the additional expenses you have to make to get it on time. So from that moment onwards, the whole industrial world has to review a bit their balance. On the one hand, you have the raising wages in the low cost countries. Not only China, it can also be eastern Europe. But it also is how can I then, "What should I do?" and "Can I manufactured in Belgium?". To take an example, first answer is always "No, that is a lot more expensive." and that is correct, but at a certain moment you also have to question yourself with what are the advantage, that is the very shortly time or there could be a very shortly time, you have to make... you have more freedom of design and you can set up co-creation, so the development lead time can reduce, that's why lot of companies have their R&D center in Belgium, we have access to a lot of talent. But you also have to, it is more strategic decision to say "If I have my manufacturing close to my R&D, and I also have a lot faster development times" because people can try out something, see it in introduction, the feedback of those processes is being put in my new design. All of that also has a speed effect, and I think that's where, also industry 4.0 technologies come into play. Then you talk about modelling techniques, Digital twins, we will probably hear off, all these kind of things that enable simulations, will support the new setup of your supply chain. Another example would be 3D printing I have been... Ok, I have been a fan of 3D printing in the last five years, but I stopped being a fan because it could not deliver on that promise, but from a distance, 3D printing can offer, on demand, product that you need in the quantity that you need, so there is no more need for inventories. It is a correct statement, but in practice, what you see is that a lot of companies, they did not design their parts for 3D printing. They designed for conventional manufacturing and as a consequence the cost of 3D printing are far too high. But that's a bit... Yeah, it's a bit of a ... you really have to restart the way you design, and if you do it good or in a good way from the start, you will catch all the benefits. If you just start 3D printing in the existing world, yeah, that is more expensive and it doesn't make sense, and I think this mindset shift is still not happening. And a good example is spare parts, especially in the spare parts business. People say "Yes, 3D printing". And yes, there is a lot of potential if you start 3D printing, but a lot of these parts were not designed for 3D printing, so you first have to redesign and to go through that journey ... Yeah also cost money and this case is lost because it was not designed for them.

So it is a world in movement, a dynamic world. I hope that the pandemic has at least the positive effect that all of these things will accelerate. And on the one hand they do hey, so we see ... I will not give you numbers but as a management consulting firm we had the best year ever, and it's a lot of that Industry 4.0. Looking at the whole set above the supply chain so companies are really looking into it and I hope that they also can benefit from it after the pandemic.

That was a long answer to your first question. I hope that I will not answer each questions that late.

PDB – It's not an issue for me. For the second question, you already give some elements of answer, but so if you could just repeat quickly or just summarize what you said. To what extent have the reasons why organization want to implement Industry 4.0 changed with the Covid-19?

JVDS – I think at the end of the day, for me it's all about being future-proof. We live in a world that is so dynamic that the competition will change. 50 years ago, if you had a good product and you had mass production, nobody, not a lot of companies could compete with you. You were established. Today, with this customized perspective, you are not no longer a mass product but the customized product, a little smaller companies can tackle your niche, can develop something that is tailored to all of your different customers. So if you want to stay relevant, you have to also become flexible and then, and that is something that you will see back also in the studies, is that, typically they say: "One piece batch", I don't know if you have heard about that, but that is production volume is one piece, it is tailored to the needs of the customer. It is like for cars, just to give you an example if you order for instance an Audi today, the lead times have gone up to nine months because it has always been the case because all the options that you can select. It is really your car that is produced. It's a combination of all the different options that you have chosen, and because they have already a kind of lead time issue, that's why you have to wait so long for personalized car. You can imagine the same concept in different industrial companies, not car, not whatever products can be, B2B or B2C, and these kind of things will pop up. So companies if they want to be future-proof they have to reflect on how they can play in this world that is so more dynamic, required so much more flexibility. And Covid-19 has, ja, I don't think it has increased that part, but it has...I guess ... I am just thinking out loud while I'm speaking...

PDB – Don't worry, no problem.

JVDS – What happened during Covid-19 is that people have more and more even adopt the order online. The "Amazon.com", "Booking", ... That's consumers behaviors. We also in distance you see that more and more. "I ordered today it want it tomorrow.", and of course it's about different orders of magnitude, different amounts, different products. But this consumer behavior, "If I can do it like that in my own life, why can I not do it in my in my job, in my profession?". I think that's something that a lot of companies says now. It's a people component, it's even the same if you are, if you are working for another company, and you use your smartphone today for banking, for whatever, ... and you enter your factory, and the first thing you need to do is take pen and paper to write down certain inputs and to send it to another person. What would you feel? How would you look at that? It's not really attractive and that is something that I think company started realizing, in this job market where there is a lot of pressure on attracting talent and not finding it. "How can I be attractive also for future generations?". I am from a generation that still knows a life without a smartphone, and I'm not even that old, I am 37 years old. But if you now graduate, you cannot imagine a life without smart phones, always having access to all information that you want. That is, that is really different, but there is still a generation that is even older than me and that is 50 years old, and how can you help them to embrace new technologies? I think that that's a bit the people component cannot be underestimated.

PDB – To what extent have the traditional barriers of the implementation of industry 4.0 been affected by the Covid-19?

JVDS – So I think, if you look at the traditional barriers, the top three is: the lack of a digital knowledge and digital vision; number two is the budget, not only financially but also resources and number three is the lack of an adoption by people because you can invest a lot, you can have the best technology, if people don't use, it does not make sense. If you look at those barriers, I think the first one, the digital vision, more and more companies are developing a more future oriented strategy or pattern, and are looking how can they refund their operations. So it has been affected in the past year. The budget, on the contrary, the second one, of course they are under pressure hey. There are a lot of companies they stated a bit of slowdown in revenue, although it is not as bad as it was anticipated last year. At the start of pandemic, everybody was panicking. I think quarter two of last year was really "Oh my God, we will never meet our numbers." and if you look also in the recent press, I saw it today, in the job market, everybody is again on track or to the levels of before the pandemic. Only the Horeca is lagging there but ok, that is understandable. And there was one other sectors also. It is, I think the budgets are... they were negatively impacted, but now they are finally opened up again. And then the last part, adoption. It's all about showing the impact, and with Covid-19 a lot of companies were not able to visit the factories or to support factory because you cannot do that alone. I think it is, it is difficult to change that you cannot spent the time that is required on the shopfloor or within factory. So from that element Covid-19 and installation of remote working does not make it either.

PDB – To what extent did the Covid-19 pandemic had an impact on implementation of industry 4.0, you already touched upon that also, do you have anything else to add on that point?

JVDS – No, no, I think it's the summarize that implementing Industry 4.0 is a technology and technology element and I think that that is the same, but it's the people element that has changed the level of involvement, the support, the change element, those have actually accelerate.

PDB – So did the number of project on industry 4.0 increased? You said yes. Can you say a bit more about that?

JVDS – It depends on how you... what our Industry 4.0 project, what is the scope of those projects. I think what has increased a lot is strategic part of that. The strategic reflection on “What should we now actually do to prepare or to be there to be future-proof?” So those projects have really accelerated. The number of implementations, they are at the same level, they did not drop that because also the running projects just continued. But the real implementations have not increased yet, but of course it is just a matter of timing cause a lot more companies now have a strategy so they also want to implement that strategy and then you have implementations. So I think it is from a timing perspective, more and more companies are developing their strategy, so those industry 4.0 projects have increased.

PDB – Ok, great, so what may be the consequences of an acceleration in implementations, of for industry 4.0 overall?

JVDS – Well, I think, I think this is a bit of a continuous cycle that reinforces itself. And because more and more companies are looking into it, there will be more and more solutions developed. There are very good and fit for the purpose because there are more solutions available, more companies will adopt it. Because more companies will adopted those solutions will also have a bigger market and will become cheaper and even more companies will accept it. So I really think it has a positive consequences because all of this, It's a kind of, I don't know how to say it in English, but “cold water fear”. A lot of companies have ambition, but they don't want to be the first because yeah, let's the other one, yeah challenged the child diseases and tackle it. And then when it's all ok then, then we will adopt it.

Well, I think all this whole process will accelerate. And then as companies look into it, they see what is already out there, they start using it. They can also, exchange in and between another and that's that I think, and that's all to do with the pandemics, that is more how industry has to evolve. That is the setup of ecosystems and therefore you have organizations like “FlandersMake”, you have “Agoria”, that try to bring together different perspectives, different best practices, also PwC, but then more in commercial models, of course what we do is, give examples of what other industries do to inspire our clients and in this way you can bring the whole industry, to a bigger, to a higher level. But therefore you need to open up. You need to be able or willing to accept external external, I mean externals examples, because that's something that you might learn if you if you move into let's say in a kind of consulting track to industrial companies. Everybody says “We are unique”, “We have challenges nobody can solve because we are unique.”. So It may be disappointing but nobody is unique. There are some elements in our very specific but 80,90% of the challenges, have been faced by somebody else already before and they have even found a solution. So it is really a mindset shift again. That you need to open up, explore a bit for what is out there already and then apply it to your specific environment. And that I see as one of the critical success factors going forward, regardless of Industry 4.0 because it can go a lot further that only the technology part.

PDB – Ok, great. What type of organizations or what are the characteristics of the organizations that have been the most impacted regarding the acceleration of industry 4.0?

JVDS – Yeah, that's a good question, and I don't think I have an immediate answer for that. What kind of direction are you looking for? Because characteristics of a company...

PDB – Yes, actually it's on purpose that the question is quite large so that I let people answer however they want. But the idea that I already got was a comparing the large and smaller organizations or more related to the fact that the company which had already good basis and a lot of connectivity inside where less impacted and so on.

JVDS – Yeah, and that is the size of the company. There's a digital maturity you can call it. But that is only, let's say my personal opinion and what I think, the “should have”, and there is the actual reality. I believe that smaller companies can really benefit the most. But the reality tells us, smaller companies, it is not their priority to adopt Industry 4.0 there. It is typically bigger investment, and it's really kind of strategic part who take that big part of your investment, go to new technologies and digitalization. But I think they really they should be most impacted. What we do see is that larger companies they activated bigger projects, they can also benefit of course hey. But if you look at the Belgian landscape of the industry companies, we are at KMO country. We are a new country, and yeah only is a smaller portion is benefiting from it.

I was thinking if I could add some kind of sector view. So if for example is construction benefiting more than just your products or chemicals. But that is that is quite.. I don't see that as a differentiator. I cannot really answer that,

from my view, every company that wants to move, every company can benefit from Industry 4.0, not to the same degree, because also maybe that's another angle and can maybe a bit deferring to your first question and "What is Industry 4.0?" and I think we also have to explain that there are different levels that a company can benefit from Industry 4.0. And a lot of times that is, it is only looked at as optimizing your internal processes and so how can you produce better, faster, cheaper, the same product as you produce today? And yeah, there are two other components which I think are as important and even more important. The second component is: what type of projects do you produce? There you enter the connected product definition instead of just a one-off machine or product. You have sensors that generate data, with the data, you can deliver other services. In a typical example, is maintenance. So in the past that was..., you acquire a machine, that's the product. So from now on it's a machine with a maintenance contract. And you don't need to do anything else, we will track the data. It is all online in the cloud. We can see from a distance that if something going wrong, and maybe there are specific agreements that the maintenance is done by company. So from a pure machine manufacturer, you are moving into a machine manufacturer with services.

And that is that is a third component added that this model. Because also the pricing then of the machine can change. Instead of having one of his best like if you would, if you would buy a car, it's a large investment for you as a person. But if I can pay, if I can open and I can enter a lease model where instead of having to throw all the money on the table in one, I just ask you for a monthly fee and that monthly fee covers insurance, maintenance, that's the lease model of cars. Yeah, I can better plan my expenses. And therefore maybe the whole model that I have created as a supplier becomes different. You can do car share, this kind of stuff. You can leave it yourself or with different people, you'll use it together. And this business model element, of course it is not the same, we are not talking about cars here, but all these principles are new is our new ways of thinking and this is the really the futuristic elements of Industry 4.0 where a lot of new things become possible.

Another example would be if you have a lot of companies that have an over capacity. If you if you buy an expensive printer, and you can only load it for 10% of the time. What would people have done in the past year? They totally would not have invested in the printer, or they would just only have use 10%. Today with all technologies Industry 4.0 who can start loading the machine with not your own products but with other people's, other companies products. And then you become a manufacturer only based on that one machine that you provide. These are just examples, to make it a bit more practical, but this kind of thinking, and this is "What can I do differently than I did in the past?", there we see still a lot of education, sometimes also discussion, to see when it's really feasible and what stays in that idea. And time will tell, but I think those components are typically not at this. If you speak to a technology player an Industry 4.0 because they just say we have to use my technology as an industrial company. I think you can gain a lot more by looking at the full picture, and that's where this strategic exercises or "What should I do?", "Which direction should I go?", "How can I make a difference?" are really important.

PDB – So yes, I only have one question left. What do you see for the future of the Industry 4.0? Which again you partly answered already.

JVDS – Well, I see, I hope I see a promising future. I think it's only the path we actually follow and there are technologies that are becoming more and more valuable and also mature enough to be used at scale. I think of Internet of Things, I think of Artificial Intelligence. And all of them can be blocked in, let's say a certain maturity curve it, but the examples are there and once you have examples, people will start believing into the story and are more and more opening up to apply. And I think that is that is always require. I have been doing this for the last six years or so. I can tell you that the first year I was trying to convince people off the head of the impact. It was a hard time. And that was the end, is "Yeah I like what you're saying it only makes sense, but not now." I have seen in the past five years, six years that that has changed. There are still people to be convinced, but the portion is reduced and more and more people are buying into the story and are starting to apply it. And of course steps by steps, nothing goes immediately. But I think... yeah, that is what I see for Industry 4.0. That takes some time with a slower adoption curve. I think the pandemic has accelerated, the typical journey that we go through, if you have this kind of industrial revolution. But I see that if it continues on this page, in the next five years, lots will change. That's my personal belief.

APPENDIX 6: Interview 5 – Jochen Vincke

Pierrick De Bock: PDB

Jochen Vincke: JV

PDB – First, can you present yourself in a few words, as well as your experience with Industry 4.0?

JV – Yeah, so I'm sorry I just realized my video is down. Uhm, so I'm Jochen, partner at PwC, with my specific area of interest being manufacturing. I'm also a member of the Board of “FlandersMAKE”, which is an investment vehicle from the government to enable research in industrialization, so digitization and manufacturing where there's always a kind of a collaboration between either different companies and academics, or within just the companies that are trying to innovate in manufacturing. In my role, I think I started as a consultant in 2005, in manufacturing, most of the time and the last 8-9 years we saw a trend coming which was about what we call Industry 4.0, which is about, uhm, taking a next step in applying new technologies within a manufacturing environment. Uhm, so in that sense we invested quite heavily in the first, so if you would say eight to four years ago, we invested a lot in getting to know new technologies like 3D printing, getting to know the companies that are doing Additive Manufacturing, working with tablets for work instructions in manufacturing, trying to see what is truth and reality in terms of artificial intelligence, Machine Learning, what can it really do, and so on. How can it help? So we experimented a lot, especially with startups, startup technology companies as well, like Robo Vision, which was one of the winners of the company of the year award, and so on. So we tried to scan the market a lot, I would say eight to five years ago. We learned a lot, we have a lot of use cases there that we looked at to “What can this particular piece of technology mean for a manufacturing company?”. But we saw that there was a shift in mindset somewhere around five to four years ago, where some of the industries were taking a leap, ahead of other industries trying to invest more in digitization and the new technologies to improve their performance and to gain a competitive advantage across uhm versus peers. We mainly saw this in chemical industry, where there's a where they are ahead of other industries. Typically large assets, with also the funding and the typical profiles you would expect to be interested in new technology. A lot of engineers, and so. ...

PDB – Sorry I cannot hear you anymore. Yeah, ok.

JV – ... so they invested a lot and it's different than what we did before, they invested in larger programs. Starting with the digital vision: “Hey, where do we want to go?”, “What do we want to realize?” and more safely at work. We don't want any uhm workers anymore doing inspections on their own in a confined space for example. Uhm, or we want to improve the yields and productivities by using new data, analytics and so on and so they they really started more from a vision and then plug that into a road map which would transform their entire organization. Also having sufficient attention to the impact on the workers. So how can we get people to be, let's say upskilled, what is the impact that it will have on our workers? And then that happened five four years to go till two years ago.

Let's say a year and a half ago and... Then we saw the willingness to try and ... you still there?

PDB – Yes, ok, you are just back now.

JV – (talking about the last year and a half) Yeah, so the the number of technologies, the number of companies that ask questions to us to to help them out really exploded. The willingness to try new technology, also all of a sudden, it was very high. And, uh, I think Johan probably told you about... The remote assistance with smart glasses that you can actually be on sites following someone else who is wearing a smart glasses that you can talk to free screen share screens and so on. So that's really popular because there's basically no other means to get into a factory in Asia. New people being hired had no opportunity whatsoever to see new factories. So all of these technologies were very easily adopted. And, for example, there's a company that is supplying this this kind of remote surface software. It's called “Help Lightning”. It's an American company. Their revenues in the first quarter of last year, it had already tripled. And it only exploded even more. Also, if we look at the providers of smart glasses and so on, they can hardly keep up with demands, and so it's really, we really see an acceleration in certain specific technologies.

So a very long answer to an introduction.

PDB – It's ok, you already answered some part of the other questions. With you own words, how do you define Industry 4.0?

JV – Well, for me, Industry 4.0 is a is a container, ... How do you call it? “Container begrijp”, it is something which covers a lot of loads I would think, and for me it's the summary of all new technologies that can be applied

in an industrial environment. Which is a step further than automating. So in the seventies, eighties, nineties you had a lot of automation that we already had because of computer power because of the sheer cost element that dropped quite significantly. A lot of these new technologies has become far more accessible and the advances in machine learning, for example what RoboVision does, for quality control or with vision, using vision for quality control that wasn't possible 20 years ago. So all of these things, tablets that are there, is just making use of new technologies to the best of your possibility in a manufacturing environment.

PDB – So to what extent do you think that uh, Industry 4.0 is a solution to the issues that have been raised with the Covid-19?

JV – It's not the only solution, hey. It covers part of the issues. The parts where you can no longer travel where you need, in the past people, a lot of companies are still heavily relying on expert knowledge from certain expert profiles which of course, are linked to a certain person, and this person lives in a certain geography and ... These are typical roles that that were shipped around the world over time and they may go from one issue to the other where the the fire is burning the most. There they go and then that process knowledge is something where I think Industry 4.0 can play a big role. It's in capturing knowledge of people, putting that into work instructions, uhm, proving their knowledge with mathematical models, trying to capture really how they dissect problems and put that in into a logical decision tree which you can put into a tablet again and share with others. So capturing knowledge of persons into a kind of you could even say it's a digital tool of a person. That you can almost use them instead of having the person there. That's one element that I think Industry 4.0 will have an impact.

The second one is the travel restrictions and it's a very short term one, travel restrictions can be solved by technology for a part and not entirely, but at least for a part it helps. And although it's simple, but all the video conferencing and so on, we used to have a lot of issues getting people to connect, especially people which are more used to being in a factory, than behind a PC, but all those issues are gone now. Every meeting starts on time, everyone knows how a mic works and the collaboration virtually has improved exponentially, I would say. If you look at how teams are now working virtually together, I think those elements can be solved.

What cannot be solved by Industry 4.0, not entirely is the fact that our, especially in certain industries or supply chains, are becoming too long and so especially in in high tech and in assembly environments, we see that if you have global supply chains, they're very, uhm, sensitive to disruption. And that part you can, you can manage it better with technologies by tracking and tracing solutions and and those kind of elements, and putting in buffers and with your supply and so on. It will help a little bit, but as long as you stay with global supply chains you will always have a higher sensitivity to disruption. I think there's a... There's an evolution coming where we're moving more towards what I would call "local for local", that you, uhm, make sure that the critical elements are closer by, and that you have more like no longer anorexia, they called, from lead to anorexia in the past, so you don't have the interactions, but your buffer around your company, and I think that business model "local for local" production is going to solve some of the issues that we faced with Covid-19.

There's a very interesting one that you can use in in your research. It's called the floating farm. I don't know if you heard about it. The floating farm is a is a dairy factory. It's basically a boat with cows on in the harbor of Rotterdam and what they do is. It's local for local production, so they have cows on the boats and the boat itself is a factory to get the milk, process the milk and also to make cheese and yogurt. So what they do is they have the production there on the boat in the Harbor of Rotterdam, and then the products are are being sold there or delivered with electric, small electric vehicles into the city center. That's one example. Another example that I know of is that Oatley, I don't know if you heard about the Oatley?

PDB – Yes, I know about it.

JV – Oatley is building a factory in the middle of Singapore in a high story building. So in a flat instead of having a factory which you would typically have in an industrial area and Singapore is limited in space, so they said "Ok, our market is there. Let's build a factory within a normal building", and I think you will see more and more of this coming. So how can we produce locally in an urbanized environment? So you don't need to rely on a global supply chain.

PDB – Just to be sure, so you said that teams, the use of Teams, is something that is impacted. Do you think that Teams and the chat function and everything are part of Industry 4.0?

JV – For me it is part of Industry 4.0 because it's a mean to connect people which was not possible before. Now is it? Is it really advanced technology? You could you could discuss. Yeah, but the fact that it has not been used as extensively as as it is being used now is for me, part of the solution on becoming better performing teams, virtual

teams then. So it is for me part of the container. When you try to use technology to the better, so it's not all about the fancy drones and Additive Manufacturing and putting everything in a Blockchain and so on.

PDB – Ok, great uhm. So actually, what is the most interesting technology or characteristic of Industry 4.0 regarding the Covid-19?

JV – There's there's some. Can I mention three? For me there are, there are three.

PDB – Yeah, as much as you want.

JV – There's a... Let's start with the easiest one. The easiest one for me is everything which will impact supply chain is track and tracing technology, and so putting sensors and and GPS location on any package by use of microcontrollers and sensors and so on. They will always become, the batteries will become more strong, the type of, uhm, sensors will become better so that the cost will go down. So that is something that will stay forever and you're really going to go towards really package by package tracking on the package itself. Uhm, or on your delivery on your palate or on your car.... So that is something that is used to to stay and it's really going to alter the way we manage logistics, so that's one which is very important.

The second one I would say is everything that, uhm, helps operators, workers in a factory everything what we would call and I think Johan will have talked to you about the connected worker? Everything that connects a worker to the right information at the right time at the right place. Meaning, for example, that a worker in the past when you when you joined a company and you started working for example in a dairy factory. You would typically follow a more experienced person and you would follow him for six months, and while you were doing that, you would learn the job. What you see now is that some companies have, as a KPI, the number of days or the number of hours that the person needs in terms of training, because before he's fully deployable and Bombadil, for example, the train builder has that as a KPI. And if you look at the benefit of logging a lot of the work instructions and a way of working into for example tablets that feed you one by one, the steps to take even depending on the level of experience that you have, you can have a more detailed one or a more high level, uhm, or smart glasses that do the same, uhm, that really will make a difference for an operator. So an operator job will change a lot. It's no longer relying on his own knowledge, but it's receiving information and getting advice also from tablets and so on, on how to interact. And following that advice and then constantly upgrading from the way of working. That is what I see for an operator is going to change.

And then the third thing that is having a big impact. But in selective cases, not everywhere, is come the new, well, the impact that Machine Learning and new data analytics tools can bring. Especially if you look at and then I'm looking mainly at chemicals at the yield and productivity increases, and then we're talking about energy consumption that will go down quite a bit and just process efficiency will change a lot by following the right parameters. And having that trend detection done by a computer instead of a person will allow you to far better find your, your process, and it's the combination of computer power and in-line measurement of certain parameters that will help us manage processes better. And it will lead to higher outputs and embedded yields and lower energy consumption. So that is the third one I would highlight.

PDB - Ok, and so in the context of the crisis?

JV – In the context of the crisis. The crisis will go away. So in that sense, in the context of the crisis, what is the most important one? More simple technologies like the remote assistance so you can you see what I see not being there physically. I think the collaboration tools, to allow virtual teams to work together and then come, I think IoT, so having sensors put in place and then being able to track them from location, I can I can even show you some that we implement ourselves. You spent half the day implementing sensors and you have the full view on the performance of a certain, uhm production line. I'll just show you just to show you how easy that goes. That is really changed. In the past we had a lot of issues. We had to build uhm, 15 years ago, we had to build paper versions. Then we started using access databases to do those kind of elements. In the meantime you just put in... host disabled, I cannot share my screen apparently. You disabled host disabled participant screen sharing.

PDB – I should be able to allow you.

JV – Ok, well it's not that important. It's just that that has a big influence. If you can see production. But basically it's just you implement sensors at the right place on a production line and with the right application you're able to see all of the stops, the speed, the things that happened. Within half a day it is all set up. And that is a huge difference from before that you can have these insights even. Ok ok, good. So that is that is also in the latest Covid an important one.

PDB – Ok, great. To what extent do you think that the reasons for companies to implement industry 4.0 has changed with the Covid-19?

JV – There's a, I think Covid-19 has highlighted the need for higher transparency of operations. Because of the disruption, not only in your own, uhm, network of factories but also in the suppliers network and the suppliers' suppliers. That is, that is a huge impact that even this week I think the BMW factory in Germany is on is on hold because there are no more chips available to put in the in the cars and for seeing that happening is something which is which has been proven to be very difficult. We... I cannot tell you how many discussions I had with clients which were all in the automotive chain and, the automotive chain is not just purely cars. Are the automotive chain is really chemicals. If you look at the components that go into a car, there's of course steel and aluminum and so on. But if you go to the other, how do you call it, the plastic parts. That whole chain goes all the way down to the refineries. And there's glass fiber in there, there's polymers in there, there's resins that we need to make, and then people really lost their. So what happened with Covid is that people had to socially distance. And in an assembly environment like a car environment was difficult to do at the start, so the company stopped producing. Everyone was at home. But the, the effect of that in supply chain, something called the bullwhip effect. I guess you probably saw that, that effect came through the chain late, and also in an amplified way. So what happened is that all of a sudden people are still producing down the chain. All of a sudden it stopped because in the front they were no longer producing and they didn't know. Ok, so they stopped everything. And the difficulty was, for example I work for a glass fiber company that that makes glass fiber that goes into components for cars. But they have big furnaces. So you have a furnace of glass. You cannot just stop that and need to keep that going because otherwise your furnace collapses so they didn't know how many furnaces do we keep. Do you keep them all? Do we need them all or just a few of them? Can we use this video to do some big maintenance that we've seen yes or no, and everyone is a bit lost. In the end, the company I had in mind stopped quite a bit of their furnaces and did a major maintenance overall on some of the furnaces and all of a sudden, the demand picked again. Because the companies launched again and they had to catch up to cover for all the empty stocks in the chain and they were really lost so they could not deliver the volumes that were asked by their clients anymore, but their customers anymore. So that bullwhip effect has had a huge effect on full view you could say the full chain, and I think transparency in that chain has become a priority for a lot of companies, and you can get that transparency by new technology, by track and tracing using IoT, and so on. I think that is something which a lot of companies realized.

And then the second thing because of Covid is again the fact that, and that's a very short term thing, that you couldn't travel and so on. Brings us back to the all the remote assistance technology, those kind of things.

PDB – Ok, and on the other side then. To what extent do you think the barriers to implement Industry 4.0 have being affected by the Covid-19?

JV – Uh, the barriers have been lifted extensively because people had to...First of all, a lot of the... this might sound strange. When Covid hits, the companies had to shut down. A lot of management teams were in crisis mode. Trying to coop with that. And then they were all there, and then this is going to be controversial. But all of management was at home, all of the project engineers were at home, only the workers were allowed in the factories. All of a sudden these guys need to think what the hell do we do now? So we saw an increase in trainings so people want to get trained more and which you can do virtually. We saw an increase for remote assistance technology and the fact that this management layer, all of a sudden had a bit more time, made them think. Also I reflect on how are we going to manage our factories, our operations. And it's led them a lot to using new technology and the fear of using technology at the same time has been taking away because, has been taken away because the necessity to use it. So there's a double effect there that there was time and a necessity to look at new technologies. And on the other hand people had to use it, which took away the fear not to use it. And the two together have really made technology, uhm, booming last year and not the first half a year, but after that it is really jumping.

PDB – Ok, uhm, did the number of Industry 4.0 project increased?

JV – Yes, but that was already the case before. So, we track, in our team we track the type of projects we do in the revenue we get from them. We have what we call traditional, uhm, manufacturing work which is about improving OEE so efficiencies and so on, turn around and so on, so really go for savings in a manufacturing environment and then we had a portion of our revenue which was linked to Industry 4.0, and this could be doing pilot projects with a new type of technology and draw a vision system additive manufacturing a new analytics project and so on, uhm, and we saw gradually that the part from Industry 4.0 was already increasing last four, thee, two one years. That was already taking a bigger chunk. What you see now is that it has almost become 50-50. And we've hit the spot where the normal old fashioned traditional projects actually, already integrate the Industry 4.0 part, so we've hit a point where you say it's no longer different to do the traditional stuff versus the Industry 4.0 stuff. And it's all

merging into the new way of working. I think that's also because of Covid. It's now far more accepted to work with new technologies and to test it to try things than before.

PDB – Yes, what do you think are the consequences of that acceleration? Or can be the consequences of that acceleration?

JV – It's difficult to say at this point, but I think it will distance the winners from the laggards more, so people that have been investing in new technology that allows them to work at higher productivities or allows them to differentiate their product more to the needs of a specific customer. They will take more distance from the companies that have not done that. If you didn't take the opportunity now to invest, I think it will be running behind and you'll lose market share as a company, so there's a... I think people are now moving into investing in new technology out of fear of lagging behind rather than they wish to be running in front. And that's different, if you have a wish to be running in front, there's typically less companies that have that explicit tuition. Also, that explicit funding to do so. If your fear is to be left behind, you typically have a lot of extra companies that are trying to invest in technology to keep up with the with the leaders of the pack. I think that is going to be different.

PDB – Ok, and so to what extent do you think there was an acceleration of projects? But in the sense of the project being demanded to go faster?

JV – I don't think that has been the case. That's not what we saw and when Covid hits, we went through a couple of phases and first phase was to help us get through the crisis and that is something we got and that meant doing savings programs. So trying to limit the spending, see where there was still some money to save so that we could make sure that our clients get through the crisis with the least damage possible. That was the first period of projects we had and then after that, I think somewhere after last summer and September, October last last time we typically had projects where we supported vaccine distribution and so on for manufacturing vaccines. So life sciences has done really great. But also companies started looking forward to the same story told earlier that companies have time and they wanted to see how they can improve. So they started looking at what new things you want to implement. But the timeline has never been the major push there, so I cannot recall us having a discussion with the client saying, you know we had this project foreseen. We want to do it in half of the time. That is not something that we had.

PDB – So yes, ok. What type of organizations or what are the characteristics of organizations that have been or should have been the most impacted by the Covid-19, in relation with the Industry 4.0?

JV – Uhm, but the first impact of course, everywhere where we had a lot of people together in the same room were heavily impacted because that could not be done. So there we see that it's very depending on the on the industry. So we saw a retail was actually quite booming because everyone started buying everything and there's instead of going to a restaurant we went to the shop. And what I what we do see is that it did not really reflect in the profitability, so the revenue went up of retail. But the profitability, not necessarily. So there's something to think of. The life sciences really boomed. Of course, I mean the big pharma companies, really, uhm had a lot of extra work, a lot of extra projects, a lot to do. Of course, that we're helping delivering and producing Pfizer vaccines like Belgium and US as well, so there's a lot, uhm, that didn't sit very well and then you had a bit of the what you could call industrial manufacturing or discrete manufacturing and assembly and another type of projects where it is really depending on how close people were to each other in the factory to see how much uhm, people had to, or how long these companies had to stop. Not having people in the factory. That is definitely, what we did see that everything to has to do with home improvement, I don't know if you know Unilin as a company? It's part of the Mohawk group. They make carpet and and vinyl floor, for flooring and so one, flooring solutions I should say. They just boomed as of the summer, so everyone started doing home improvements and the fact that they lost capacity because of the closures and then all of a sudden, had everyone looking to renovate their house, or to renovate the part and so on, isolation all those, all those elements really boomed.. And then fashion industry I think had a very poor season, couple of seasons, so it's really there's... There's a big differentiation depending on the industry. Airline industry, doing not so well. So it's difficult to say there's winners and losers out of the crisis.

PDB – Ok, and regarding the let's say, uh, a difference between a large organization and a smaller organization?

JV – Thing I'm trying to think of examples. I don't think that that makes a big difference. Large versus small. It is more this sector you are in, in my opinion that made a difference. Uhm, I already see, if you look at technology stocks, how much they searched and then whether you're a small company or a big one if you were into technology, I think you had a good time last year, and if you were into fashion and he had a small shop or a small production house building and making clothes and you will probably have had a bad time, so it I don't think it's linked to the size of company.

PDB – Ok, great. Regarding kind of all the above question, is there some specificities about Belgium? Regarding how the Covid impacted Industry 4.0?

JV – I have to think about that. Did it? Did it impact Belgium differently than other? Let's say more or less Western countries? I don't think so. I don't think there was a big difference. There is some side effects which you see due to coincidence as you could say we have a lot of Pharmaceutical industry Pfizer, GSK and so on. So those industries actually did very well and they're a big part of our industry in Belgium we saw the chemical industry picking up quite fast as well right? Which is also quite big in Belgium and the whole cluster is made in Antwerp and somewhere, all the chemical companies those it very well and then the third point I would like to make is that we do have quite a lot of knowledge like iMac and research on semiconductors and so on, which brings a huge opportunity for them. To also try with it because of the crisis but I would not say there's a big difference, uhm, with other countries in how we experience the crisis. I don't feel that's the way for it to other territories of PwC. And if I listen how the business is going, we went through the same cycle. So all countries went to through a dip last year, April May, June. And depending on the country, then you had a relaunch. As of July, August, September, some little bit later on, but most of them went through the same cycle and now at all-time highs.

PDB – Ok, and then the last question. So what do you see for the future of the Industry 4.0?

JV – Well, I think the term Industry 4.0 will disappear. Uhm, because it's just going to be basic maintenance, management, quality management, production management, operations management and the technology is only a means to go to a certain level of performance so, I see that going away. I don't, I don't think people will talk about Industry 4.0 in as the “new thing” to do. It's just going to be mainstream and it allows it, it gives us some opportunities. Yeah, I think it will bring us opportunities to work on some of the megatrends, and I think if you look at how the population in the world is evolving and we're going for increased urbanization. Meaning people live closer to each other around urban cities, that requires more, in my opinion, gives an opening for more local for local production and so you have more localized manufacturing and new technologies will enable that. I think you can manufacture, there's a lot of companies experimenting with what was called micro factories. So you try to manufacture on small scale closer to your customers. I see that happening and also the fact that customers always want the more differentiated specifically for the made products. You see it in in medicine as well, personalized medications and those kind of things, but also in products. Personalization of your car of your coffee machine, whatever, these things are coming. And I think new technologies will enable us to do so, but closer to the market. So I see, going from very big centralized manufacturing in low wage countries, I see that becoming a network of smaller factories closer to the markets. I think that is going to happen, and that will only be possible because of technologies developed during the in the Industry 4.0 age.

If you want a good example, a good example is Twikit, t-w-i-k-i-t. It's a company that allows you to personalize, for example, your BMW Mini Cooper at your box, and then you can put for example your name on the dashboard or on the wheels and this kind of personalization is going to be more and more coming our way. That you can really have a personalized computer. Put your name on your desk or on your coffee machine. I think these things are going to be coming our way more and more.

PDB – Ok, that's pretty much it for the question I had. I don't know if you have anything to add?

JV – No, I think. Let me think little bit further. I think I made most of the points that I wanted to make, so there's any questions let me know. I hope we can get enough, I would say, manufacturing, in our society here in Belgium as well, to make sure that we keep on thriving in that our education levels are going in the right direction so people are taking more technology savvy. And that we support entrepreneurship so we can also build companies here. So there's a... There's a lot of, I think there's, uh, that it is difficult to estimate how the competitive landscape between countries will change? Uhm, especially now with all the talks about how to tax. It's maybe far away from your current question, but how to tax new technologies? For example, I have a technology, I will make it very simple. It is a technology which allows uhm, companies that use filling machines to fill bottles, whatever beer, milk, tomato juice that allows us to analyze those filling machines and that can help you improve the uptime of that equipment. I sell it to you. I sell it to your Chinese company. Chinese colleague. I sell it to a US guy and that's... but that software is basically running out of Belgium. And I made my revenues here profiting from information I guess from a different country. So how do you? How do you tax that? Where is the added value? Is it the data that you get from the other country or is it the algorithm that you run here? Taxes, how countries are going to be looking at that right. For example, Facebook makes a lot of money out of Belgium consumers, should we get part of that tax or not? Or is that all done in the US? and that that might shift a bit the power landscape in terms of how technology is being applied in the world? There are other people that can help you more to build a view on that.

PDB – It's a bit away from what I'm working on, but it's interesting indeed.

JV – Yeah, it will have an impact. Also if you take it a step further and you know that's a lot of the, and it is very recent, the lot of the big technology companies in in China, have been facing fines and so on. Not really 100% clear why they get the fines, but it seems that they're going through a bit of rough border. So it's I think the politics will have a big influence on. How easy, how easy it's going to be to to roll out global technologies? So that's also something to keep an eye on.

PDB – Great, thank you. Thank you a lot for everything.

Abstract :

Industry 4.0 is a wide concept, defined in many ways. Its acceleration can therefore be understood in different ways depending on perspectives. This work explores the impacts that the Covid-19 crisis has on the fourth industrial revolution, focusing on how it is accelerated. Based on an exploration of the literature and insights from Industry 4.0 experts, the concept should have been accelerated theoretically, and observations show how that acceleration manifests itself. Barriers to the implementation of the idea have been lifted by the pandemic, and some of the benefits offered by are more valuable than before. But it is the fact that companies have started to think more about the concept, and that more applications were considered, that have been the main impacts at the moment. Most of the factors that have played into that acceleration are in fact only accentuated or highlighted by the crisis related to the Covid-19, confirming the idea that Industry 4.0 is more an evolution than a revolution. Various nuances regarding the acceleration are provided in this work, as well as where it can be found.

UNIVERSITÉ CATHOLIQUE DE LOUVAIN
Louvain School of Management

Place des Doyens, 1 bte L2.01.01, 1348 Louvain-la-Neuve
Boulevard Emile Devreux 6, 6000 Charleroi, Belgique
Chaussée de Binche 151, 7000 Mons, Belgique
www.uclouvain.be/lsm