Master Degree in Innovation & Entrepreneurship

Master Degree in Innovation & Industrial Management

ENGAGING 5G NETWORKS WITH A SMART FACTORY ECOSYSTEM

A case study of Smarta Fabriker

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ABSTRACT

The following research plumbs the field of conjunction amid two separate industries, those of telecommunications and industrial manufacturing. These two entities are undergoing a period of transition and turnaround, attributable to the innovations respectively brought out by 5G networks and Industry 4.0.

The research project Smarta Fabriker, promoted by the Göteborgs Tekniska College, furnishes evidences for the investigation of a smart factory prototype built in collaboration with over 50 companies specialized in different fields. Moreover, the analysis goes through the collaboration of the Västra Götaland region with different education entities in Göteborg and with the innovative cluster of companies located in the Lindholmen Science Park, in accordance with the theoretical fundamentals set by the Triple Helix framework. A foremost stress is put on the connectivity of the factory, provided by Swedish telecom operator Ericsson, in order to dig up a strategy for 5G operators in a smart factory environment.

The research provides a managerial perspective to the smart factory world, finding out the business transformations of different categories of companies (i.e. industrial manufacturers, telecom operators and IT consultants) together with the depiction of a comprehensive value-creation chain of the entire ecosystem and the classification of the technologies involved in the project with respect to their status in the market.

Key words: smart manufacturing, 5G strategy, Cloud and Edge Computing, Augmented Reality, Triple-Helix framework, value chain, Industry 4.0

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ABBREVIATIONS

5G – Fifth Generation (of wireless systems)

AI – Artificial Intelligence

AR – Augmented Reality

CAPEX – Capital Expenditure

CESC – Cloud Enabled Small Cells

CRM – Customer Relationship Management

CSR – Corporate Social Responsibility

D2D – Device to Device

ERP – Enterprise Resource Planning

FDI – Foreign Direct Investment

GSM – Global System for Mobile communication

GTC – Goteborgs Tekniska College

IAR – Industrial Augmented Reality

ICT – Information and Communication Technology

IEEE – Institute of Electronics and Electrical Engineers

IoT – Internet of Things

IPR – Intellectual Property Right

ITS – Intelligent Transport System

ITU – International Telecommunication Union

KPI – Key Performance Indicator

LTE – Long Term Evolution

M2M – Machine to Machine

MC – Mass Customization

MES – Manufacturing Execution System

MIMO – Multiple Input Multiple Output

MTC – Machine Type Communication

MVNO – Mobile Virtual Network Operator

NFV – Network Function Virtualization

OPEX – Operative Expenditure

OTT – Over The Top

PLC – Programmable Logic Controller

PLR – Packet Loss Rate

R&D – Research and Development

RMS – Reconfigurable Manufacturing System

SCADA – Supervisory Control and Data Acquisition

SCNO – Small Cells Network Operator

UMTS – Universal Mobile Telecommunication System

VR – Virtual Reality

VSCNO – Virtual Small Cells Network Operator

1. INTRODUCTION

The following thesis aims at the formulation of the synergies between two fields that suddenly got crucial in the market. The telecommunication industry and its latest update in terms of network capacity, namely 5G, contains a suite of technologies that is shifting the core target of the sector from physical consumers to manufacturing entities and public administration. Innovations in terms of latency and bandwidth foster the creation of a suitable architecture for autonomous machines, that go from driving cars to gantries and big factories. This means that, among cities' administrations, vehicles' producers and manufacturing companies, there is a huge extent of human and non-human resources employed in the implementation of such architecture in their project management scenarios. The advantages of this framework are countless and better explained in the theoretical section of this research. Nevertheless, the salient ones are resource and cost efficiency, business sustainability and higher flexibility of the companies' lower levels in the organization.

The author chose the manufacturing industry as a complement of this study for its extreme actuality, together with the opportunity provided by the Ericsson team to deal with an ongoing project such as Smarta Fabriker, that took place in the vicinity of the author and fulfilled his expectations in terms of students' management and relevance of the topic in combination with the course of study he is pursuing.

1.1 Project outline – Smarta Fabriker

Starting in January 2017, the Smarta Fabriker project aims at being a platform to spread knowledge about industrial digitization and smart manufacturing.

The establishment of this project started back in January 2016, when the Swedish government presented the new industrialization plan. At the same time, several studies identified that today's trends in term of digitization and automation will result in a shortage of industrial educators at high school level as well as university and civil engineers. The new industrialization plan asserts that the knowledge and technology advancements faced by the Swedish business sector and overall economy can no longer be taken for granted.

As a consequence, one of the strategy's main spotlight is knowledge-lifting, which aims at ensuring that the skills' "supply system" meets the needs of the local economy and promote its long-term development.
The project consists in the construction of two demonstrators (*minifabriker*) with associated exhibitions in the Universeum of Gothenburg and the Balthazar of Skövde. Everything is run by Göteborgs Teksniska College, which acts as an intermediary between the project's stakeholders.

The process can be divided into three phases: rigging, building and spreading. The factory produces VR glasses made of cardboard, and their virtual content can be reproduced through the project's app. The automated factory process is divided into two parallel flows: cardboard processing and delivery of lenses. Cardboard processing starts when visitors place their order at the exhibition or through the project's app. Subsequently, production starts with the robot retrieving a carton sheet from the magazine and draws it throughout a printer. In this step, the carton sheet is labelled with a QR code and a text decided by the visitor. Thanks to the QR code, the cardboard sheet will act as information carrier throughout the process. The final outcome of this first process is a carton portion of the glasses. Lens delivery then starts with the little robot picking a pair of lenses from one of the boxes on the conveyor. The robot places the lenses in a fixture that drives up to a hanger where the lenses are hooked. The hanger carries the lenses along a lane and drops them in the hands of the visitor.

During the autumn, the project management conducted 10 master's degree together with participating companies. The mechanical construction of the factory was initiated in December 2016 with a class of CAD designers from YRGO, supported by SKF designers. The thesis workers are spread across the different companies, but weekly planning and follow-up meetings are held at Visual Arena, in the Lindholmen Science Park. The mini-factory in Gothenburg was built by high school students from the Göteborgs Tekniska College. Altogether, the project entailed approximately 21,000 hours of students' work (smartafabriker.se, 2018).

1.2 Company description – Ericsson

Ericsson is one of the worldwide leading companies in providing connectivity infrastructures and services within the telecommunication industry.

The company was established in 1876 by Lars Magnus Ericsson and is currently headquartered in Stockholm. It started its business as a telegraph repair shop, and gave rise to its international expansions through collaboration with Siemens and Bell. The company provided both infrastructure management and device production to the industry, despite incurring in a downturn for mobile sales in the early 2000s. The production was spun-off to a joint venture with Sony, allowing Ericsson to concentrate on the upcoming era of mobile networks. Ericsson led the market when GSM (i.e. the second generation of mobile networks) was implemented at a consumer level, and so did with 3G between 2003 and 2004.

Today, Ericsson is a business to business company operating with both wired and wireless base networks and providing their functionalities to wholesale operators. Apart from the network business unit, Ericsson has three other areas, that are digital services, managed services (cloud, data and network optimization operations) and IoT and other emerging businesses.

The company owns over 45.000 patents and 100 license agreements, and has around 100.000 employees spread around the world. It accounted sales for $20 billion in 2017, and a net loss of $3.5 billion.

1.4 Problems statement

In order to define which problems may hinder this research from being conducted, the description of the ideal situation should be included.

Ideally, the research aims at an in-depth analysis of the Smarta Fabriker project to define synergies between the different partners and technologies. Moreover, the path is expected to go further into which consequences the project may have in the Swedish market as well as in all the other potential ones. Anyway, this paragraph is intended to be distinguished from the one concerning the research boundaries and limitations, as this last one wills to describe the constraints that the researcher will find in the data collection and analysis process.

The Smarta Fabriker project needed a managerial perspective among all the engineering students that were undertaking their thesis. The project manager was really interested in the drafting of the Triple-Helix framework as well as the Ericsson manager was in the outline of the 5G implementation in smart factories.

Thus, four main problem areas are what the author plans to investigate and overcome.
The first one is the alignment of the technologies involved in the project within the time horizon. Virtual reality, 5G and 3D scanning/printing are three main fundamentals of Smarta Fabriker, and some of them might not be ready yet for such practical purposes. It is the author's intention to verify the feasible application of these ones in their respective and awaited domains.

Secondly, the project still has to see its market targets clarified. The potential consumer's point of view is blurred, as no specific market requirements are set and no previous experiences have occurred, hence there is not a lot of room for benchmarking and comparison.

Likewise, the very high number of partners and companies involved exposes the project to misinterpretations in their roles. A big effort is to be put in the definition of roles of all the companies in order to avoid both overlapping and blanks. This not only means to group partners with respect to their main task in the project (e.g. Ericsson with 5G or SKF with monitoring components), but also to outline linkages between different functions and among different partners.

At last, the project is "confined" in the Swedish market, even if this was an explicit choice of the project authors. The fact that the language of the website as well as the whole social media coverage is set in Swedish, and that the project initially focused on Swedish-native students as their only master thesis resource, are just two hints of the Swedish orientation of Smarta Fabriker. The main issue is in the balance between two aspects, a positive and a negative one. The former is the strong collaboration with the Swedish government and institutions, such as the region Västra Götaland which is partly funding the project. Instead, the latter stands in the potential struggles that Smarta Fabriker could find in expanding the project abroad. A flexible attitude is needed to offset the lack of internationalization opportunities that the project is temporarily facing.

1.3 Research question

Taking the presence of diverse fields of interest into account, this kind of research entails a designed work that mutually integrates them, probing eventual synergies and influences.
With this being said, the research branches out into two separate research questions, both connected with the Smarta Fabriker project. The first one concerns the telecommunication environment, which is what the author has planned as the starting point of this research. Coaction between the Internet of Things and the super-wide bandwidth requirements of the 5G networks has been under the spotlight for the past decade. Moreover, together with smart cities and smart houses, the Industry 4.0 is the main practical application of such coaction.
Thus, the author chose Ericsson and its highly focused 5G strategy to outline what are the influences and implications of the 5G technology in a smart factory environment, taking evidences from the Smarta Fabriker case to sketch out the current situation and to describe how it could progress in the near future.

Research Question #1:

How can Ericsson's 5G strategy guide the Smarta Fabriker project?

This first research question starts from the Ericsson's point of view and moves to the Smarta Fabriker project, albeit gradually, emerging evidences from a theoretical basement of relationships between 5G and the Internet of Things, using a "push" approach.
On the other hand, a second research question is needed in order to fully understand how the Smarta Fabriker project works out. This is done by categorizing different groups of actors among the partners involved in the project.
The macro groups are the following:

- Investors
- Telecommunication operators
- Knowledge suppliers
- Cloud and IoT consultants
- Robots and machineries suppliers

These macro groups are thereby examined to sort out content, timing and extent of their respective moves, pulling out a sequence of movers, according to the status of all the technologies involved in the project (virtual and augmented reality, robot automation, 5G networks, Cloud computing etc.). A value chain draft is then provided as a final outcome of this second research, analysing the internal/business environment as well as the external one, meant as the customers' perspective and readiness.

Research Question #2:

What is the moving sequence and the value chain of the actors involved in the Smarta Fabriker project?

The author chose to respond to two different research questions for two separate reasons. The first one is because of the relevance of both fields (telecommunication and manufacturing) that call for different perspectives and discussions. The second one is due to the fact that a unique research question could have hindered the ramification of the research into several and separate matters, that are the technologies of the research, the role of the companies and the relationship between the telecom operator and the manufacturer.

Throughout the research, two important terms have to be clarified. The first one is the "strategy" referred to in the first RQ: strategy is meant as both the moves that a telecom operator have to undertake to optimize the implementation of the 5G technology in the business of manufacturers/factory based companies. The second term is ecosystem, that is cited both in the title of the report and in the analysis: the "smart factory ecosystem" comprises the multitude of stakeholders that take part in the business of a smart factory, such as IT consultants and connectivity providers. The following research involves, within the term "ecosystem", the institutional actors, namely the region, and the schools/universities, together with the business companies that take part in the project.

1.5 Research boundaries and limitations

As mentioned in the previous paragraph, boundaries and limitations are intended as those that the author will encounter during the research, and not those strictly related to Smarta Fabriker. A first drawback is linked to the already cited "Swedish focus" of the project. A language barrier can be easily overcome, due to the average English proficiency of the Swedish population. On the other hand, the strong geographical footprint may prevent the research from being extended to other markets, leading to an extreme focus on the Swedish market itself.

Besides, the multitude of companies involved (roughly 50), combined with the limited time span available to pursue this research, makes it difficult to thoroughly break down all the business linkages between the companies themselves. Interviewing as many companies as possible would enhance the results, leading to a further approach to the research question. Still, a lot of free space is left to future and further researches, and these will be discussed in the conclusive chapter.

An important viewpoint is the starting theme of the thesis, which is the telecommunication industry. The author's initial purpose was to develop a project work to analyse the 5G strategy of different companies, as a consequence of his passion for this sector. This may constitute a preliminary bias owing to an involuntary focus on the telecommunication side of the project, even if it will still be a central issue, and it could prevent the author from meticulously investigating the core business of the project, namely the smart factory world.
Splitting up the thesis into two different research questions can preventively solve this problem, leaving freedom to the author to explore both fields at once.

Finally, carrying out a project with two different supervisors may create dissimilarities in their requirements and intentions. The author's will is to coordinate their inputs to diversify the approach to the data collection path and analysis, as well as the theoretical framework, resulting in a better final product.

1.6 Thesis disposition

This report follows the structure set by the University of Gothenburg and exercised by most of the Anglo-Saxon universities around the world for managerial subjects.
The thesis is divided into six main chapters and three other sections. The main chapters are the following:

- Introduction
- Theoretical background
- Research methodology
- Empirical findings
- Data analysis
- Conclusions

The introduction aims at preparing the reader to the research path and intention. On top of the introduction to Smarta Fabriker and Ericsson, the first chapter provides the research questions, the research limitations (meant as the limits that the author himself will have during the research) and the problems statement (meant as the boundaries that the Smarta Fabriker project sets to the validity of the research).

The theoretical background is divided into three sub-sections, covering the whole research matter. The first two sections, namely Industry 4.0 and 5G networks, are provided to educate the reader to the two fields that encircle the study. Contrariwise, the third section converts these two fields in a business and innovation context, where the interaction between government, education institutions and companies is described under the Triple Helix model.

The research methodology broadly describes how, and through what, the research is conducted. The methodology of this report can be summarized as “qualitative analysis through an individual case study, using and inductive approach and unstructured interviews”. Besides, the chapter provides the description of the sample and the validity and reliability of the research, as well as an explanation of the layout of the fourth and fifth chapter. Due to this, the in-depth description of these two chapters is put off to paragraphs 3.5 and 3.6.

The other auxiliary sections are the following:

- Abstract
- References
- Appendix

Where the abstract serves as the self-contained and very short summary of the thesis, the references collect the citation used by the author to write the document, and the appendix contains a guideline of the interview as well as a short description of the companies in the sample.

2. THEORETICAL BACKGROUND

The purpose of this chapter is to give the reader a broad background of what is found in the literature about the technologies and business repercussions that gave rise to the Smarta Fabriker project.

The following theory is then exploited to draw up the interviews' content and to link these together in order to design the analysis.

Therefore, two big domains constitute the notional framework of this research, and they are the Industry 4.0 context and the telecommunication industry. All the sub technologies are then labelled under these last two paragraphs.

In addition, a third paragraph provides the system's layout of the project, namely the "Triple Helix model", which basically portrays the business synergies of the education-business-government tripod.

2.1 Industry 4.0

Industry 4.0 is a term often referred to the fourth stage of the industrial development started during the second half of the 18th century. The first industrial revolution introduced the concept of mechanization in the manufacturing production. The two following stages were led by the emergence of Fordism and electrification in the first place and after that by the revolution of telecommunications and Internet. (Rojko 2017)

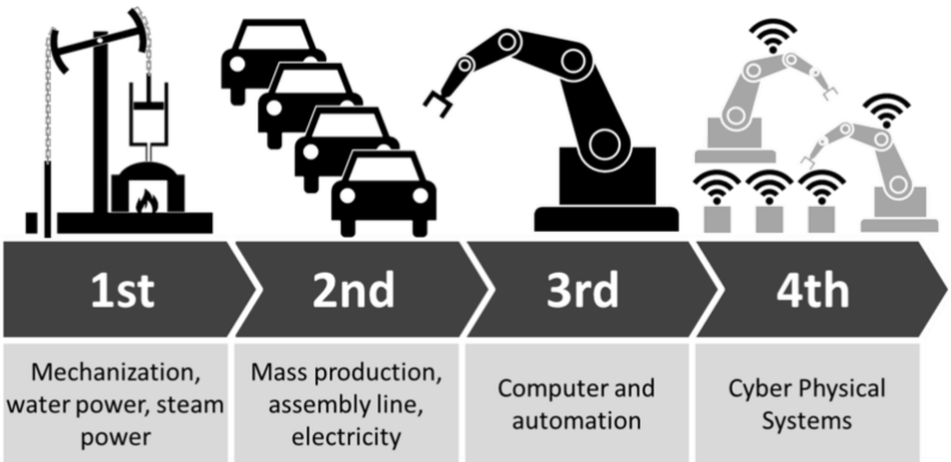

Fig. 1 – The four industrial revolutions – Forbes

The fourth industrial revolution is exponentially introducing new conceptions and setting new achievements to the companies' manufacturing processes.
These can be summarized in the following:

- digital mapping and process virtualization
- availability and use of the Internet of Things
- integration of technical processes and business processes in the companies
- implementation of 'smart' means and 'smart' products in the industrial production, measuring performances with autonomous systems. (Lucke et al. 2008)

Gathering together these features and other modern techniques, just in time production, LEAN manufacturing, and taking advantage of the lower cost workforce in emerging countries, the Industry 4.0 aims at decreasing:

- production costs by 10-30%
- logistic costs by 10-30%
- quality management costs by 10-20%. (Rojko 2017)

The 4.0 model sets up a scenario where physical and digital systems merge. Preventive maintenance is held though the same process parameters, from the physical object to the digital records of performance. Procurement and distribution are now even more individualized, meaning that each line of product has its custom and automated value chain. Consequently, each product and service is developed individually, attracting processes of open innovation and product intelligence.

A substantial change is done under the organizational point of view. Organizations are now decentralized, taking advantage of the decentralized communication and interaction between machineries and plants and avoiding a heavy reliance on a single entity. Besides, these self-organizations strive to achieve shared values between profitability and social responsibility.
C.S.R. embraces sustainability and resource efficiency and new manufacturing processes are designed to accomplish these framework conditions. (Lasi, Heiner, et al. 2014)

2.1.1 Business implications

The rise of Industry 4.0 initiated different business model and set-ups.
Within the characteristics of new businesses, Lasi and Heiner (2014) list these as the most relevant:

- *Resource efficiency*, as the focus on sustainability in an industrial perspective leads to the avoidance of ecological wastes
- *Decentralization of the decision-making process,* resulting in a cut in organizational hierarchies
- *Demand individualization*, turning the market from a seller oriented to a buyer oriented one. This phenomenon is known as "batch size one"
- *Short cycle periods and faster trends*, as innovative mind-sets bring pace at the forefront of the enterprises' requirements
- *Flexibility and adaptation* in the product development phase.

Aside from the shorter time-to-market, smart manufacturing businesses bring out countless advantages for companies, with the likes of faster consumer responsiveness, friendlier and more easy-going working environment, and the easier admittance of mass production strategies, developing into sub-strategies such as mass customization. (Rojko 2017)

A further mention in the new business framework is the heavier dependence on Information Technology. A lot of companies nowadays are using Enterprise Resource Planning (ERP from now on) systems, to support business activities like sales and distribution, accounting, human resource management, supply chain management and so on. Traditionally, ERP systems involve a centralized decision process, shifting responsibilities to the upper levels of the organigram. The divergence between this and the Industry 4.0 machine-to-machine flows of communication is gradually decreasing, entailing a fast adaptation of these tools in the new manufacturing era. The most famous ERP systems are the one furnished by SAP and Oracle.
A second set of IT tools used in the automated industry is the Manufacturing Execution System (MES) that operates to report and schedule production, to dispatch and track products, and for the maintenance, performance analysis and resource allocation.

Supervisory Control and Data Acquisition (SCADA) is the third level of the automation pyramid, and it is related to the management of all the controllers on a process level.
In contrast, the last level is characterized by the device/machine level control, involving robot controllers. Being individually managed, it is less likely to be subjected to the limits of dynamic adaptation of the first floors.
A final concern is the integration of this internal organization aspects with the external environment, which concerns the Business Intelligence management and the CRM (Customer Relationship Management). (Rojko 2017)

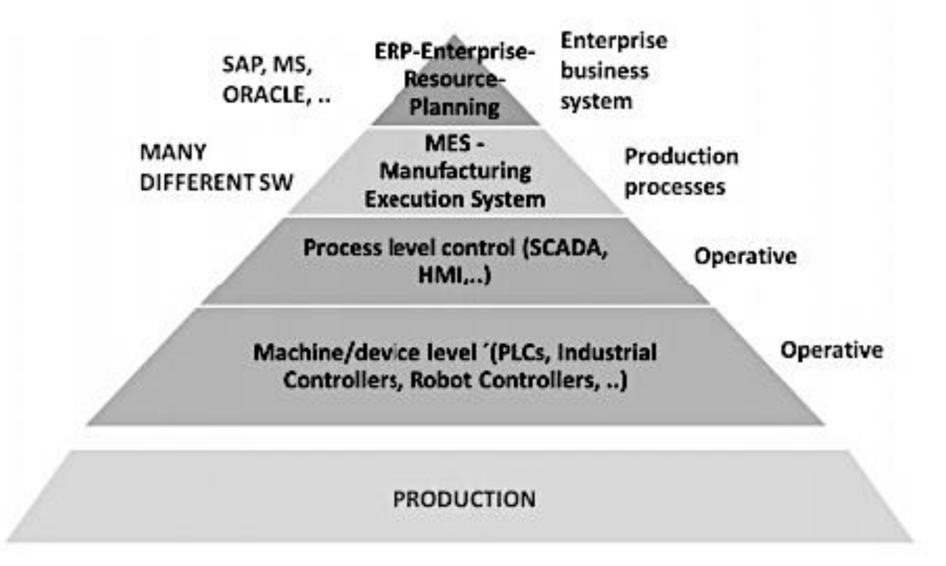

Fig. 2 – Automation pyramid in modern production systems - *Rojko 2017*

2.1.2 Supply-chain implications

Narrowing down the viewpoint of the theoretical description, it is now fundamental to dig into how the value chain has its arrangement altered due to the previously described business implications.
The second research question seeks for these alterations in a practical business case, outlining how different actors are supposed to interact within the following boundaries.
Manufacturing producers are changing their production process from the design of the product to the after-sale service.

- More flexible processes are assisting the production of small lot sizes, smoothening the mass customization. The implementation of smart machines and robots results in a more autonomous communication and more autonomous decisions, facilitating the differentiation of products that are still produced of a large scale.

- IT systems automate the production line

- Physical prototypes are drastically decreasing their existence, due to the automated design of products and the integration of the different value chain segments.

- In flow and out flow logistics are automatically adjusted through autonomous and smart vehicles (Rüßmann et al. 2015)

As mentioned, the primary outcome entails mass customization (MC) strategies. They solve the everlasting dilemma of choosing between economies of scale or scope.
MC requires two main prerequisites: a modularized product design and a strong integration between the different value chain members.

The product architecture is modularized and decoupled in different supply chain steps that present very small interdependencies among them. The product is developed at a higher pace and the time to market is shortened.
Reconfigurable manufacturing systems enable cost efficiency to companies aiming at a flexible production process, making it both easy and efficient to add or remove machine components in a less complex way. By the way, distributed planning activities are riskier owing to the fact that the controlling and monitoring phases are less straightforward and employees lose sight of the overall product architecture. Process modularization is already a thing, where decisions are predominantly taken by humans on the basis of their previous experiences: the key is adapting what is already made by flexible companies to these new virtualized processes, in order to avoid this lack of supervision.

Furthermore, value-chain actors need to work side-by-side and flexibly in order to smoothly pursue a proper MC strategy.
When the complexity of a process increases, the added value decreases. This means that collaborative manufacturing processes are fundamental, especially when dealing with small of

medium enterprises with a limited set of resources. In addition, collaborative networks let companies adapt to shortened product life cycles with a higher agility.
Companies should move the spotlight to core competencies while outsourcing activities where they are weaker, enabling the sharing of innovation and resources. (Brettel et al. 2014)

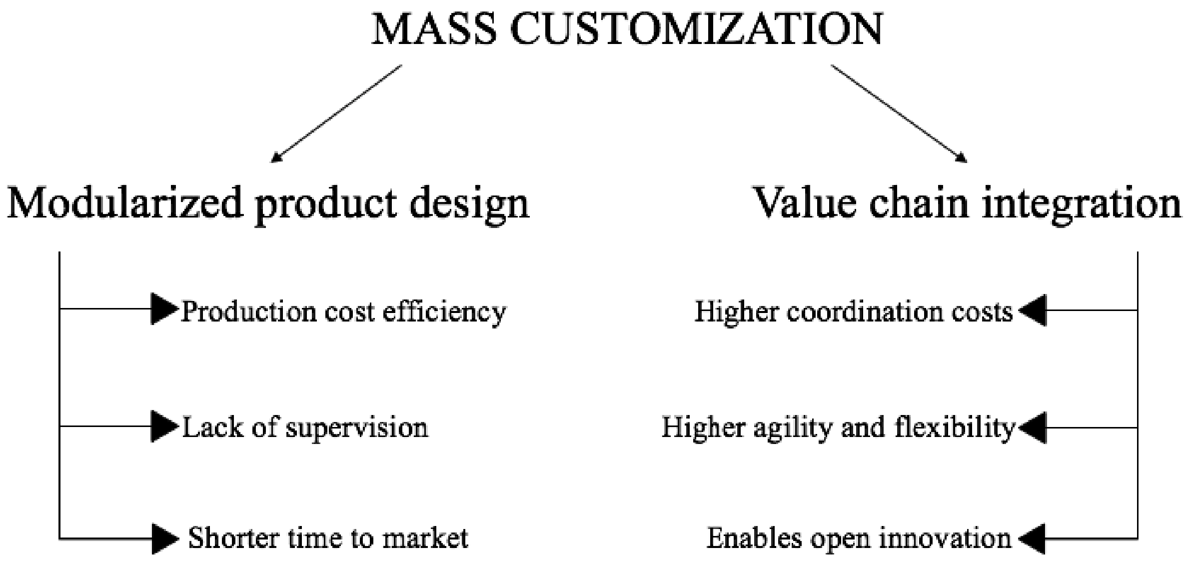

Fig. 3 – Personal rearrangement of the mass customization strategy

The integration of ICT components in physical machines led to the diffusion of Reconfigurable Manufacturing Systems (RMS). Being the latest advance in the development of a manufacturing system, RMS are able to adapt their hardware and software components to follow ever-changing market requirements of quantity and nature of the diverse products, giving rise to more flexible processes. The ability to make autonomous decisions based on machine learning algorithms together with real-time data capture and analysis through embedded sensors constitute the so called Logistic 4.0.
Interoperability and continuous information flows between devices in the key link between the manufacturing and the telecommunication industry, where new generation networks operate to set the latency at zero and to boost the reliability of these interactions. (Rojko 2017)

2.1.3 Additive manufacturing and industrial augmented reality

In a smart factory environment, additive manufacturing and the industrial application of augmented reality stand as two fundamental technologies in the majority of the smart processes.

The most popular implementation of additive manufacturing is 3D printing, generally used to quickly visualize prototypes avoiding them to be physically created. Implementing it in a decentralized and modularized assembly line reduces transport distances and stock on hand. (Rüßmann et al. 2015)
In fact, a noteworthy debate is arising on the transition of 3D printing from a prototyping application to a production method. Additive manufacturing is now widely used to produce small batches of customized products that bring advantages in the factory, such as complex, lightweight and flexible designs. For example, aerospace companies currently use 3D printing to employ new designs so as to reduce aircraft weight, lowering their expenses for raw materials (e.g. titanium).
This ability to produce small components in a fully automated way is crucial when manufacturing companies aim at a flexible process, especially under a mass customization regime. (Zawadzki & Żywicki 2016)

A second but not less important process-virtualization technique is the Industrial Augmented Reality (IAR).
The term Augmented Reality entails a set of technologies combining physical assets with computer generated texts and images or animations. It is defined as a real-time view of an enhanced or augmented world environment, mixing real and virtual objects. In contrast, Virtual Reality is a fully immersive technology consisting in a 360-degree views of a simulated world. Still, their systems components are very similar, making them comparable in a lot of business models.
From an industrial point of view, AR is applicable in segments like product development and interactive augmented prototyping, not too far from the additive manufacturing ones. These two collaborative design tools simplify know-how distribution both with fast in-flows and out-flows of communication within the shop floor. (Nunes et al. 2017)

The followings are the actual usages of AR in an Industry 4.0 context:

- Human resource training in geographically dispersed companies
- Logistics and store management
- Designing prototypes and visualization
- Production of components and assembling
- Safety and risk management at a shop floor level
- Maintenance and remote assistance to reduce human errors and execution times
- Quality checks and screening activities. (Pierdicca et al. 2017)

2.2 The 5G environment

The fifth generation of wireless systems, also known as 5G, is a set of new and upcoming technologies impacting the industry of telecommunication.

Implying the first mobile phones - arisen at the end of the 1970s - as the main category of devices for the first generation of wireless networks (1G), the progression of these technologies was gradual but progressively exponential. GSM (Global System for Mobile Communication) represented the first incremental step from the primitive devices, bringing mobility in the voice communication. General Packet Radio Service (2.5G) was the first set of equipment that provided mobile data communication in a time when internet was still at its early stages. UMTS (3G) introduced the concept of multiservice technology, kicking off the convergence phenomenon of telecommunication in a single device, namely the smartphone. It allowed a single device hold enough data for mobile communication, internet services and video display and transmission. LTE (4G) is now the current generation, delivering the first example of mobile broadband. (Tudzarov et al 2017)

The international telecommunication union describes the technologies of the 5^{th} generation as following:

- Different frequency usage through *millimetre waves*, transmitting signals on a new span of the spectrum. The frequency involved is way higher, going up to 300 GHz, compared

to the previous one reaching a maximum frequency of 6 GHz. These waves are indeed thinner, swinging between 1 and 10 mm, while the previous ones were measured in tens of centimetres.
This results in a wider bandwidth for every device, but also provides waves that would find it difficult to pass through thick buildings and constructions due to their thinness.

- *Small cells* distributed all over the streets. This helps to overcome this last drawback, because small cells – portable base stations with a minimal energy requirements – will be spread all over 5G areas to avoid the loss and dispersion of signal owing to the interference of objects.

- *Massive Multiple Input Multiple Output* (MIMO). This conceptualizes the ability of 5G stations to not decrease signal's power when more devices are connected at once. A single 4G station usually supports around 12 antennas at once, whereas 5G ones sustain up to 100. Immediate example of this is the smartphone usage in stadiums or concerts, where the connection speed is usually lower because of the presence of too many devices in a limited set of space.

- *Beamforming*, which entails an intelligent system for data traffic distribution that instantly chooses the best delivery route for information in an efficient and fast paced way. This drastically reduces the latency between inputs and outputs of a single data.

- *Full duplex transceivers*, able to transmit and receive information simultaneously. This means that ingoing and outgoing information will not collide if moving at the same time, enabling and facilitating the modular structure that constitutes machine to machine communication.

2.2.1 New business horizons

First thing coming to mind when dealing with such innovation is which disruptive technologies and services may derive from it.

To kick off, Boccardi et al (2014) classified the impact of the main technologies through the Henderson-Clark model, measuring their disruption at a both architectural and component level. Architectural changes are meant as the introduction of new types of nodes or new functions in existing ones. Component changes embrace variations in the design of a class of network nodes.

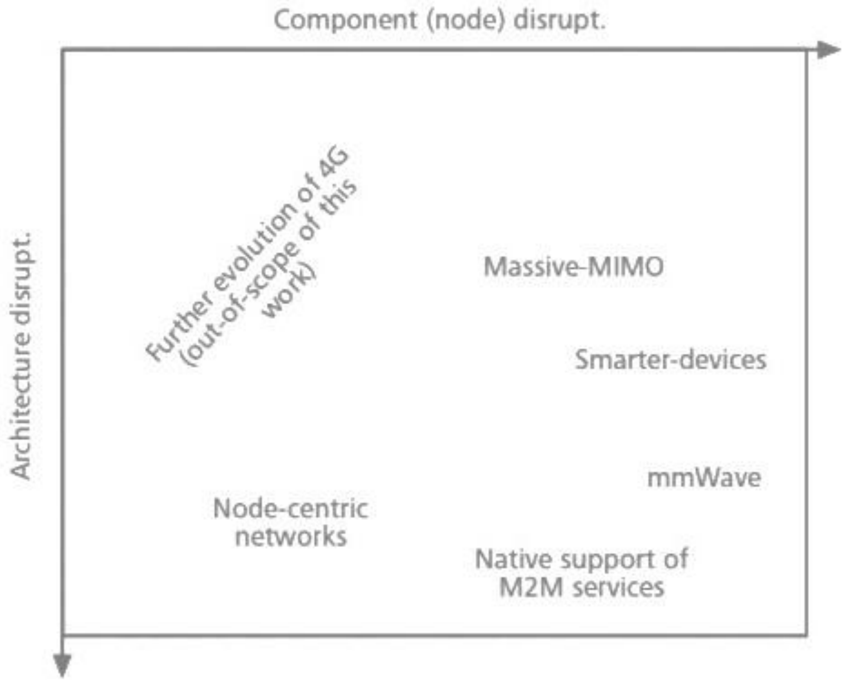

Fig. 4 – Impact of the different technologies at an architectural and component level – Boccardi et. Al (2014)

- *Node-centric networks*: the change in information flows will cause better routes and extremely lower latency. This leads to drastic changes from an architectural point of view.

- *Massive MIMO*: new types of deployments will be triggered by a change in the design of network nodes.

- *Smarter devices*: barely involving architectural changes, a smarter device means initiation to a new era of connectivity, namely D2D (device to device).

- *Millimetre wave* (mmWave): signal will increase its frequency and expand the bandwidth. Innovations will incur in both components and architectures.

- *Native support for machine-to-machine (M2M) communication*: that is, the origin of Industry 4.0. This will entail low data-rate services and low-latency data transmission. New ideas will be brought at both architectural and component level.

From a business perspective, 5G necessitates a broad variety of use cases and ought to satisfy customer expectations under countless aspects. As a result, the expected 5G network is often referred to as a "one-size-fit-all" system aiming to satisfy an "average consumer" scenario.

The functions that an operator may undertake with these new technologies do not diverge from the traditional ones.
The first one is the *Connectivity provider,* entailing the company to provide retail functions either with consumers and businesses (such as MVNO). This is done to enhance a better IP connectivity and/or a guaranteed Quality of Service.
A second role is the *Asset provider,* where operators offer defined part (e.g. capacity) of the infrastructure for a 3rd party provider. This offer takes in models with the likes of Infrastructure as a Service (IaaS), Network as a Service (NaaS) or Platform as a Service (PaaS).
The final role is the *Partner service provider,* in which companies integrate multimedia communication services partnering with 3rd parties/OTT players. A more specific version of that is the "tailored partner services" business model enabled by the ability for OTT (e.g. content providers) to move on and create customized services explicitly based on their demand and content.

These three types of actors aim at creating value through a modern and original cluster of value proposition fields. The majors are:

- Security
- Identity
- Privacy
- Real-time interaction
- Real-time experience

- Guaranteed reliability & connectivity
- Seamless experience
- Context (Tudzarov et al. 2017)

Chochliouros et al (2017) examine other market and business perspectives. Lower entry barriers will promote the institution of new market opportunities and players, such as function developers and facility managers. The so-called CESC technology empowers the establishment of a remodelled multi-tenant cloud enabled Radio Area Network that will be further discussed in the next paragraph. Nevertheless, a new wave of core players will be expected to flood the market to better manage the small cell ecosystem. These players, known as SCNOs (Small Cell Network Operators) will be at the main focus among other actors, positioned in the value chain through Figure 2.6.

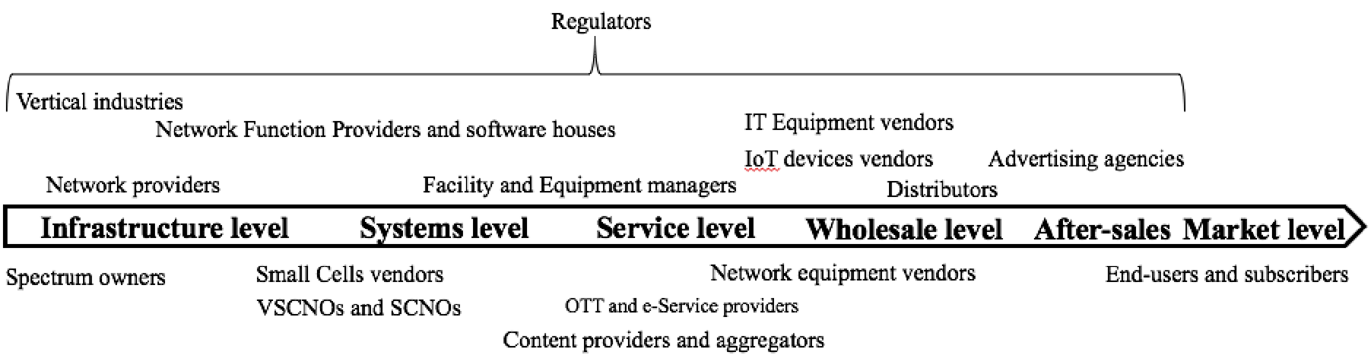

Fig. 5 – Personal depiction of the future telecommunication value chain considering the emerging actors of the 5G environment

These actors collaborate in all the markets that the new 5G power will access. But nevertheless, to assist the specific research area, the spotlight of the research is steered on industrial perspectives, without deepening themes like e-health, smart broadcast, smart users-mobility etc.

The industrial applications of the new 5G disruptive technologies is put off to paragraph 2.2.3 of this document.

2.2.2 Linkages with computing technologies

The following section illustrates how two innovations, specifically 5G networks (incremental innovation) and both Cloud and Edge Computing (radical innovations), might conjoin in today's markets and business.

To define Cloud Computing and Edge Computing, part of the literature tends to overlap both of them, implying one technology to substitute the other. As a matter of fact, the most recent Edge technology is complementary to the already established cloud storage techniques.
Cloud computing consists in the virtualization of the data storage, processing and transmission, making these actions more cost efficient and immediate. Edge computing aims at pushing the processing of these data in proximity of the application/service involved, in order to further improve the quality of the information flow and to decrease its lead times. Nevertheless, shifting the entire data inventory control and analysis at closer stations, together with the processing architecture and the storage centre, would result in an unmanageable and unsecured mess, first and foremost due to the small dimensions of the edge stations and for their supposedly high number.
For this reason, Cloud Computing and Edge Computing should coexist to let the enormous 5G network work properly. (Linthicum, 2017)
The abovementioned CESC paves the way towards the network intelligence and applications approaching to the network edge, with the help of the NFV technology. Small cells entail hardware accelerators and low-power processors for time critical operations so as to builds a highly manageable and clustered edge computing infrastructure. This allows new stakeholders to flexibly join the value chain by acting as "neutral host providers" in high traffic areas where "densification" of multiple networks is nowadays not properly managed.

Even if 5G is seen as a gradual increment of the previous generations of networks, the exigency of completely new systems and the extremely high quantity demanded make some experts talk about a drastic innovation. This means higher CAPEX, but the efficiency of these systems leads to a drastic decrease of OPEX, shifting the business of this industry to an even more capital and infrastructure intensive model. (Chochliouros et al. 2017)

2.2.3 Industry 4.0 applications

The paradigm of 5G as a network involving every object powered with energy opens up to a broad set of application and new business models. This encompasses the so-called Industry 4.0, which is deeply described in the section 2.1. In this paragraph, the scope is drawing up how 5G shapes the I4.0 model.

The next generation of mobile communication is applied in the smart factory environment through what is widely referred to as machine-type communication (MTC) and the Internet of Things. Tens of billions of factory components will use their embedded communication capabilities and integrated sensors to act on their local environment and use remote triggers based on intelligent logic. IoT will also set specific requirements on networking such as reliability, security and performance (latency, throughput time). (N.G.M.N. 2015)
As for this last element, the industrial application of 5G is often referred as latency-critical. This is due to the fact that the machines involved deal with materials and components that may be either fragile or extremely heavy: repositioning them compels the system automation to be as fast and reliable as possible.
For this reason, several standards and quantitative requirements were set to prevent the smart factory to be incomplete or obsolete. In 2014, when 5G was at its infancy, six elements were identified for the definition of the 5G network standard acceptability.

Requirements	*Desired value*	*Application example*
Latency	<5 ms	Control and safety applications
Battery life	>10 years	Connect hard to reach physical elements, low maintenance
Connectivity	300.000 devices per application	Massive M2M connectivity
Reliability	99,99%	Protection and control
Data rate	1-10 Gb/s	Virtual representation
Seamless and quick connectivity		Mobile physical devices

Tab. 1 - Table of KPIs for telecommunications in smart factories – Varghese et al. (2014)

Low latency entails the control and safety of the applications. A substantial M2M connectivity requires an access point supporting plentiful devices. Maintenance for this connectivity should be very low, therefore a durable battery is necessary. A battery life for wireless connections longer than 10 years means that several hard to reach sensors with very low data rate and low maintenance requirements could be connected. Reliability plays a key role in industrial requirements with safety protection and control applications. For instance, high data rate systems may be required for a factory that has its whole operation sequence maintained and controlled through a virtual presence. Anyway, reliability is often defined through the PLR (Packet Loss Rate).
Moreover, 5G should be able to provide an all-encompassing connectivity experience for the devices that may transition from outdoors to indoors locations. A single communication protocol will not be capable of addressing all the requirements, hence the standard will involve various radio access technologies in order to provide a seamless connectivity experience. (Varghese et al. 2014)

With the research being brought on, the specific activities of 5G in an industrial environment have been broken down into different functions and judged with definite KPIs. Within this ecosystem, five latency-critical activities of IoT are classified:

- *Factory Automation* applications are characterized by real-time machines regulation and systems in production, where machine parts are in motion within a limited space (e.g., a job shop). Examples of this are high-speed assembly, packaging and palletizing. They are generally considered to be highly demanding in terms of both latency and reliability. The reliability requirements for factory automation applications are typically 10^{-9} PLR, while the latency requirements vary from 250 μs to 10 ms.

- *Process Automation* includes functions for monitoring and diagnostics of industrial elements and processes including heating, cooling, mixing, stirring and pumping procedures. The measured values among these applications slightly change. As a result, the latency requirements for these services range from 50 to 100 ms with affordable PLR of up to 10^{-3}. The coverage area is often quite broad (e.g., a power plant) and comprises multiple buildings and outdoor sites.

- *Smart Grids* have relatively less strict latency requirements compared to the previous two. Thus, latency and PLR are respectively expected to be up to 20 ms and 10^{-6}. However, the communication range, thus the space needed, is of a way bigger extent (i.e., up to a few kilometres).

- *Intelligent Transport Systems* consists of activities such as autonomous driving and optimization of road traffic. These activities have requirements that differ, especially within the device density and the data size. With road safety being a crucial matter in this topic, its main function consists in warning other road devices about collisions or other dangerous situations. (Schulz et al. 2017)

The tables underneath summarize the expected KPIs for each activity:

Use Cases	*Latency (ms)*	*Reliability (PLR)*	*Update time (ms)*	*Data size (bytes)*
Factory automation	0.25 to 10	10^{-9}	0.5 to 50	10 to 300
Manufacturing cells	5	10^{-9}	50	<16
Machine tools	0.25	10^{-9}	0.5	50
Printing machines	1	10^{-9}	2	30
Packaging machines	2.5	10^{-9}	5	15
Process automation	50 to 100	10^{-3} to 10^{-4}	100 to 5000	40 to 100
Smart grids	3 to 20	10^{-6}	10 to 100	80 to 1000
ITS				
Road safety urban	10 to 100	10^{-3} to 10^{-5}	100	<500
Road safety highway	10 to 100	10^{-3} to 10^{-5}	100	<500
Urban intersection	<100	10^{-5}	1000	1M/car

Traffic efficiency	<100	10^{-3}	1000	1000

Tab. 2 – Table of KPIs for smart industrial activities' network – Schulz et al. (2017)

Use cases	*Device density*	*Communication range (m)*	*Mobility (km/h)*
Factory automation	0.33 to 3 devices/m^2	50 to 1000	<30
Manufacturing cells	0.33 to 3 devices/m^2	50 to 1000	<30
Machine tools	0.33 to 3 devices/m^2	50 to 1000	<30
Printing machines	0.33 to 3 devices/m^2	50 to 1000	<30
Packaging machines	0.33 to 3 devices/m^2	50 to 1000	<30
Process automation	1000 devices/plant	100 to 500	<5
Smart Grids	10 to 2000 devices/km^2	A few m to km	0
ITS			
Road safety - urban	3000/km^2	500	<100
Road safety - highway	500/km^2	2000	<500
Urban intersection	3000/km^2	200	<50
Traffic efficiency	3000/km^2	2000	<500

Tab. 3 – Table of KPIs for smart industrial activities' network – Schulz et al. (2017)

2.3 Triple helix framework

This section's goal is to describe which synergies incur in the so-called "Triple Helix" framework, which entails coaction between universities and other education entities, government and other public institutions, and the business environment.

This framework, also referred to as the “national system for innovation”, was born as the engine that could better generate knowledge in the modern society mainly for business, engineering and medical purposes. Henceforth, the framework developed new features and synergies in all the three axes, going through different stages in accordance with the technologies and the society’s behaviour of the respective epochs.

According to Etzkowitz (2003), the model can be expressed through 10 propositions:

- The linkages between the three entities are what generates innovation. Innovations are the comprehensive phenomenon of all the dynamics between the single bodies.
- The creation of new organizational layouts, new social arrays and new channels for interaction are at the same level of the product innovation and invention as outcomes of the model.
- The model is interactive, and this means that synergies occur in both ways between all the entities. The model may have an “*ex-ante*” perspective, where knowledge generated in academia is transferred to business companies, or an “*ex-post*” perspective, where problems deriving from companies arise the research process in universities.
- The “capitalization of knowledge” exploits the new risk sharing mechanisms, stimulating the early stages investments through companies like the venture capital ones.
- Capital is no longer intended as exclusively financial, due to the value that social, cultural and intellectual ownerships have gained in the past decades. “Who you know” and “what you know” are now equivalent to “what you have”.
- The globalization process is getting more decentralized, having its origin in regional entities and at a smaller scale than before.
- Emerging economies have their opportunity to catch-up throughout local support policies and transparency, attracting FDIs from the outside.
- New technologies and innovation enhance the reorganization of institutional spheres as well as industries.
- Universities have the power to drive the development of regional economies, albeit declining, through focused research and incentives for outgoing students. (e.g. Karlskrona Ronneby in Sweden with the shipbuilding sector)

- A Triple Helix region has the ability to move from a technological paradigm to another through broad-based research and multiple interacting knowledge-producing institutions.

Each axis of the tripod presents different features due to the dissimilarities of the three bodies. Each one cooperates with each other in order to pursue the same goal; therefore, matching up the objectives is the key for a smooth cooperation, avoiding conflicts of interest or information asymmetries.

Leaving the obvious knowledge and education dimension aside, the education-business axis consists in four main areas:

- Research join ventures, that engages in commissioned research and academic consultancy
- Spin-outs, start-ups, university incubators and science parks
- Personnel pooling and linkages, establishing networks and incentivising exchanges, like company visits or lectures held by managers
- Universities' IPRs

The government-business axis entails:

- IPRs, in a larger extent than the education-businesses area because the government is generally who shapes and regulates the intellectual property policy
- Corporate tax policies, with a strong emphasis or R&D incentives and venture capitals
- Competition and market policies

Lastly, the government-education axis regulates the funding procedures, both financial and tangible, as in the case of research labs or other incentives. (Shurtliff 2014)

The description of such ecosystem implies a parity condition within the three parties, which is something hard to reach and sometimes idealistic. The system is often driven by the government, which has its bargaining power superior to the one of universities and companies, and is usually seen as the engine of such tripod. On the other hand, some visions see the business environment as the central pivot of the society (Nyman, 2015). Notwithstanding these disproportions, it is not the main purpose of this section to deeply describe every single vision of this ecosystem.

The graph underneath straightforwardly summarizes the synergies incurring in the three axes:

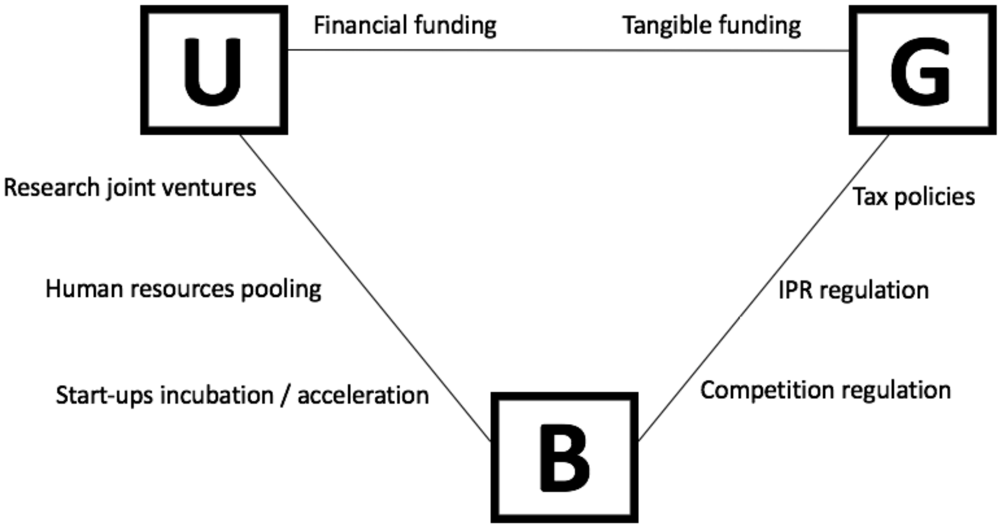

Fig. 6 – Personal rearrangement of the Triple-Helix framework - Source: author

3. RESEARCH METHODOLOGY

This chapter aims at circumscribing the methods that the author used to investigate the research question. With the project being done for two universities at the same time, it is important to outline the different approaches that this may imply.

In general, the research is composed following the Anglo-Saxon approach that entails a data-gathering section and an analysis of the data in comparison with the provided theoretical background.

The main source for this methodology section is Bryman and Bell's "Business Research Methods" (2015).

3.1 Strategy of the research

In order to best pair the concerns that the author is facing in the field of innovation and industrial management, the research was better indicated to be qualitative. Tailoring a quantitative research around the 5G and Industry 4.0 connection would have been possible by giving a strong emphasis on real-time data analytics or the accounting implication of the investments on new technologies.

By contrast, the author wanted to match the need of a business perspective of the industry transformations in relation to the newest technologies with a qualitative research that could encircle the business breakthroughs in a widely descriptive and complete way.

The undertaken approach is inductive. Bryman and Bell (2015) state that the inductive approach is aimed at generating theory through the examination of real-life occurrences, whereas the deductive one starts from a theoretical basement to shape a business layout.

With the research being qualitative, the connection with an inductive approach is immediate. Ordinarily, the best way to create a theory is by analysing a case study, either individual or multiple, with qualitative research tools such as interviews, focus groups and open answers questionnaires. This strategy is chiefly applied in the second research question, where the generation of a value chain draft is the consequence of the Smarta Fabriker project investigation.

As for the first research question, the goals are labelled in two fragments. The first goal is to test the theoretical background of the 5th generation of networks, its standards, and its business expectations, through the Smarta Fabriker environment. The second one aims at discovering Ericsson and its competitors' progression in the future telecommunication market, their customer perspectives, and general knowledge of the 5G disruptions through the analysis of the interviewees insights. The combination of the two leads to the answer to the first research question.

The thesis is then structured to compare the literature's notions with the empirical findings extracted from the interviews. Therefore, the author arranged the second chapter in order to extract some easily comparable areas:

- Industry 4.0
- Cloud and Edge computing
- 5G networks
- Public institutions
- Universities

These areas are the nucleus of the data gathering phase, where stakeholders are interviewed to get findings about the technologies' status, the future telecommunication market and its adjacency with the upcoming Industry 4.0.

Thus, the analysis aims at comparing the theoretical framework with the empirical findings to find commonalities and discrepancies and to probe the research questions.

3.2 Systematic literature review

The strategy outlined in the paragraph above brings to the reader's attention how crucial the theoretical framework is for this research to be accurately conducted.
This review aspires to describe the principles with which the theory was written down, listing sources and assumptions and the inclusion/exclusion criteria.

The following table exhibits a summarized inclusion and exclusion paradigm employed by the author to establish the theoretical section.

Inclusion	**Exclusion**
Business and market perspectives	Engineering and technical knowledge
Value chain and supply chain implications	Innovation models of diffusion
Analysis of the technologies	Analysis of the intellectual property rights

Tab. 4 – Inclusion and Exclusion criteria

Because of the initial focus of the research, namely the telecommunication industry, and of the Industry 4.0 subject arisen from the selection of Smarta Fabriker as the case study, the theoretical framework is necessarily structured around these two fields.
The author used the report from Rojko (2017) to describe the very basics of the smart factory. The business and supply chain implications, together with the spotlight on the additive manufacturing processes, are the result of the scrutiny of reports found on the SuperSearch tool of the University of Gothenburg and other databases like Google Scholar and the Journal of Product Innovation. The remarkable articles in this field are those from Rüßmann et al. (2015) and Lasi & Heiner (2014).
The 5G environment was written taking advantage of the agreement between the University of Gothenburg and the Institute of Electrical and Electronics Engineers (IEEE). The institute's database was key for the research about 5G, thanks to their multiple researches not only focused on the technical depiction of the network processes, but foremost on the repercussions at a business level. Thanks to this, the drafting of paragraph 2.2 was smooth, highlighting what doors are going to be opened from this breakthrough technology and its application within the smart factory. A further dissertation is held on computing technologies as a main driver of 5G.

These two sections represent an odd approach to a theoretical basement for a master thesis. Nevertheless, Industry 4.0 and 5G constituted the fundamentals of the research, and the amount of literature that surrounded them deserved an in-depth description. As a matter of fact, the extremely recent emergence of these two topics in the business environment denotes the contemporaneousness of the academic articles used as a source, all issued after 2014.

On the contrary, the third paragraph of the theoretical framework depicts the so called “Triple-Helix model”. The main aspect that differentiates Smarta Fabriker from other projects is the no-profit mechanism that involves the region and the local universities and colleges with the unique goal to spread knowledge about Industry 4.0. As a consequence, the Triple-Helix model and the massive amount of literature that encompasses it are the perfect matches to theoretically embed Smarta Fabriker into a business context.

3.3 Research design

Undertaking a qualitative research is ordinary when the researcher wants to simplify complex concepts for the readers. Usually, the case study is the best way to give real examples of an unknown or relatively blurry subject. As a consequence, the author chose Smarta Fabriker as a proper *individual case study* to outline and illustrate an unknown and unapplied technology like 5G and its connection with the smart industry environment.

A cross sectional and longitudinal study would be more suitable for this class of subjects as benchmarking among different standpoints allows a clear-cut demarcation of the research edges and prevents the single case to be exploited through generalized statements. Conversely, the time limitation imposed by both universities does not allow the author to engage in such research design for the sake of the project quality. Besides, Smarta Fabriker embodies the characteristics of a wide-ranging case that prevents the research from being too generic. The extent of bodies involved in the ecosystem makes it one of the most appealing studies in the whole Swedish innovation industry, being it clustered in the Lindholmen Science Park together with all the partners and universities. World leading companies in their respective markets, with the likes of ABB, Microsoft, Volvo and Ericsson cooperate so as to make it extremely competitive with respect to other similar projects, making it hard at the same time to leave space to generalization for this matter.

The inherent rationality of the case study is the analysis of the groups in the ecosystem and the emergence of a value chain that highlights the interactions among them. For instance, the linkage between industrial suppliers and IoT consultants is brought to attention through the emphasis on the synergies in the project between ABB (robots producer) and Cybercom (innovative consultancy company). This steers the research from a macro to a micro level, pinpointing the edges of the research domain and the collaborations incurring internally.

The interactions that will be observed, either generically and specifically, are the following:

- Robots producers with IT consultants, telecommunication operators and manufacturing companies
- Telecommunication operators with companies in their same industry, cloud computing operators, industrial manufacturers and consumers
- IoT consultants as a liaison between industrial suppliers and telecommunication operators
- Business companies with the government institutions and the education bodies, according to the Triple Helix Model

3.4 Research method

The method applied in this research has to counter both the strategy planned and the research design. As for Bryman and Bell (2015), the research strategy is what shapes the research methods used to collect data. As a result, the qualitative and inductive kind of research most likely demands tools such as unstructured interviews and focus groups. The reason behind that is the ease with which such means find practical evidences from theoretical sources. Unlike structured interviews, that allow data gatherings to be immediately comparable and therefore are ideal for quantitative research, unstructured interviews are more flexible and enable the interviewer to drive the interviewee towards his preferred areas of research. Likewise, unstructured interviews are more suitable for this particular research due to the author's objective to examine the case from the perspective of actors covering completely different roles. On the other hand, focus groups are more complex to operate within this exact research because of their problematic arrangement and because of the time limitations. Thus, few initial focus groups were organized in order to introduce the author to the research scope, and they will henceforth be described.

As mentioned before, the author wanted to analyse the viewpoint of all the parties involved in the project. ABB was chosen to represent the tangible materials suppliers, as it furnishes all the robots to the Smarta Fabriker project. Ericsson is the main telecommunications provider; thus, two interviewees are needed to examine the viewpoint of this segment. Cybercom, which is an IT consultancy company, gave evidences on the process analytics and on cloud technologies.
To represent the Triple Helix model, a respondent from the region Västra Götaland and one from Göteborgs Tekniska College were chosen.
The following table recapitulates the interviews' features.

ENTITY	NAME	MANSION	TIME
ABB	Björn Magnusson	Global Key Account Manager	30'
ERICSSON	Sebastian Elmgren	Smart Manufacturing Portfolio Manager	30'
Göteborgs Tekniska College	Johannes Persson	LEAN Coach and Consultant	30
VÄSTRA GÖTALANDSREGIONEN	Hans Fogelberg	R&D and Innovation Policy Expert	45'
CYBERCOM GROUP	Henrik Löventoft	IoT/Cloud Business Manager	30'

Tab. 5 – Interviews

The interviews were sectioned in order to compile the data categories prepared by the author. Such categories are explained in paragraph 3.5.

Aside from the interviews, the author took part in various focus groups that acted as an introduction field for the research, having a worthwhile role in the formulation of both research questions and in the study's kick off. These focus groups took place in the Lindholmen Science Park in Gothenburg between February and March 2018, taking advantage of the proximity of all the participants coming from different companies, more specifically in the Ericsson Garage and Chalmers University. The participants were Jonas Wilhelmsson, Global Engagement Director at Ericsson, Fredrik Flyrin, Innovation Program Manager at Ericsson, Johan Bengtsson, Project Manager at Smarta Fabriker, and Per Östling, Advisor at First to Know.

3.4.1 Validity

The validity of a research assesses how the insights emerged from it can be compared and replicated in other cases. Even if the notion of validity is mostly intended for quantitative research, being quantitative data more easily paralleled among them, it can be extended to a qualitative research through the codification of qualitative statements and the subsequent resemblance of them with other circumstances. Such validity can be intended as internal and external.

The internal validity measures the level of comparability with the theoretical basements. In the case of the Smarta Fabriker project, the internal validity is remarkably acknowledged. The theories behind the 5G networks and smart factories emerged in very recent researches, often pursued at a very decentralized level by highly recognized institutions (such as the IEEE and the ITU). It is also significant to mention that this whole ecosystem still needs to be fully converted from fictitious to concrete, as no one still knows what will exactly happen when it matters to 5G networks. On the other hand, Industry 4.0 has more defined strategies and layouts. As a final point, the Triple Helix model is more generalizable and the synergies incurred in this specific research may find discrepancies with what is mentioned in the theory.

When it comes to the external validity, seen as the ability of the research to be generalized to other similar cases, it is debatable that this study will find the same repercussions elsewhere. The creation of this project is the result of a particular situation of cooperation in an innovative country such as Sweden, and more specifically within a cluster of innovative companies in the

Lindholmen Science Park in Göteborg. Even if the case study does not focus on a single company, the complementarities of the companies involved together with the joint support of the institutions and the education system are something hardly found in the market. Other reasons for a fairly low external validity are aligned with the research limitations mentioned in section 1.5.

3.4.2 Reliability

Analogously to the validity, the reliability of a qualitative research is something to be investigated indirectly. Still, the external reliability of the research is respected for both the first and the second research question. As stated by one interviewee, the telecommunication industry is highly standardized and all the actors incur are incentivised to collaborate for their customers, whether businesses or consumers. Therefore, the influence of a connectivity provider in a smart factory project arises the same results for different cases worldwide. At the same time, the second research question has the goal of obtaining a value chain that generalizes commonalities among different players in a reliable way.

As for the internal reliability, the interviewees were chosen together with the project manager in order to best represent the different players of the project. Still, more than forty companies are represented by interviewees coming from five entities, making this study slightly reliable internally.

3.4.3 Description of the sample

The interviewees were chosen together with Johan Bengtsson, project manager of Smarta Fabriker, and Fredrik Flyrin, Ericsson's innovation program manager and supervisors for the master thesis done with Smarta Fabriker. The author's sampling criterion and objective was to get evidences from authors representing as many parts of the value chain as possible.
The explicitly required ones were a representative for the manufacturing actors, a 5G expert from Ericsson, a cloud/AR expert operating within the project, a member from the education system (either from GTC or Chalmers) and a member of the region in charge of the project. Due to time limitations, the author could not get evidences from other optional interviewees,

that were another student doing his master thesis project with Smarta Fabriker - to get other perspectives for the education system – and another Ericsson's worker, to strengthen the analysis on the 5G strategy.

3.5 Empirical findings layout

The data gathered for the research were labelled beforehand, so as to make the drafting of chapter 4 smoother and straightforward. This was made in order to codify the information through aimed topics chosen by the author/interviewer, conducting customized interviews at the same time due to the diversity of the encompassed entities.

The first goal is common to all the interviews, and it is to outline the *role* of the entity represented and its contribution to the Smarta Fabriker project, analysing the incentives behind such collaboration.

The second class of questions concerned the *status of the technologies* utilized in the project, namely artificial intelligence, cloud and edge computing, augmented and virtual reality, and 5G networks. This was made in order to get insights for the "moving sequence" outlined in the analysis and mentioned in the second research question. The insights are comprehensive in all the interviews but slightly steered towards the technology that the interviewee mostly deals with (for example, the focus of the interview with Björn Magnusson from ABB was artificial intelligence).

The third section is tailored for both research questions and is related to the *organizational implications* of these new technologies in future companies. For the sake of clarity, such implications are about the systems of communication and flows of information within the company, the outcomes related to the layout of the assembly lines and the decision-making processes variations.

The most important part of the data collection to get results for the second research question is the fourth one, that is about *value-chain repercussions*. Questions were explicitly aimed at understanding how the synergies with the external environment change in these new industrial era (conversely to the organizational implications that anal-ysed the internal variations). Rapprochement of industries and convergence of roles, as well as the disjunction of others, are the main focus of it.

A fifth section is written to describe the *business level consequences* of smart factories, meant as how the market's strategies will turn out after the shift to this new production system. Finally, the sixth section analyses possible after-effects from the *perspective of the consumer*, with it being distant yet so close to the businesses at this point.

3.6 Analysis and conclusions layout

The fifth and sixth chapters compare the second with the fourth one, following criteria that are elected by the author. This means that such chapters entail a personal perspective of the author, either in the reinterpretation of the findings or in the comparison with the theoretical background.

The data analysis is rearranged in order to find responses to the research questions. It starts off with a general comparison between the theory and the findings; subsequently, two sections are respectively dedicated to the two research questions, with the second one being broken down into two more sub-sections, one for the moving sequence and one for the value chain of the actors participating in the project.

The conclusions have the purpose of summarize the final findings of the study as well as providing suggestions from the author. It is thereby divided into three sections, that are a summarized reply to both research questions, recommendations by the author on the smart factory research matter as well as a basis for future research proposals on the same field.

4. EMPIRICAL FINDINGS

The following section aims at outlining the reasonableness and practicability of the research topic as articulated by the interviewees. Thus, the content of the section consists of empirical data rearranged by the author in a clearer way, in order for the reader to get what the aim of the research is.

Information in this chapter derives from the interviews. Thus, no add-ins nor personal opinions from the author will be included, leaving space in the analysis to depict the similarities and/or complementarities of the theory with the data. All the sub-sections are involved in both research questions, albeit with different propensity, with the intention of demonstrating how all the players congregates in a joint ecosystem. Notwithstanding the difference concerning their standpoints, the answers gathered from the interviews are hardly diverging, suggesting the unity of purposes that characterizes this working environment. The spread of knowledge as a main goal for all the stakeholders helped the author to gain evidences and insights without any particular struggle, being able to work alongside other students in order to exchange viewpoints.

The author chose to write down the chapter following a cross-sectional approach. Such approach entails a section for each area argued in all the interviews, preventing the sections to be structured for each company. This should both help the reader to have a holistic view on the data and assist the author in the drafting of the analysis.

4.1 Roles within the project

As mentioned in the previous chapter, five different professionals, all coming from different stakeholders, were interviewed in order to compose this section. Three of them worked in companies, namely ABB, Ericsson and Cybercom, while one belonged to the region Västra Götaland and one operated within the education system, more specifically in the Göteborgs Tekniska College.

Starting from the goal that each entity has in relation to this project, it is evident that due to a structured and organized network of incentives, all the entities work for a unique target, that is to create and share knowledge. The most palpable validation emerges from the statements of mr. Hans Fogelberg, R&D and Innovation Policy Expert at Västra Götaland, the region of Göteborg and main driver of this project. *"The main reason for this is that manufacturing is not as popular among students as it should be. Smarta Fabriker has a lot of legitimacy among the top companies (like Volvo) and this means that top managements are all involved in this, which is not what you usually see in other random projects"* he said, sustaining that the diffusion of manufacturing among young students is an important driver for the future economy. *"The region is in a way responsible for achieving long term growth and for developing an economy which is knowledge based, favouring the manufacturing cluster of companies in western Sweden".*

He also put the spotlight on the tangibility of the smart manufacturing world. Young people tend to be skeptical about it as it is seen as something extremely future oriented. On the contrary, the region wants to approach them and showing how it is already being implemented in companies, fitting the interest of the region itself for the autonomous manufacturing industry.

With the same purpose, the professor and consultant Johannes Persson, represented the Göteborgs Tekniska College in this research. GTC is the owner of the project, and their goal, as stated by Persson, is to spread knowledge about the digitalization and technology within the region, and to show that it can be funny, in order to get more motivated people to join their school.

With this being said, the project works owing to the network of incentives started from the region and moving to all the other stakeholders. The region finances the project with the purpose of long term growth and knowledge diffusion. The GTC and Chalmers University have more means for the students' hands-on practice and gain attractiveness, as well as companies that take advantage of the funding to experiment their technologies and prototype the outcome of their researches.

In particular, Ericsson provides the connectivity of the factory and gets feedbacks for their 5G infrastructure. As stated by the Smart Manufacturing Portfolio Manager, mr. Sebastian Elmgren, the reasons for this collaboration is for experimentation and research, excluding commercial targets.

He also explained why choosing a smart factory as an experiment for 5G was one of their first choices, along with the fact that smart manufacturing is at the moment the most immediate and straightforward application at a market level. Elmgren outlined that compared to the other generations, 3G and 4G were built for human needs, so they were only getting faster and faster with larger bandwidth. For 5G, the market has the first technologies that are designed for machines and applicable for industrial cases. *"That is why 5G will come in different flavours"* asserting to the different implications that such technology has on a business level, and that will be further discussed in the next paragraph.

At the same time, Björn Magnusson, Global Key Account Manager at ABB, cooperated with the author to outline how ABB is working with Smarta Fabriker and what are their short and long-term goals.
ABB is a multinational company that operates in the production of robotics, heavy electrical equipment, and generally on automation technologies. Their basic task in Smarta Fabriker consists of providing control systems and robots, making them one of the core companies in this ecosystem. As mentioned by mr. Magnusson, ABB is furnishing robots that are smaller than the ones the use for the usual production, but with the same standards. As a consequence, what they get in return is what they refer to as digital twin. "*The project is divided in several parts, but the business driver is to produce a digital twin, which is a digitalized version of our factory, and we are doing that with Smarta Fabriker. In this way, we can manage the production from our computers, not only by seeing a 3D version of the production but also by managing the PLC and controlling part".* And again, when asked why did ABB choose this project, he stressed that the final purpose is to tailor the market for virtual commissioning. As robot commissioning procedures require a lot of time, in this way they can manage such commissioning with a virtual design. *"Doing that as a system integrator can save us a lot of time. You can fulfil the production demand and send that to the robots and to the ERP systems".* They also have a parallel project with Ericsson to switch the communication protocols to 5G, in order to accelerate the process of conversion of the factories from LTE connection to 5G.

Lastly, Cybercom represents the main connection between factories and telecommunications, providing consulting services to link the respective know-hows via cloud based systems and information flow accelerators. Henrik Löventoft, IoT and Cloud Business Manager at

Cybercom, explained their role as developers of the app for machine monitoring and ordering: *"We are developing everything within the cloud, together with the mobile app and the hololens' application, which concerns the digital twin. We manage the connection between the cloud and the edge"*.

The following table summarizes the tasks and goals for each stakeholder involved in the Smarta Fabriker project.

ENTITY	**ROLE**	**OBJECTIVE**
ABB	Provider of control systems and robot supervision	Formulation of a market for virtual commissioning
ERICSSON	Provider of connectivity for the factory	Getting feedbacks for a 5G connection in a smart factory application
Göteborgs Tekniska College	Students participating in the development of the factory	Sharing knowledge about smart manufacturing
VÄSTRA GÖTALANDSREGIONEN	Sponsor and funder	Long term growth and development of knowledge-based economy
CYBERCOM GROUP	Technical consultancy for the development of the app for machine monitoring and ordering	Fostering the development of the factory

Tab. 6 – Roles of the companies in the project

4.2 Status of technologies

One of the main concerns of the research is to pinpoint the status of the innovative tools encompassed in the project, in order to get evidences for the second research question, and in particular for the arrangement of the “moving sequence” of these actors.

The technologies involved are several, but the author decided to group them in four comprehensive categories to foster the codification of the qualitative statements into measurable units.

The categories are the following:

- AR/VR
- Cloud and Edge computing
- Autonomous robots and machineries (also intended as artificial intelligence)
- 5G

The interaction of these four groups of technologies allows the effective performance of the factory and constitutes a driver for the future progress of the smart factory. As mentioned in the website of the University of Chalmers, Cloud-Based PLC is aimed at implementing cloud based technology, implementing and evaluating a distributed virtual PLC in the cloud as well as evaluating and prototyping the cloud security model of the virtual PLC.

Most of the respondents agrees on the fact that Cloud Computing is something already fully implemented and marketable. Cybercom is the main player operating with Cloud Computing, taking advantage of their expertise in that field. “*Cloud computing is already there, we all know that”* said mr. Löventoft. Furthermore, mr. Persson from GTC stressed that Cloud computing is happening now, but it will still be a very important topic for at least the next 10 years. *“If you want to connect everything, it has to be in the cloud. The only possible problem about cloud is cyber security, because companies are really worried about their data. Anyway, cloud will shift from a plus to a necessity, a standard”.*

It is then fundamental to outline the distinction between Cloud and Edge Computing. As pointed out in the theoretical section, Edge is a move forward in the virtual computing technologies. This concept is thereafter strengthened by mr. Löventoft: *“If you look at predictive* *maintenance, you do the measurement of the data and their modelling and performances in the cloud, sending that back to the edge. Such technology (Edge) is becoming the biggest trend because it helps to send the right things to the Cloud, and not just random things".*

Moving on to AR and VR, the discussion gets more intricate. To begin with, they are now both dealing with same issues at a factory level, but with the progression of the technologies they will inevitably diverge the usages and applications. Mr. Löventoft asserts that AR and VR are both related to the digital twin concept. "*They are both 1 or 2 years away in terms of reaching the market, but the applications will be different".* But as a matter of fact, AR will be the game-changing technology for the industrial IoT. "*AR is still on the stage, but we have some values already. Cost savings and consequences on the processes are something that still needs time, while we are already experiencing consequences with training and modelling with AR devices"* he said, referring to a 4 years horizon.

ABB's Björn Magnusson says that the next parameter they will focus on is the implementation of AR and VR in their factory, and this will happen for the next 3 years. Analogously, mr. Elmgren from Ericsson agrees with this position.
Conversely, mr. Persson extends the time-to-market to 5 years. *"AR is more useful than VR, but there are still some concerns to sort out. One of these is that the goggles used for AR are uncomfortable and too big, but in 5 years there will be normal glasses with AR embedded in them. I bet that 2 billion people will use AR in their everyday lives in 10 years".*

As to machine to machine artificial intelligence, the visions of all the stakeholders is definitely more prudential. First and foremost, AI is a very broad and unconstrained field that is hard to define, thus it is difficult to forecast its market implementation.
Anyway, mr. Magnusson states that "*we are working on that, it is the next step. Smarta Fabriker is in its 1.0 stage but we are planning for the 2.0 through the combination with 5G".* 8 to 10 years is the time he expects for AI to be fully operative.

A further opinion is given by the region Västra Götaland. "*These technologies are accelerating in only few companies, and the development of these companies will be very important.*

Automation is the basis of manufacturing but many companies are not enough advanced on it. [...] That is due to the really high cost of autonomous robots and because smaller companies do not know how to do it, so there is a lack of knowledge" said mr. Fogelberg. *"We are in a transition phase, and don't know what is really going to happen next. The analytics side will be key, because solution providers are those driving the change. The mechanism is top-down, so there is the need of people that knows what to do and take decisions. We have not yet entered the area where the manufacturing system itself knows what to do".*

And about the time horizon, he added that he is pessimistic about it. Companies are still exploring this world, and do not know when it will really take off. *"Technologies are available for certain specific areas, but that is not the same thing as proper implementation. We can compare it to autonomous vehicles: they are already here, but they will be used at least after 15 years, the same as for machine to machine".*

A similar belief belongs to Ericsson - "*Today 95% of a factory connectivity is with cables. Our strategy to cut these cables is driven by flexibility and predictability, and will stress us out for the next 10 years at least"* – and more optimistically to Cybercom – *"If you see it from an AI and maintenance perspective, I guess that the technologies are there but the companies still need 6-7 years to gather information in that direction, thus they are researching applications of that".*

Lastly, GTC's Persson sustains that, among all the listed tools, AI is the furthest away. *"We went to a fair in Hannover and we found only four examples of AI out of thousands of exhibitors. A lot of them are trying it, but they did not implement it. Artificial intelligence for me is when a machine can make a decision and adapt to that. It is not only condition based answering to yes/no problems, but is something more complex and broader. It needs more time than 5G".*

The final study is done on 5G networks. 5G took years to be developed, but now that the technologies are here, there is another important step to overtake. "*5G is in a testing status. It is not commercialized, but with SKF we already have a 5G area running in Gothenburg for example"* says mr. Elmgren from Ericsson. *"The first problem is that there are no commercial licenses anywhere in the world for 5G. Everything is done on a test basis when you have a temporary term for working on those frequencies. I would say that the commercial deployment* *will be by 2020, that is when the product will be commercialized and when we have an available spectrum for wholesale companies to buy equipment".*

Less than 2 years is the same time to market expected from both mr. Persson from GTC and mr. Löventoft from Cybercom. ABB's position is more long-term oriented: "*Smarta Fabriker is our field to test robots in 5G networks. We need the same time for 5G and for M2M communication to be properly installed in our factories"* said mr. Magnusson.

The following table summarizes the data collected vis-à-vis the technology status. The numbers stand for the expected time horizon for the technology to be implemented at a market level.

ENTITY	**5G**	**Cloud and Edge**	**AR/VR**	**AI**
ABB	8-10y	0	3y	8-10y
ERICSSON	2y	0	/	10y
Göteborgs Tekniska College	1y	0	5y	10y
CYBERCOM GROUP	1y	0	4y	6-7y

Tab. 7 – Technology statuses

4.3 Organizational implications

Together with changes in the consumer's behaviour and in the external environment, the emergence of Industry 4.0 affects innovative companies from an inner perspective. The disposal of accessible and automated tools enables the managers to arrange the layouts of their business units in different and more flexible ways, with the purpose of empowering the resource efficiency and reaching a mass customization mechanism.

The first concern is on the decision-making design within the company, and the contiguous flow of data and information among the company level in accordance with the information systems cited in the second chapter (Figure 2.2).
A decision-making process can be held at a centralized or decentralized level. Both processes occur in the organisational chart of ABB, "*because the management level still needs to know everything, but for separate programs like this one (Smarta Fabriker) we need a more agile and local team to take decisions*". In most companies, ERP system are connected to the production level in order to stream the performances of both sales and supply chains to the job-floor. "*It does not happen with Smarta Fabriker. We use more MES system, to link the customer's order with the production line*".

Another fundamental driver of the decision making in a company is the combination of Cloud and Edge Computing. The combination of them both does not only affect the storage of data and the programming of the robots, but they also enhance the information flow between the machine and the job-floor operator.
Mr. Persson better explained this: "*there is Edge and Cloud decision making. Basically, with Edge you can directly decide without sending information somewhere else. It means that the machine takes the decision autonomously. With Cloud, information is more centralized and data are processed there with artificial intelligence. What you need is a machine that acts and reacts to different factors, taking decisions that humans can't do. In a short-term perspective, you will have way more knowledge about the processes through condition-based monitoring, and that is because we connect everything and figure out what is ok and what is not. Conversely, in a longer time horizon, the machine is expected to act and react autonomously against a problem or any other event*".

The Triple-Helix view of this whole matter entails variations in all the three institutions to develop a clearer and stronger cooperation.
The region is the driver of this transition. *"This is mostly happening at a research level. A lot of universities and research centres are responding to the requirements that come from the region. The advantage is that our system is really agile, with fast responding times of maximum one year, due to the fact that Sweden is both a high-tech country but not so big. You can typically gather the most important people together from the same area and take a decision very easily".* This statement from mr. Fogelberg underlines how Sweden, and specifically Västa Götaland, represents the most suitable country for the enactment of such cooperation.
To react to these requirements, the education system is stimulated in pooling their resources to help the region to pursue its goal. According to Johannes Persson, "*GTC is changing his organization. In 1998 we were just a secondary high school, but after that we started with consultancies and other types of education to servitize our researches".*

One last face to consider is the management of the human resources within the organization. On the word of mr. Magnusson from ABB, "*an important standpoint is the change of culture in our employers. We have mechanical, electrical and PLC programmers, and as they are separated we need to make them work together to reach these goals with an innovative perspective".* And as to the autonomous communication between robots, he analysed how the upcoming machine to machine era can change the whole process control, eventually creating some problems. *"We are still in the machine learning phase. That could even be a problem if you do not control their development as they start to take autonomous decisions that may be wrong. We are implementing this to small machines, but just to program machines to behave in a specific way".* Hence, the shift from machine learning to machine-to-machine is put under the spotlight from manager of big innovative companies.

4.4 Value chain repercussions

In order to get confirmations for the interpretation of the comprehensive value chain investigated in the second research question, the respondents were asked questions on the role they perceive their respective company or entity to have in this ecosystem, and how this relates to the future of their respective markets. The linkages between the actors are examined to understand the drivers and the incentives on these collaborations.

The upcoming servitization trend, that will be further debated in the next paragraph, is one first variable of the change of the value chain of innovative companies. The result of such trend is the rapprochement of the company with the customer. The sale of a single end product keeps the company reactive merely in the after-sale phase, whereas with a bundle of services that surrounds a single product, the company has way more chances to interact with the users to gain more feedbacks and create more win-win situations.

Such interaction with the customers necessitates a switch from reactiveness to proactiveness. As a result of the combination of services requiring the effort of more than one company, there is a conciliation of actors at the top of the value chain to accelerate their time-to-market and time-to-response. Cyberom's Henrik Löventoft agrees that: "*The new economy is networking. We are a consultancy company, so we are actually helping companies with the likes of Ericsson and ABB in supplying their services. We have contacts on an everyday basis, so as to gain advantage on our competitors and satisfy their customers more. It is all about elasticity".*
The region itself supports this idea. *"It is not common to call ABB to fix 2 robots and get an immediate and positive response. This project is the solution to show how these companies operate".* Besides, mr. Fogelberg explains what they to within this framework: *"We communicate with companies even if exactly within the framework of this project. Still, we have contacts at high level and our concerns are if they plan e.g. a new plant or if e.g. they do not have enough software engineers. We have the picture of what they need and collaborate with them to anticipate the market requirements. We push the supply instead of being pulled by the demand".*

Repercussion 1): *Rapprochement of the companies with their customers due to servitization.*

Repercussion 2): *Focus on the networks with other firms to create proactiveness.*

The knowledge-intensive economy that the region wants to pursue, in accordance with the strong focus on the youngest human resources available (i.e. high school students) is highly affecting the value chain from the side of the Triple-Helix framework. *"The tangibility of the manufacturing industry can't be explained through Power Point presentations and lectures, instead it should be explored with a real scenario, which is what Smarta Fabriker is. This project is an answer to the concern that many companies had for young people. A lot of students are fascinated by this autonomous world without knowing that it is actually existing and tangible, and that it is already implemented in companies. The task of the region is to drive people towards the interest of the region, and this project fits the interest of the region for autonomous manufacturing"*. This changes the focus of the national economy from profit-driven to knowledge and innovation-driven.

From this angle, the education system is moving closer to the governmental institutions and is raising their value in the national innovation system. The reason behind it is that the only interaction between the business level and the governmental institutions embraces monetary investments, and regulations (that do not concern this particular case as the study is at a regional level). Thus, the education system is the only entity working in a continuous and ongoing connection with both parties.

This is better described by mr. Persson*: "We are in a network of cooperation in the region. We exchange knowledge and receive support from other companies. We enhance the region and the companies through the spread of digitalization, and that requires us to be present in both sides while at the same time bringing on with our main activity, that is education. This is a key era for research, and we are doing our best to promote its diffusion. We do not create knowledge through research, we just spread it"*.

Moreover, a further confirmation comes from Cybercom: "*We have contacts mostly with the universities. Talent acquisition and marketing/building knowledge are the main drivers. Therefore, we have less interaction with the region"*.

Repercussion 3): *Education entities act with both parties to deliver the circulation of knowledge planned by the region.*

As a matter of fact, the rapidly changing environment in which the companies operate brings difficulty in the demarcation of their roles. Technical and innovative consultancy companies are in the very centre of such environment, having their tasks completely changing from a year to another. As a result, they have to face this situation through the nurturing of cross-skilled employment. Cybercom has four different departments, namely digitalisation, Internet of Things, secure connectivity and cloud services, and this witnesses how such companies have to have a broad and cross-sectioned focus by simultaneously being extremely specialized.

"*The only remarkable change in our role is not the fact that with the enrichment of the technological market, we need to know more stuff in the value chain due to the emergence of new actors, which means more customers. We take more responsibility in the delivery"* says mr. Löventoft. Furthermore, he kills the debate stating that they collaborate with both (telecoms and manufacturers) acting in the middle of the cooperation, *"and that is where we want to stay*".

This makes us understand that the convergence of these two worlds resulted in a convergence of the consultancy companies behind them, that should now be able to face the problems deriving from both industries.

Repercussion 4): *Consultancy companies have their tasks converged to simultaneously face the demands of both markets.*

The final concern amongst the value chain is the effective synergy that incurs between the telecommunication operators and the manufacturing companies, and how such synergy will change in the foreseeable future. The dispute is the following: due to the gradual increase of interactions incurring between telecom operators and manufacturers, will these industries overlap arising a single entity or will they continue to equally cooperate?

ABB's Björn Magnusson defends his company's position showing skepticism: "*We mostly work together with Ericsson to embed the 5G technology to our robots. A lot of people tend to say that telecommunication companies will tend to overtake the whole market, but we have the expertise and experience from industries by our side, that telecom providers do not have. I think it is a perfect cooperation, and it will stay like this in the future".*

Before moving on, a further consideration must be expressed. In fact, the comprehensive value chain that integrates all the companies involved in the Smarta Fabriker project implicitly includes effects deriving from the specific markets of all the underlying actors. In this case, the telecommunication market has remarkable repercussions as to their position in the external value chain but, according to mr. Elmgren, this does not happen at an internal level. In fact, when shown the value chain depicted in paragraph 2.2.1, he asserted that Ericsson's work is mainly on an infrastructure level, occasionally providing some services on top. *"We do not supply any devices. We provide the infrastructure that moves data from the device ecosystem to the application and MES/ERP systems' layer. We do not have the domain knowledge to produce devices, that means that we will stay in the connectivity segment"*. Mr. Elmgren stresses on the fact that the telecommunication industry is highly standardized, because that is what creates value for all the players. *"If you produce a phone, you want it to work everywhere in the world and so on, so there is a tight cooperation to make everything work".*

Leaving aside the establishment of new operators that deals with new 5G technologies such as the Cloud Enabled Small Cells, this means that the value proposition within the telecommunication segment will relatively remain unchanged. What will change will be in the interaction with manufacturers but, as mentioned above, the two industries will start to cooperate at the same level.

A further validation comes from the Ericsson's website itself. It states that "*by using 5G to meet key challenges in digitalization for industries such as manufacturing, telecom operators can act as more than network developers, addressing new revenue streams by becoming service enablers and even service creators. Digitalization of industry-specific business processes creates a vast opportunity for telecom operators to offer their customers not only ICT services but also a new strategic direction using 5G technologies to enhance efficiency and competitiveness – laying the foundation for growth"*.

Repercussion 5): *Telecom operators and manufacturers are acting in cooperation to furnish the connectivity infrastructure by one side, the industrial expertise by the other. The design of services is practised together.*

4.5 Business level consequences

The following section aims at outlining the changes that are incurring to the business model of the companies participating in the Smarta Fabriker project.

The interaction between telecom and industrial manufacturers is altering their business models from various perspectives. From the findings that arose in the interviews, the author is extracting the most noteworthy aspects that incur at a business level in Ericsson and ABB, predominantly to find answers to the first research question.

From the interview with mr. Björn Magnusson, the following were the most inspiring cues:

- The company will follow the servitization trend.
- This will result in the robots working on demand, reducing resource wastes.
- The after-sales phase will require less effort due to the less capital intensity of the services over the end product.
- Easier control on the robots.
- Smart automation is a vehicle to reach the objectives of reduction (production costs, logistic costs and quality management costs decreased by 10-30%).
- Increase of the customers differentiation, keeping the volumes high (mass customization).

Ericsson likewise provided critical information on the way to combine 5G with the smart factory.
This is what emerged from the interview with Sebastian Elmgren:

- 5G will be customizable. By connecting a car, you can benefit from low latency with a narrower bandwidth; connecting the area of a concert, you will need a larger bandwidth even with a higher latency. Another variable is the battery life of the device.
- 5G will address more connection-demanding applications.
- The strong improvement on wireless connectivity will boost the flexibility of the job-floor (see paragraph 4.3).
- Broader product mix of the companies.
- Cost savings due to less cabling.
- More reliable than other wireless connections like Wi-fi and Bluetooth.
- Shorter product life-cycles.
- Massive number of sensors that enables a better prediction for preventive maintenance and performance measurement.
- Most critical technologies are the MM waves and the streamlining of the network that allows a lower latency.

In addition, Mr. Elmgren stressed that Ericsson will slightly avoid the huge investment that the other operators will face to implement 5G. *"I would see big investments for an operator that covers a whole country. That does not happen when you just want to cover a factory. Furthermore, if you have devices that use the 4G network, you just have to switch out the frequency dependent path lines and the upgrade will be not costly. As a consequence, I don't think that the investment from a factory perspective will be huge, and that is why I see the smart factory as the first application of 5G. As for Ericsson, we will not face huge investments because we do not invest in technologies. What we do is investing in research and create equipment that the other operators and vendors buy from us. In this way, we get more value from the investments in 5G than the expenditures we have on it".* This justify why Ericsson and all the connectivity providers in this market are in the very centre of the 5G ecosystem, and are the ones with more profit opportunities, disregarding the investments in such technology.

4.6 Consumer's perspectives

The physical consumer is an outlying topic in a discussion that relates exclusively to business to business companies. Nevertheless, the author tried to go through some implications that the 5G environment implemented in production factories may have in the consumption habits of the physical consumer.

The field is blurred and uncertain, as most of the respondents reply. *"It is difficult to find differences from a customer perspective; all of this has more implications at a social level. For Sweden, for example, it helps to spread knowledge and preserve manufacturing. The benefits are that we can manufacture in a cost-efficient way very high-quality products. The solution is just knowing how to use manufacturing, so benefits are visible from a knowledge economy perspective. The only advantage for end consumers that I see is that products are just better and cheaper, but it is a long-term perspective".*

The long-term perspective debated by region's Hans Fogelberg is strengthened by mr. Elmgren. His point is that the same happened with 3G and with 4G; due to this proactive and push approach, the release of this kind of technology is always surrounded by uncertainty. But now, with both 3G and 4G, there are millions of applications used at a consumer's level. Anyway, his first perception is that augmented and virtual reality will be fully implemented in the everyday lives of consumers through smartphones and other devices, and therefore they will totally take advantage of the extremely powerful 5G network.

One last consideration belongs to Cybercom's Henrik Löventoft: *"Everything is becoming more transparent, so basically the value chain will be more explicit and product/production will be clearer. And transparency leads to other values, like efficiency, cost gains, lower prices and better quality. And it allows us to create new services"*.

5. DATA ANALYSIS

In the following section, the author wants to readdress the purpose of the research to its starting pillars. The research questions mentioned in the first chapter were meant to drive the research within specific railways, whilst some other subjects not considered in the starting point entered in the research field to make it more complete.

The first research question points at what are the usages and applications of 5G in the industrial Internet of Things and in the next generation of the industrial manufacturing. These applications are examined through their feasibility, usefulness and time horizon. The RQ is satisfied taking evidences from the role of the stakeholders, the status of the technologies and the business level consequences described in the first, second and fifth sections of the previous paragraph, and the subsequent alignment with the theoretical basis.

The second one concerns the actors biasing the smart factories. The aim is to examine the relevance of their role and the impact they have on other stakeholders. The RQ is thereafter responded through the examination of the value chain repercussions listed in section 4.4. The outcome arisen from the status of the technologies and displayed in the relating table will be used to sketch out a moving sequence of the stakeholders.

As a consequence, three sections are arranged to draft the analysis of the research. The first one underlines the correspondences and the inconsistencies between the theoretical section and the data collected in the interviews. The second one generally analyses the circumstances around the first research question, while the third one answers to the second research question.

The language and writing technique adopted by the author includes the personal analysis of all the content, either theoretical or empirical, previously cited in the work. Nonetheless, the following chapter is written accordingly to a source or basis, that can be either included in the previous chapters or perceived in all the sessions/discussions/focus groups/colloquiums attended in the Lindholmen Science Park during the period of the research.

5.1 Theory and findings' comparison

The three main theoretical fields used to kick off the research were all investigated in the findings. The comparison between such section is explained thereafter.

5.1.1 Industry 4.0

To start off, what emerges from the theoretical section of Industry 4.0, aside from its main features, is the business and supply chain consequences of this new era. Within the concepts of Industry 4.0, the Smarta Fabriker project has a strong focus on what is mentioned as "digital mapping and process virtualization" in the theory. The correspondence arises from the creation of the "digital twin" as a main goal for the project and repeatedly emphasized by ABB in the interviews. Another key correspondence stands in the employment of smart means to autonomously measure industrial performance, done in collaboration with Cybercom through the app for machine monitoring.

From an auditing perspective, no results in terms of cost efficiency are reached by the companies using the Smarta Fabriker model. The time before reaching a 10-30% cost reduction due to smart means is still long, while we are still in the phase of assessing CAPEX and initial investments.

Besides, the decentralization of policy and decision-making practises, when going through the findings, emerges in two ways. The first one is in a present and short-term perspective, and consists of the distribution of decision makers in smaller teams that are assigned single tasks of collaborations with other companies, with the purpose of creating agility and flexibility in the organization. This was stressed at both institutional and business level, namely from GTC and ABB. On the contrary, a long-term perspective is shaped by the M2M communication in the factory. Once machines will be able to take their own decisions about production processes, the distribution of decisional power will be even further placed at the bottom floor of the organization, with every single device overcoming humans in decisional hierarchies. In order to have this verified in factories, the market should wait for the development of artificial intelligence at full capacity and its implementation in the Edge architecture.

With regards to the automation pyramid, the technological development will comprise the operative level, including tools with the likes of MES and SCADA, as confirmed by ABB and

Cybercom. ERP systems are no longer in the very centre of companies' strategies, as their principles of centralization of decision-making power to the upper levels of the organization are unaligned with the future development of Industry 4.0.

Within the supply chain consequences, the main concern was about Mass Customization. Companies are discussing such strategy and its feasibility, but still, besides the few statements by ABB, the findings are not enough to build up a general MC path for manufacturing companies. The perception is that such companies are still in the mass production phase, and will gradually increase the level of individualization of their products once 5G will drive the flexibility of the job-floors.

The last concern of Industry 4.0 was the industrial usage of augmented reality. Among the applications catalogued from the theory, the project enhances the usage of IAR foremost for employee training and education, together with virtual modelling of the factory (part of the digital twin) and partly for the process monitoring. Conversely, augmented reality is not yet employed for cost saving purposes nor for process acceleration, however they are both in the plans of most companies.

5.1.2 5G Networks

Moving on to 5G networks, the interview with mr. Elmgren from Ericsson alongside the insights provided by the other entities suggests different fields of similarities and differences with the theory.

The comparison starts with the innovative disruptions that 5G is bringing to the network infrastructure specifically for smart factories. Ericsson revealed the criticality of Node-centric networks and mmWaves in this field, as they are the two main drivers of low latency and reliability of the connection within a factory.

From a value chain perspective, no changes incur internally to the telecommunication industry due to its high standardization, except for the Small Cells technology and other minor changes brought by 5G and discussed in the theory. Ericsson will still cover the role of connectivity and service provider, acting at an infrastructure level.

Cloud technologies and particularly Edge computing are fostered by the 5G technology, as it will both accelerate the computing speed and enable the clearing of wires in factories.

Lastly no discussion was made on quantitative aspects of 5G. The critical activities displayed in tables 2.8 and 2.9 were broken down from a qualitative perspective, and the emphasized activities were those concerning the factory and the process automation.

5.1.3 Triple Helix framework

The Triple Helix framework was described in the theory with a generalized walkthrough of the synergies between governmental institutions, education institutions and business companies.
In the Smarta Fabriker project, the governmental institution involved is the Västra Götaland region, while the education system is represented by the GTC and the University of Chalmers. Therefore, the application of this framework should be transferred at a regional level. Anyway, the region is the main driver of the model, due to the fact that all kinds of incentives taking place in the project start from Västra Götaland. The main incentive is the nurture of manufacturing knowledge among the young students in the region. The approach of the model is ex-post, as theoretical knowledge is created after the real-life happenings of the project.
With regards to the linkages between the actors, the framework corresponds between theory and practice in just some of them, as a result of the regional level of the model and the no profit nature of the project. The correspondences are the following:

- The flow between governmental institutions and companies is merely financial. Other minor synergies occur thanks to the proactiveness of the region in helping the companies with their businesses, for example with commissions on new plants or demands for more engineers. Still, this mostly happens outside the Smarta Fabriker project.
- A very hot axis is the one between the companies and the education system. The project provides practice for students as well as research for the companies. In addition, students are employed as human side-resources.

All in all, the project indirectly brings advantages to all the parties. As mentioned in the theory, value and profit is not only financial but also social, cultural and intellectual, as “who you know” and “what you know” are now equivalent to “what you have”.

5.2 5G manifestations in smart factories

This section works as a reply to the first research question, and merely aims at gathering all the focus points of the 5G – smart factories axis that were itemised during the study. The outcome follows the inductive approach described in section 3.1, that is a generation of a hypothetical strategy for connectivity providers (e.g. Huawei, Cisco or Nokia) in a smart factory environment. This is generated by the moves that Ericsson is doing both in a specific relation with the Smarta Fabriker project and with other generic projects. The generalization of this strategy is argued in the methodology section and is further described in the conclusions.

RQ1 says: "How can Ericsson's 5G strategy guide the Smarta Fabriker project?". The verb "guide" requires the description of the practises that are distinctive of 5G and that are "guiding" the development of smart factories, and an explanation of how they relate to such ecosystem. The practises emerged from the study can be crudely labelled under six bullet points.

The first one concerns innovative disruptions already discussed in the previous paragraphs. As mentioned, the component and architectural disruptions brought by 5G are node-centric networks, millimetre waves, a massive MIMO, the use of smarter devices and native support for M2M communication. The analysis of the findings results in the relevance of the first two for the implementation of 5G networks in a smart factory.
Boccardi et al. (2014) describe such node-centric networks saying that "*it may be time to reconsider the concepts of uplink and downlink, as well as control and data channels, to better route information flows with different priorities and purposes toward different sets of nodes within the network".* This allows the reader to understand the immediate relationship between such technology and the low latency advantage that this brings to smart factories.
At the same time, mmWaves gain relevance in a smart factory environment because they are designed for niche applications. With factories not necessarily being big and roomy, the use of a higher frequency has no drawbacks, and leads to a smoother and cleaner connectivity.

The second concept is the progress in the virtualization of factories encouraged by 5G. The digital twin is a key aspect for Smarta Fabriker and has more than once been witnessed as a driver for the acceleration of processes within the factory, more specifically for preventive maintenance purposes. The creation of a digital copy of the factory not only sets up a better sense of space and distance, but allows the full representation of all the processes of the factory through virtual commissioning.

Edge computing represent an additional game-changer for the industry. As a matter of fact, pushing the processing of data to branched stations around the factory enhances the flow of information and accelerates the virtualization of the process. This means that the data processing takes place in the machines spread around the factory, modularizing such process and lightening the data load in the Cloud.
All in all, the small cell technology promoted by 5G will inevitably be a main component of the machine learning advancement through the Edge technology.

A fourth standpoint is emphasized by ABB and supported by Ericsson and is the servitization trend that is shifting the business model of most companies. Ericcson's mr. Elmgren sustained that Ericsson is starting to provide more services related to the infrastructure thanks to this new 5G era, and same was for ABB's mr. Magnusson that listed servitization as a main consequence of the rapprochement of the company with their customers. For example, with the effective 5G connection, machines will work at such a powerful and flawless regime that manufacturing companies will find it better to pay the commission to companies like ABB for the production of a stock of products.

Another crucial adjustment is the drastic increase in the flexibility of the factories. The concept is really straightforward: 5G will provide a better wireless technology than, for instance, Wi-fi or Bluetooth, being able to wirelessly connect machines in a factory. This denotes a reduction of wires and so an easier mobility of the machines thus of the process, smoothening the change in production lines and in products.

In conclusion, the application of autonomous movements in a factory requires the connection to be extremely reliable. As stated in the theory, the reliability of a connection is based on the PLR. Through the findings emerged from the interview with mr. Elmgren, 5G not only will provide a more reliable connection, but a connection that can be regulated in relation to the usage you make of it. If a machine needs a PLR of 10^{-9} (e.g. a printing machine), then the thoughput time and latency as well as the battery life can be weakened. This leads to an extremely reliable connection that will accept very little process inefficiencies and thus a lesser need for maintenance and problem fixing.

The following table summarizes the innovations of 5G together with how they can enrich manufacturing factories;

5G technologies	**Factory progress**
Node-centric networks and mmWaves	Low latency and unrestricted network due to a different frequency
Process virtualization	Creation of the digital twin and better representation of the physical process
Edge computing	Facilitation of the information flow among the machines and avoidance of a Cloud overload
Servitization of the infrastructures	Lower costs and more sustainable business model for manufacturing companies
Enhanced wireless connection	More mobility of the factory components and higher flexibility of the product development phase
Low packet loss rate	Higher reliability and less faults in the autonomous production

Tab. 8 – 5G innovations related to the smart factory environment

As the research question explicitly asks “how” such strategy can guide a smart factory, it is implicit that manufacturers look at the aspects cited in the table to provide a connectivity set in their autonomous factories.

5.3 The smart factory ecosystem

The section at stake is intended as a response to the second research question. To make it clearer for the reader, the response was split into two separate paragraphs. The first one concerns the moving sequence of the actors according to the status of the technologies involved in the project. Conversely, the second one takes advantage from the previous section as well as the findings related to the Triple-Helix framework to depict a comprehensive value chain of the actors involved in a general smart factory ecosystem.

As a matter of fact, such ecosystem is represented including categories of companies and not specific ones.

5.3.1 Stakeholders' moving sequence

The term "moving sequence" is intended as when the four groups of technologies (Augmented and virtual reality, Cloud and Edge computing, 5G networks and Artificial Intelligence) will be implemented in the market at a business level, meaning that they will be used by innovative companies for their businesses. Within the synergies incurring among these technologies (e.g., how a new augmented reality tool could upgrade a smart robot), there is always a technology that innovates before another. The final outcome is a sequence made in accordance with table 4.2 as well as an analysis of the moves that the respective operators will undertake.

Such sequence is a straight result of the questions asked to the respondents. The elaborated results are the following.

Year	**Technology**	**Moves' dynamics**
2018	Cloud and Edge computing	The technology is already here
2022	AR/VR	Embedding the technology in common glasses; acceleration in process components to increase the cost reduction; easier product development phase
	5G networks	Diffusion of commercial licenses; availability of the spectrum for wholesale companies; protocol switching in all the adaptable LTE devices
2023	Cloud and Edge computing (re-adaptation)	Adaptation of the Edge architecture to the Small Cell technology brought by 5G

2026	Artificial intelligence (machine learning)	Definition of a market for AI; price reduction of autonomous robots; diffusion of more algorithms for robots' management
	Artificial intelligence (machine to machine)	Creation of algorithms that allow the machines to take decision autonomously; creation of an architecture for the communication among the machines

Tab. 9 – Moving sequence of the smart factory stakeholders

The analysis of the findings arose that Cloud computing is a technology that has been around for more than 5 years now and is used at a market scale.

Augmented and Virtual Realities are in an experimenting phase slightly corresponding to the peak of inflated expectations in the Gartner's Hype Cycle.

Besides, 5G standards are already experimented and settled. Likewise, what is argued by Ericsson is that no commercial licenses are available for the spectrum, making 5G not implementable on a market scale, as well as its infrastructure being extremely costly, so that really few companies in that world can afford such investment.

The future employment of 5G will require a re-adaptation of the Cloud and Edge architecture to the small cell technology, resulting in an acceleration of the processing time due to a better distributed system.

Finally, AI is the furthest technology due to its high requirements in terms of problems definition, reasoning and motion. Machine learning will come sooner because of its lack of full autonomy of the robots. In fact, machine learning still requires a human input, which is what distinguishes it from machine to machine.

5.3.2 Stakeholders' value chain

To represent a value chain of all the stakeholders, the following section will no longer relate to the technologies but to the companies themselves.

To start off, a proper definition of "value chain" is required; with such concept being introduced by Porter in the late 1970s, the value chain has changed its perception with the advancement of both markets and technologies as well as the diffusion of the idea of a "global" value chain.
The Cambridge Institute for Sustainable Leadership asserts the definition of value chain in comparison with supply chain. Whereby "supply chain" refers to the system and resources required to move a product or service from supplier to customer, a 'value chain' considers the manner in which value is added throughout the chain, both on a product/service level and on a stakeholder level. This shows how more suitable it is for this study to use the value chain to analyse this environment, where actors of different kind are involved.
A further dissertation should be done to define the value created. The project Smarta Fabriker has the sole intention to create knowledge and word of mouth about the smart manufacturing world. However, the purpose of the research is to generalize the concept behind Smarta Fabriker to the future smart factories, that will have the creation of tangible products through autonomous processes as a value proposition.
Therefore, the value chain considers the aspects that are typical of the Smarta Fabriker project (e.g. the support of the government and the education system, the presence of a consultancy company for the Cloud platform) and transfers them to a generic smart factory ecosystem that aims at the development of a smart production system.

The sources considered for the arrangement of such value chain are:

- The repercussions described in 4.4
- The findings emerged about the Triple Helix model
- The telecommunication value chain outlined in the theory
- Other indirect findings in 4.3 and 4.5
- Theory from paragraph 2.1 to strengthen concepts from the findings

To start off, the five repercussions deriving from the interviews are at the basis of the creation of the graph. Here they are listed:

1) Rapprochement of the companies with their customers due to servitization.

2) Focus on the networks with other firms to create proactiveness.

3) Education entities act with both parties (governmental institutions and business companies) to deliver the circulation of knowledge planned by the region.
4) Consultancy companies have their tasks converged to simultaneously face the demands of both markets (telecom and manufacturing).
5) Telecom operators and manufacturers are acting in cooperation to furnish the connectivity infrastructure by one side, the industrial expertise by the other. The design of services is practised together.

Other aspects included are both from an organizational/internal and market/external perspective.
Starting off from the former, companies have their value chain dynamics altered by two important internal factors, that are flexibility and agility. The first one is driven by the autonomous production itself, that allows manager to effortlessly change the organizational layout of the company vis-à-vis the market, whilst the second one is a consequence of the development of faster and more effective information systems, both on an enterprise and operative level (Figure 2.2). The combination of these two factors inevitably changes the way companies behave with each other within the smart factory chain.
On the other hand, the external perspective is changed due to several improvements brought by Industry 4.0. To begin with, the easing of the after-sales phase is a direct consequence of the servitization trend, due to the fact that services require less effort than end product from the standpoint of maintenance, support and so forth. Likewise, mass customization will increase the variety of customers for each company due to the high individualization of the products. This ends up being a direct consequence of the high flexibility brought by autonomous machines. In addition, such enlargement of the customers' base for most manufacturing companies can be extended to the connectivity providers. The declarations of mr. Elmgren concerning the role of Ericcson in the telecommunication industry shows how they are expanding their purview with new IoT and Cloud services, converting our hypothesis of convergence of roles among these companies into a thesis.

The new value chain for this ecosystem, including the abovementioned analysis, is depicted in Fig. 7

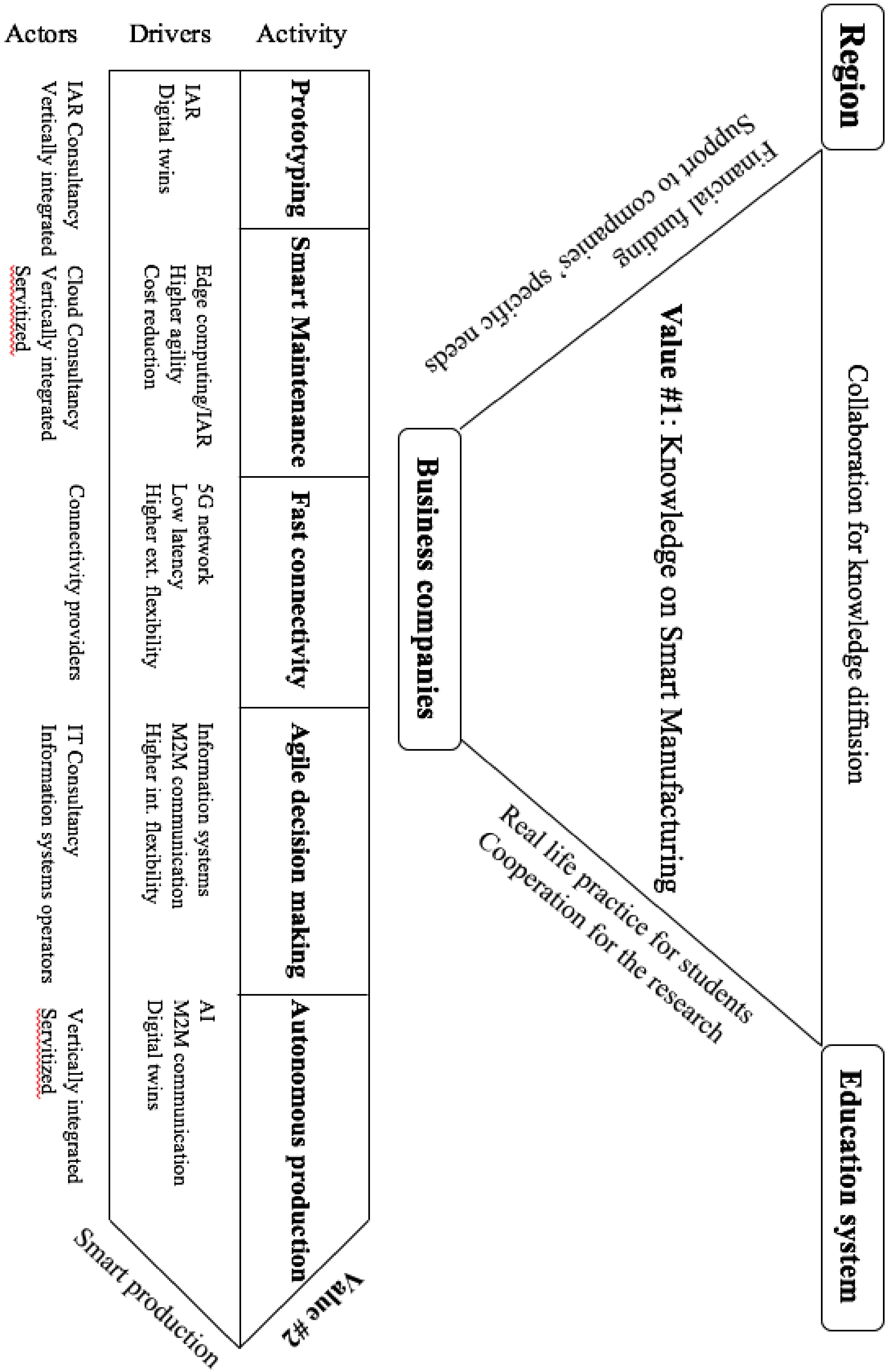

Fig. 7 – Comprehensive value chain of the smart factory ecosystem – Source: author

The figure exhibits the activities involved in the smart production process alongside the advancements led by Industry 4.0. Each activity is linked to its drivers, namely the technologies involved and the advantages brought to the companies, and to the actors employed in such phases. As to the actors, most of the activities can be either vertically integrated (meaning that they can be pursued by the manufacturers themselves) or outsourced to consultancy companies. In addition, the value chain is matched with the innovation system that acts in respect of the companies, following the theory set by the Triple-Helix framework.

As explained before, the values that such system proposes are two. The first one encompasses the Triple-Helix framework and is the generation of knowledge about smart manufacturing. The second one is more business oriented, and it understandably is the creation of products using smart processes.

6. CONCLUSIONS

The conclusion of this research has the purpose to sum up the work for the reader, taking stock of the findings and designing future scenarios. The section links back to the introduction to compare expectations with results.

What were set by the author as preliminary objectives have all been pursued in a different extent. The hard duty of combining studies from two different industries, namely telecommunication and manufacturing, was accomplished thanks to the academic support as well as the presence of a high degree of innovation among the companies involved. The difficulty that stood in the examination of a similar topic from a managerial perspective was high, due to the countless technicalities that shaped the Smarta Fabriker project and the smart factory in general. All in all, the research questions were replied just like the author wanted in the first place, still without showing any bias towards the results, but instead by relying on the results of the research itself.

6.1 Replies to research questions

As mentioned, the two research questions were deeply probed and fairly responded in the fifth chapter.

The first one (*How can Ericsson's 5G strategy guide the Smarta Fabriker project*) was qualitatively responded using two means: the first one consisted of the inputs provided by Ericsson in relation to their intentions concerning the 5G technology and market; the second one summarized the needs of the industrial environment in terms of connectivity, furnishing an external perspective on such innovation. The outcome is a strategy that pinpoints the critical aspects of 5G including latency critical activities, Cloud and Edge Computing architecture and other services related to the infrastructure. The strategy is summarized in Tab. 8.

At the same time, the second research question (*What is the moving sequence and the value chain of the actors involved in the Smarta Fabriker project*) is broken down into two sections. The former provides a moving sequence of the technologies involved in the project, meant as when the four groups of technologies (Augmented and virtual reality, Cloud and Edge computing, 5G networks and Artificial Intelligence) will be implemented in the market at a business level. This reply turns qualitative aspects into a slightly quantitative outcome, providing a timeline for the implementation of such technologies. The final moving sequence is displayed in Tab. 9.

The latter displays the findings in terms of market for the smart factory on a mapped value chain, that not only embraces the innovative companies, but also outlines the synergies with the Triple-Helix framework. The value chain is displayed through the evidences arisen from the Smarta Fabriker project, but, in order to make it generalizable for all the different markets and companies, the outcome lacks names of companies or other entities, whereas it cites classes or categories of them. The final value chain is displayed in Fig. 7

.

6.2 Recommendations on the research

This section aims at responding to the research problem listed in the introduction, as well as providing recommendations to the reader on the approach to the topic of smart factories.
The author overcame the problem related to the consumer’s perspective focusing the research on a business to business basis, slightly describing the physical consumer’s point of view in the empirical findings’ section.
The skimming phase of all the companies involved in the project was smooth and straightforward, thanks to the aid of Johan Bengtsson and Fredrik Flyrin. The sample was jointly decided to best represent different actors and stakeholders along the value chain. At the same time, the constraint related to the language was easily overcome due to the availability of the people involved in the project, who all spoke fluent English and were happy to explain technicalities and other aspects that were exhibited in Swedish in all the websites, including the official website of Smarta Fabriker and the database edig.nu.

Moreover, the research emerged some interesting fields of discussion.
To start off, the research probes a technical and engineering intensive field with a managerial and business approach. Such approach was arguably difficult at the start, but the uniqueness of

the work among all the other thesis, together with the focus on innovation and the interdependencies occurring within the ecosystem, made it easier for the author. The project needed a bird's eye view that grouped all the technical improvements and studies, providing a macro/business approach to all the micro/technical operations.

Moving on, the research was biased against the fact that the convergence of the telecommunication industry and the manufacturing one would have happened in favour of the telecommunication operators. Conversely, the research showed a strong equilibrium amid the two industries, with both parties defending their role as to the new industrial era. ABB argued the relevance of their industrial expertize and stressed on the future servitization trend that will renew the company, whereas Ericsson emphasized their position as infrastructure and services managers.

A further dissertation should be held on the outsourcing/vertical integration of the different activities. The research avoided a debate on the advantages/disadvantages of outsourcing/integrating the different activities in the different companies. More specifically, activities like preventive maintenance, performance monitoring, connectivity and so forth, can all be either integrated in the manufacturer business model or outsourced to other companies. The research has not argued this aspect despite the strong focus on the value chain, mainly due to the unaffordable enlargement of the research scope.

6.3 Future research proposals

The space for other researches deriving from this one is created in response to the limitation that this specific research had. Therefore, the author identified four main areas of expansion of this thesis.

The first one concerns the time limitation imposed by the university's study path. A higher number of companies involved in the project could have been interviewed to broaden the field of research. For example, the additive manufacturing section was not examined enough to get evidences on 3D scanning and printing, on their status and on their linkages with business activities. Another example was the examination of companies that were deeply involved in the Cloud computing sphere as well as the augmented reality one. Cybercom as a consulting company provided expertise on both fields without giving the author material concerning the organizational layout nor business implications of a real AR producing/Cloud computing company. Generally, a broader number of companies could have pinpointed the research more in-depth.

Another eventual proposal counteracts the focus on the Swedish market. The limited generalization of the research entails the fact that it refers to the bureaucratic/economical system specific of Sweden. To make it more generalizable, a comparison with other similar case studies in different countries is necessary, and is a possible field for further research.

A relevant alternative is sustaining this same case study through a quantitative analysis. The qualitative study brings out results that are very broad but merely specific. To make them more specific, a quantitative research on each stakeholder's field could emerge more tangible findings. For example, a quantitative analysis on the 5G strategy could have compared all the KPIs of 5G in terms of latency, PLR, device density and so forth, with the real ones.

Finally, this thesis brings a rare managerial perspective to this project, which encompasses a lot of researches with an engineering focus. A curious proposal could entail the jurisdictional field. A thesis based on the Swedish law system in terms of regional incentives, governmental incentives and European incentives, all directed towards smart factories, as well as a study focused on the patent jurisdiction and management by innovative companies dealing with the smart manufacturing world, could complete the case study in terms of viewpoints and subjects.

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E-learning, Digitization, Industry and Global collaboration – https://edig.nu

Ericcson's website - https://www.ericsson.com

Smarta Fabriker's website - https://smartafabriker.se

APPENDIX

Company profiles of the interviewees

ABB - https://new.abb.com/

ABB is a Swedish-Swiss worldwide leader in robotics, industrial automation and electrical equipment. It was born in 1988 by the merger of ASEA and Brown, Boveri and Cie.
The company values are bringing electricity from any power plant to any plug and automating industries from natural resources to finished products.
The company is the title-partner of Formula E. It has around 130.000 employees in over 100 countries and accounts revenues for around $35 bln.

CYBERCOM - https://www.cybercom.com/

Cybercom is an IT consulting company established in 1995 in Stockholm, Sweden.
It has four different departments, that are Connected Industry, Connected Consumer, Connected City and Connected Citizen. Their main customers are telecom operators, industrial manufacturers and public utilities.
It operates in 7 countries with a strong focus in the Nordic-European market. It employs around 1300 employees and accounts $120 mln.

VÄSTRA GÖTALAND – https:// http://www.vgregion.se/

Västra Götaland is a Swedish region. The capital and seat of the governor is Göteborg. Its main objectives are an above standard welfare for its citizens, including good public health, a rich cultural life and long term economic growth.
It has 1.6 mln citizens and 50.000 employees, being one of Sweden biggest employers.

GÖTEBORGS TEKSNISKA COLLEGE - http://www.goteborgstekniskacollege.se/

The technical high school of Gothenburg is a college in Gothenburg. It owns the Smarta Fabriker project. Its main activities concern the following areas: Corporate Training, Polytechnic, Vocational Adult Education and Upper secondary school.

Interviews' guideline

The following guideline does not fully represent the questions asked to the interviewees, but some notes that the author appointed before undergoing the interviews. The interviews are divided into sections to better draft out the Empirical Findings section, as explained in section 3.5.

ABB

Technology status

With Smartafabriker, are you using robots that are the same you use in your factories? Or are they used as an experiment for upcoming technologies?
Why did you choose the project?
What steps are you taking to implement 5G in your robots? Is it already implemented?
Which parameters are key for ABB in the near future (2-3 years)?
And how do you plan to take advantage from Augmented Reality?

Business level

What are the main industries you are supplying your technologies to? (Car manufacturing, energy sector, clothing manufacturing etc...)? Do you think the shift to a more service based business model will change the industries you will deal with? How will this change your relationship with customers?
Can you relate to the following objectives?

- production costs by 10-30%
- logistic costs by 10-30%
- quality management costs by 10-20%.

Can you define your strategy as a mass customization and/or do you wish to achieve it?
Do you feel that your machines are leading to a shorter time to market for companies?
Are there going to be any other remarkable variations in your business?

Organizational

How is the decision-making process set in the company? Is it centralized or does it happen at a lower level (job floor), in a decentralized way? Do you feel that decisions are gradually being made by more people?
How do you relate to the concept that machines are going to take their own decisions (AI)? When will this incur in the majority of the factories?
What are your ERP systems? How will they complement with the AI and the decentralized decision-making implications of I4.0?

Value chain

What are your relationships with the telecommunication segment (Ericsson, Tele2)?

Västra Gotaland

Value chain

The focus of the interview is on the value chain viewpoint of the project, since the region is the main driver of the Triple Helix model. What are the advantages that may arise from this collaboration? In which way will innovation be generated?
Except for the funding, what are your other inputs to the business world? (Corporate tax and IPR policies? Competition regulation?) How does it work in Sweden?

Technology status and business

I will take advantage from your R&D expertise and ask you which is the status of the technology involved in this. Smart factories? 5G? Augmented reality? Real time data analytics? What is the time horizon to see these properly used in the everyday lives of companies? And what are in your opinion the business implications of Industry 4.0? How do the market synergies switch? Will manufacturing companies cooperate more with the telecommunication segment or do you think that the telecommunication segment will expand itself and incorporate all the other businesses?
How does this project attract more FDIs? And how will Sweden take advantage from them?

Organizational

Another consequence of the Triple Helix model is the variation of the organizational layouts of the companies to better work with you and the universities. How do you think these variations occur?

Consumer's perspective

How can the physical customer benefit from these progresses?

Ericsson

Technology status

Why this project? Getting feedbacks on how to apply 5G to a factory, or have you had any other incentive, maybe from the region?
With Smartafabriker, are you implementing systems that are more developed than the one currently commercialised? Is this a sandbox for 5G?
What is the linkage between 5G and I4.0 that you are applying in SmartaFabriker? Is it just up to the communication via sim cards (supplied by Tele2), or are there some other functions involved?

Value Chain

How will your role as Ericsson change in the future market after these changes?
With this value chain, will Ericsson cover more than one role? Is it going to cover the Small Cell market?
With 5G, will your business model stick to equipment suppliers or cover other areas of the telecom market?
Connectivity provider (connecting consumers and businesses with the infrastructure), Asset provider (IaaS as a business model) Partner Service provider, following the servitization trend.
What do you think will be the changes for the other segments of telecommunication?

Business level

What is the criticality in the proper implication of 5G in the smart factory? MM waves, MIMO, Small cells, Beamforming, Full duplex?
How will you deal with the investment extent of 5G? Competitors like Huawei have a big competitive advantage on that, will you take the risk of the investments?

Consumer's perspective

How will it change? How will the other segments of the telecommunication market change? How will the consumer's behaviour change?
How do you think a consumer may take advantage of 5G in the everyday life? Do you think that the implications of 5G are more remarkable at a business or at a consumer level?

Cybercom

Role

What does your role with Smarta Fabriker consist of? *(development of app for machine monitoring and ordering")*

Technology status

You are a Cloud/IoT manager, but your task with the project seems to be more related to the Data monitoring and metrics expertise. What is the connection between these two worlds?
The goal of the research is to measure the technology status of the technologies involved in the project. Do you think that Cloud computing and the technologies you develop are ready for the market or do you need some more time?

Business level

Did 5G change the way you measure data and performance? Which criteria changed more (quantity, pace, quality and codification of data)?
Talking about the decrease in

- production costs by 10-30%
- logistic costs by 10-30%
- quality management costs by 10-20%

What do you think about this situation? Do you feel that factories still need time to reach these objectives?

Value chain

You as Cybercom are probably the most debatable actor to position in an eventual future value chain of this environment. With the rapprochement of the telecom industry in the factories and the emergence of new technologies such as the Cloud enabled small cells, do you think that you will provide knowledge and expertise on both industries or you will focus on just a section of that? How do you position yourself in the market (Raw materials production and resource planning, organizational and strategic consultancy, technical consultancy, sales and after sales consultancy)?
And how do you think you will change your relationships with other stakeholders involved? Telecoms, smart machines producers...

Do you have any other interaction with governmental and education institutions? What are the incentives for you to cooperate with them?

Organizational

Which of these do you think is the one you are verifying after 4 years? (AI advantages, Cybercom website)
Tell me something about the automation systems that you develop.

Consumer's perspective

How can the physical consumer benefit from these progresses?

Goteborgs Tekniska College

Role

How would you define the role of the GTC within the Smarta Fabriker project? And what is the objective of this collaboration?

Value chain

What are the inputs that you give to the business entities, and what do you receive in return?
What are the areas of collaboration? Do you just lend personnel to share knowledge or are there any other examples of joint researches, academic consultancy, IPRs, spin outs and start-ups incubators?
Same discussion, but with the governmental entities like the region. What are the incentives?

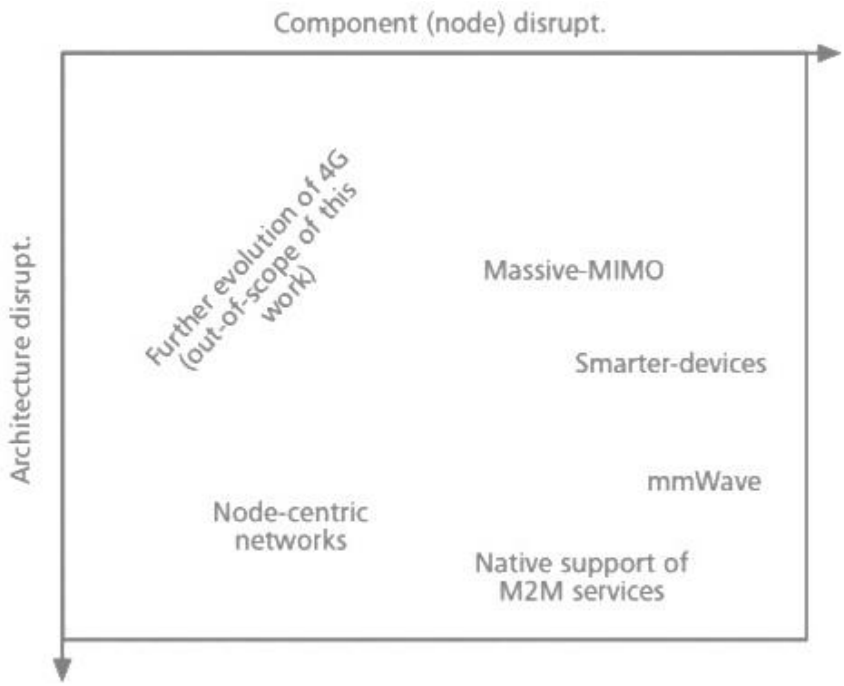
Organizational

From an organizational perspective, do you think that such collaboration with the companies lead to a change in their managerial layout? How does the decision-making process of these innovative companies change in relation to this?
And what do you think will be the variations in the organizational layout of these companies with the up-coming Industry 4.0 era? (Assembly line, job floor, lower and upper level communication...)

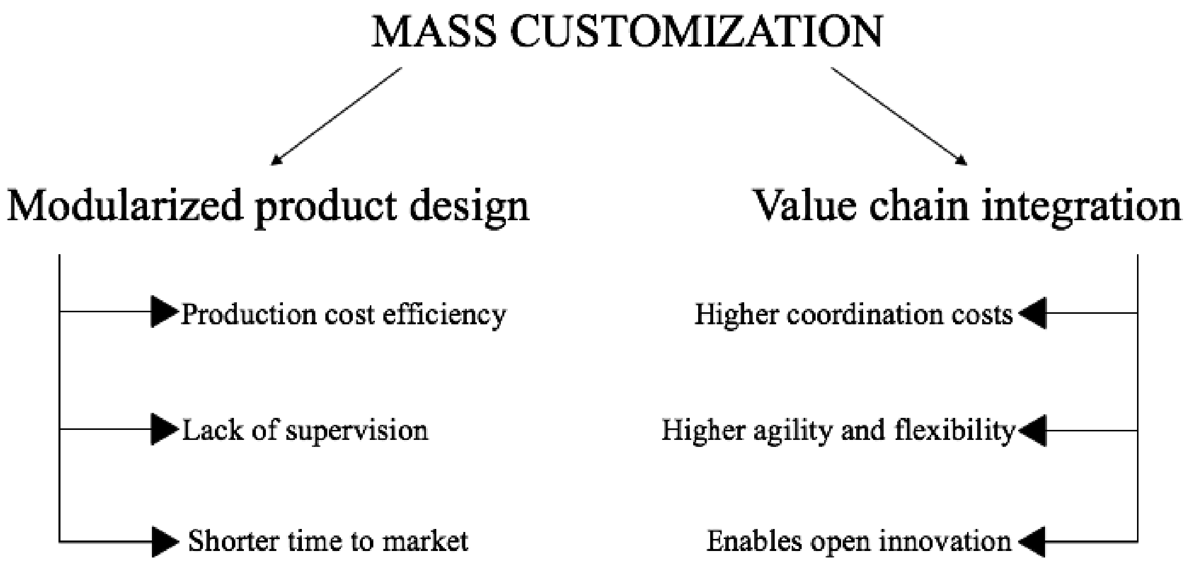
Technology

Can you make a generic statement on your perception of all these technologies in relation to their status? When they will be implemented in a market scale? (Cloud, AR/VR, 5G, Robot automation and machine learning)

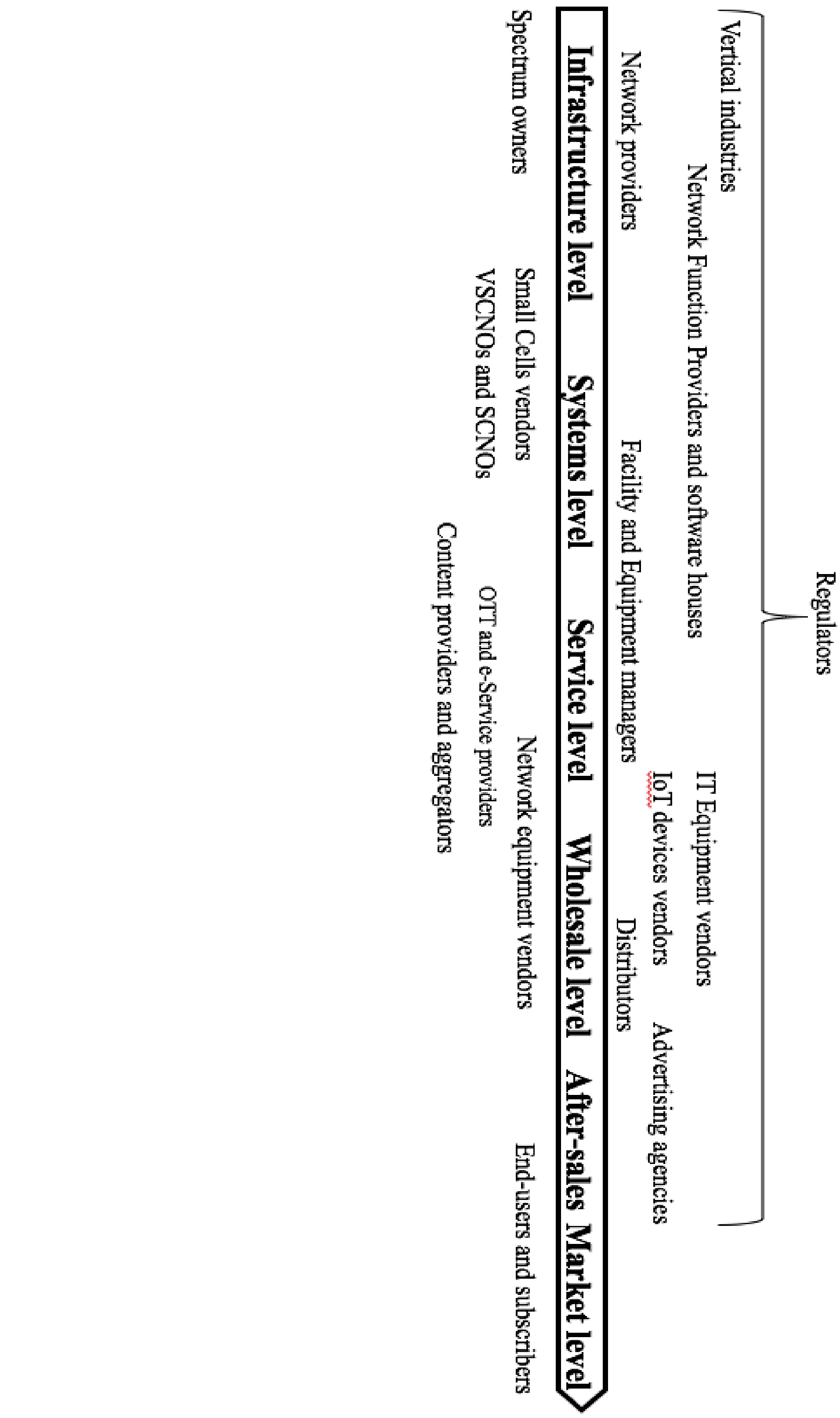
Exhibits



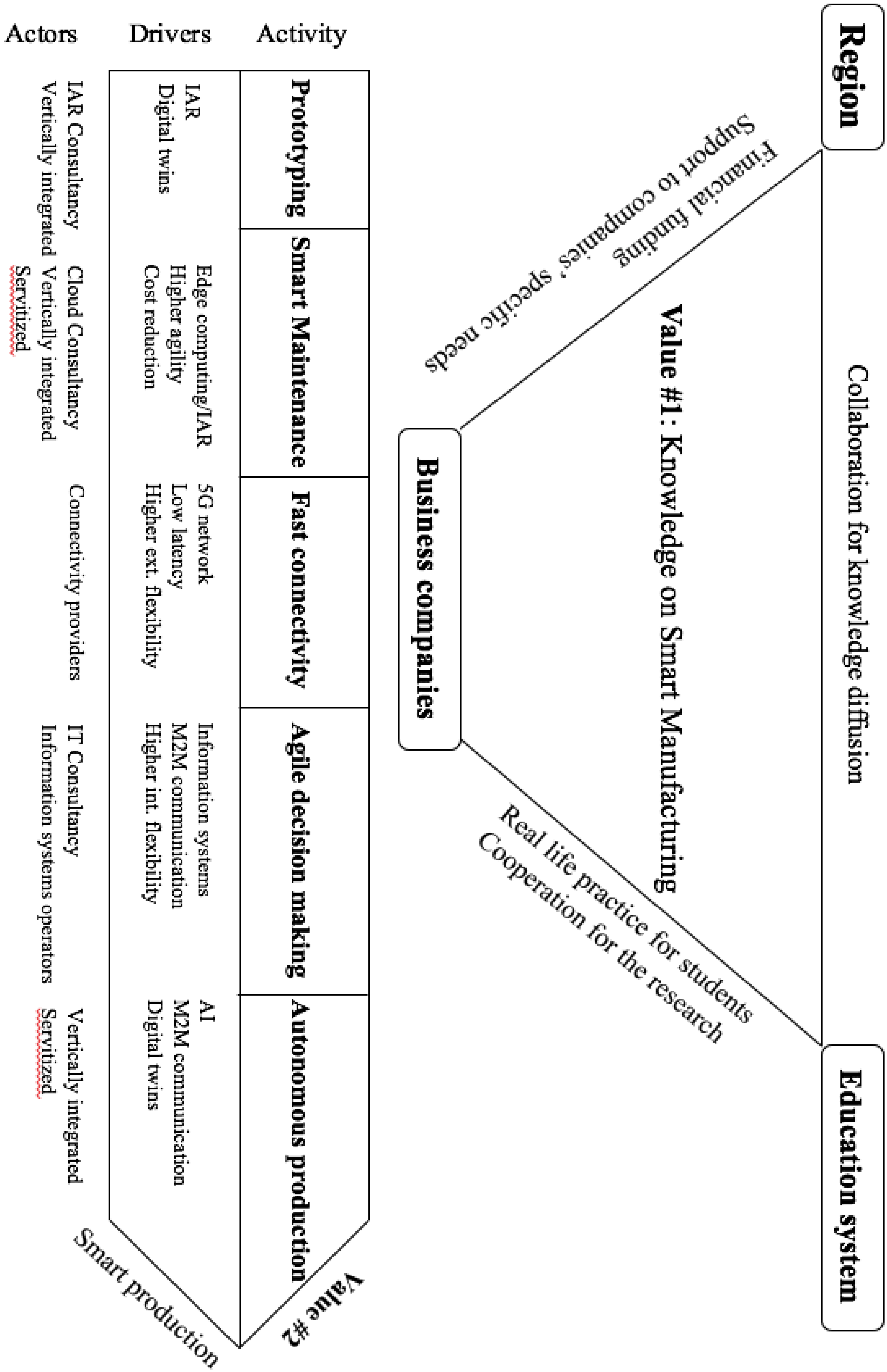
Impact of the different technologies at an architectural and component level



Personal rearrangement of the mass customization strategy



Personal depiction of the future telecommunication value chain considering the emerging actors of the 5G environment



Comprehensive value chain of the smart factory ecosystem

SUMMARY

INTRODUCTION

The following thesis aims at the formulation of the synergies between the telecommunication industry - and its latest update in terms of 5G networks – and the manufacturing industry. The project examined is called Smarta Fabriker, that was chosen due to its vicinity to the author and because it fulfilled his expectations in terms of students' management and relevance of the topic in combination with the course of study he is pursuing.

Smarta Fabriker consists in the construction of two demonstrators (minifabriker) with associated exhibitions in the Universeum of Gothenburg and the Balthazar of Skövde. The demonstrators produce VR glasses made of cardboard, and their virtual content can be reproduced through the project's app. The automated factory process is divided into two parallel flows: cardboard processing and delivery of lenses. Everything is run by Göteborgs Teksniska College, which acts as an intermediary between the project's stakeholders.
The factory furnishes evidences for both fields – telecommunication and manufacturing – because of the network connection between the machineries, that is run by Ericsson, together with the industrial characteristics of a minifactory.
Thus, the author chose Ericsson and its highly focused 5G strategy to outline what are the influences and implications of the 5G technology in a smart factory environment, taking evidences from the Smarta Fabriker case to sketch out the current situation and to describe how it could progress in the near future.

RQ1: *How can Ericsson's 5G strategy guide the Smarta Fabriker project?*

This first research question starts from the Ericsson's point of view and moves to the Smarta Fabriker project, albeit gradually, emerging evidences from a theoretical basement of relationships between 5G and the Internet of Things. On the other hand, a second research question is needed in order to fully understand how the Smarta Fabriker project works out. This is done by categorizing different groups of actors among the partners involved in the project (investors, telecommunication operator, knowledge suppliers, cloud and IoT consultants, robots and machineries suppliers). These macro groups are thereby examined to sort out content, timing and extent of their respective moves, pulling out a sequence of movers, according to the status of all the technologies involved in the project (virtual and augmented reality, robot automation, 5G networks, Cloud computing etc.). A value chain draft is then provided as a final outcome of this second research, analysing the internal/business environment as well as the external one, meant as the customers' perspective and readiness.

RQ2: *What is the moving sequence and the value chain of the actors involved in the Smarta Fabriker project?*

Throughout the research, two important terms have to be clarified. The first one is the "strategy" referred to in the first RQ: strategy is meant as both the moves that a telecom operator have to undertake to optimize the implementation of the 5G technology in the business of manufacturers/factory based companies. The second term is ecosystem, that is cited both in the title of the report and in the analysis: the "smart factory ecosystem" comprises the multitude of stakeholders that take part in the business of a smart factory, such as IT consultants and connectivity providers. The following research involves, within the term "ecosystem", the institutional actors, namely the region, and the schools/universities, together with the business companies that take part in the project.
This master thesis shows off four main limitations, all identified by the author. The first one is the "Swedish focus" of the project, that creates several types of barriers. The second one is the limited time span available compared to the multitude of companies (roughly 50) involved in the project. Thirdly, the preliminary bias of the author towards the telecommunication industry, that may create incongruities in the value chain results. Lastly, with the thesis being supervised by two different professors, the requirements may be different and may create difficulties in the drafting of the report.

THEORETICAL FRAMEWORK

The purpose of this chapter is to give the reader a broad background of what is found in the literature about the technologies and business repercussions that gave rise to the Smarta Fabriker project.

The following theory is then exploited to draw up the interviews' content and to link these together in order to design the analysis.
Therefore, two big domains constitute the notional framework of this research, and they are the Industry 4.0 context and the telecommunication industry. All the sub technologies are then labelled under these last two paragraphs.
In addition, a third paragraph provides the system's layout of the project, namely the "Triple Helix model", which basically portrays the business synergies of the education-business-government tripod.

Industry 4.0 is a term often referred to the fourth stage of the industrial development. The combination of new technologies with the innovative organizational layouts arisen in this era aims at the following results: production costs by 10-30%, logistic costs by 10-30%, quality management costs by 10-20%.

This new wave of technologies turns out to create a set of business and supply chain consequences to the majority of manufacturing companies. The business implications can be summarized as following:

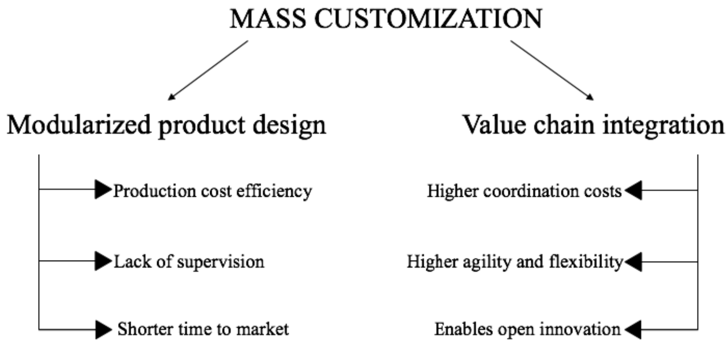
- Resource efficiency, as the focus on sustainability in an industrial perspective leads to the avoidance of ecological wastes
- Decentralization of the decision-making process, resulting in a cut in organizational hierarchies
- Demand individualization, turning the market from a seller oriented to a buyer oriented one. This phenomenon is known as "batch size one"
- Short cycle periods and faster trends, as innovative mind-sets bring pace at the forefront of the enterprises' requirements
- Flexibility and adaptation in the product development phase.

On the other hand, the supply chain implications are thereafter listed:

- More flexible processes are assisting the production of small lot sizes, smoothening the mass customization. The implementation of smart machines and robots results in a more autonomous communication and more autonomous decisions, facilitating the differentiation of products that are still produced of a large scale.

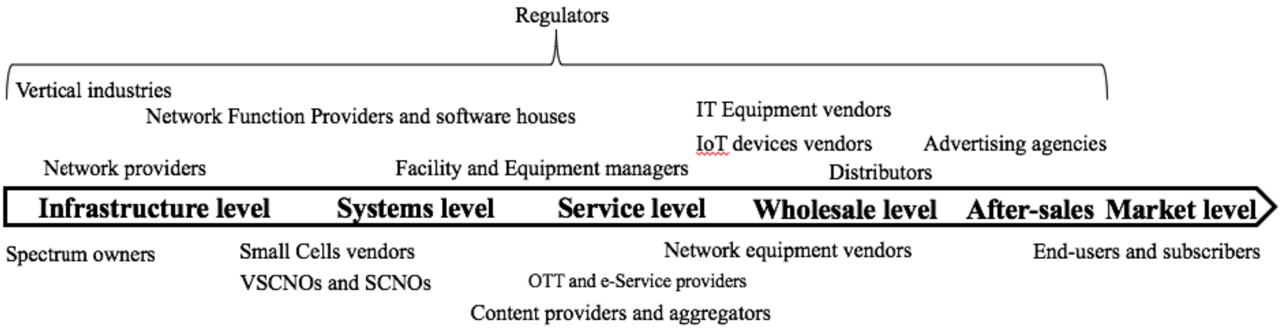
- IT systems automate the production line
- Physical prototypes are drastically decreasing their existence, due to the automated design of products and the integration of the different value chain segments.
- In flow and out flow logistics are automatically adjusted through autonomous and smart vehicles

These implications have the mass customization (MC) strategy as a primary outcome. Such strategy is summarized in the graph below.



5G networks are the second theoretical pillar of the research. The main standards of a fifth-generation network are set by the usage of *millimetre waves*, the presence of *small cells* distributed all over the streets, a *Massive Multiple Input Multiple Output* (MIMO), the "*Beamforming*" technology that entails an intelligent system for data traffic distribution, and the presence of *full duplex transceivers*, able to transmit and receive information simultaneously.

As showed in the full document, the value chain consequences of this new wave of 5G networks are not drastic. The roles of an operator are not that different than before (connectivity provider, asset provider, partner service provider). The graph below shows the representation of the telecommunication value chain in accordance to the new 5G standards implemented in the industry.



Furthermore, a relevant component of the correct implementation of 5G network is a proper Cloud and Edge computing architecture. Cloud computing consists in the virtualization of the data storage, processing and transmission, making these actions more cost efficient and immediate. Edge computing aims at pushing the processing of these data in proximity of the application/service involved, in order to further improve the quality of the information flow and to decrease its lead times. Nevertheless, shifting the entire data inventory control and analysis at closer stations, together with the processing architecture and the storage centre, would result in an unmanageable and unsecured mess, first and foremost due to the small dimensions of the edge stations and for their supposedly high number. For this reason, Cloud Computing and Edge Computing should coexist to let the enormous 5G network work properly.

The last section concerns the **Triple Helix framework,** that theorizes the interdependencies among three actors, that are governmental institutions, education institutions and business companies.

This framework can be summarized into ten propositions:

- The linkages between the three entities are what generates innovation. Innovations are the comprehensive phenomenon of all the dynamics between the single bodies.
- The creation of new organizational layouts, new social arrays and new channels for interaction are at the same level of the product innovation and invention as outcomes of the model.
- The model is interactive, and this means that synergies occur in both ways between all the entities. The model may have an "ex-ante" perspective, where knowledge generated in academia is transferred to business companies, or an "ex-post" perspective, where problems deriving from companies arise the research process in universities.

- The “capitalization of knowledge” exploits the new risk sharing mechanisms, stimulating the early stages investments through companies like the venture capital ones.
- Capital is no longer intended as exclusively financial, due to the value that social, cultural and intellectual ownerships have gained in the past decades. “Who you know” and “what you know” are now equivalent to “what you have”.
- The globalization process is getting more decentralized, having its origin in regional entities and at a smaller scale than before.
- Emerging economies have their opportunity to catch-up throughout local support policies and transparency, attracting FDIs from the outside.
- New technologies and innovation enhance the reorganization of institutional spheres as well as industries.
- Universities have the power to drive the development of regional economies, albeit declining, through focused research and incentives for outgoing students. (e.g. Karlskrona Ronneby in Sweden with the shipbuilding sector)
- A Triple Helix region has the ability to move from a technological paradigm to another through broad-based research and multiple interacting knowledge-producing institutions.

RESEARCH METHODOLOGY

The methodology used by the author to pursue this research can be summarized as following.

Research strategy: qualitative research – inductive approach
Research design: individual case study
Research method: unstructured interviews
Validity: internal – high / external – low
Reliability: internal – low / external – high

The interviews are summarized in the table below:

ENTITY	NAME	MANSION	TIME
ABB	Björn Magnusson	Global Key Account Manager	30'
ERICSSON	Sebastian Elmgren	Smart Manufacturing Portfolio Manager	30'
Göteborgs Tekniska College	Johannes Persson	LEAN Coach and Consultant	30
VÄSTRA GÖTALANDSREGIONEN	Hans Fogelberg	R&D and Innovation Policy Expert	45'
CYBERCOM GROUP	Henrik Löventoft	IoT/Cloud Business Manager	30'

EMPIRICAL FINDINGS

The findings deriving from the interviews were labelled in six separate sections.

Roles within the project

Five entities comprising governmental institutions (the region), educational institutions and business companies were interviewed. The following table maps out the role of each entity in the project.

ENTITY	ROLE	OBJECTIVE
ABB	Provider of control systems and robot supervision	Formulation of a market for virtual commissioning
ERICSSON	Provider of connectivity for the factory	Getting feedbacks for a 5G connection in a smart factory application
Göteborgs Tekniska College	Students participating in the development of the factory	Sharing knowledge about smart manufacturing
VÄSTRA GÖTALANDSREGIONEN	Sponsor and funder	Long term growth and development of knowledge-based economy
CYBERCOM GROUP	Technical consultancy for the development of the app for machine monitoring and ordering	Fostering the development of the factory

Status of technologies

At the same time, a suite of technologies that constitute the smart factory ecosystem was listed in order to outline a time horizon for the implementation of each technology in the every-day life of the market. Here is what emerged from the opinion of each interviewee:

ENTITY	5G	Cloud and Edge	AR/VR	AI
ABB	8-10y	0	3y	8-10y
ERICSSON	2y	0	/	10y
Göteborgs Tekniska College	1y	0	5y	10y
CYBERCOM GROUP	1y	0	4y	6-7y

Organizational implications

The interviewees were asked how the organizational layouts and information systems of companies will change in relation to the new industrial era.

The most relevant findings were the following:

- Decision making processes will be both centralized and decentralized. The decentralization is a consequence of the smaller teams within the organization, needed as a response to the agility required to this new market framework. Decentralization also results from the introduction of Edge computing that will enable machines to take their own decisions with artificial intelligence.
- Stronger and faster cooperation in the Triple-Helix framework, with clarity between the actors in relation of the requirements and incentives to foster the research.

- Focus on the change of culture of all the employees in the organization, that have to adapt to the new PLC systems.

Value chain repercussions

With respect to the holistic view of the smart factory ecosystem, interviewees were asked about the variations in the interdependencies between actors in the value chain. The interviews arose five main repercussions:

Repercussion 1): *Rapprochement of the companies with their customers due to servitization.*
Repercussion 2): *Focus on the networks with other firms to create proactiveness.*
Repercussion 3): *Education entities act with both parties to deliver the circulation of knowledge planned by the region.*
Repercussion 4): *Consultancy companies have their tasks converged to simultaneously face the demands of both markets.*
Repercussion 5): *Telecom operators and manufacturers are acting in cooperation to furnish the connectivity infrastructure by one side, the industrial expertise by the other. The design of services is practised together.*

Business level consequences

The focus of this section was on the changes in the business models of the two industries (telecommunication and manufacturing).

Taking ABB as an example, it expressed the following consequences:

• The company will follow the servitization trend.
• This will result in the robots working on demand, reducing resource wastes.
• The after-sales phase will require less effort due to the less capital intensity of the services over the end product.
• Smart automation is a vehicle to reach the objectives of reduction.
• Increase of the customers differentiation, keeping the volumes high (mass customization).

Conversely, Ericsson served as an example of a telecommunication operator. The implementation of 5G networks in a smart factory will take place

- 5G will be customizable. By connecting a car, you can benefit from low latency with a narrower bandwidth; connecting the area of a concert, you will need a larger bandwidth even with a higher latency. Another variable is the battery life of the device.
- 5G will address more connection-demanding applications.
- The strong improvement on wireless connectivity will boost the flexibility of the job- floor.
- Broader product mix of the companies.
- Cost savings due to less cabling.
- More reliable than other wireless connections like Wi-fi and Bluetooth.
- Shorter product life-cycles.
- Massive number of sensors that enables a better prediction for preventive maintenance and performance measurement.
- Most critical technologies are the MM waves and the streamlining of the network that allows a lower latency.

Consumer's perspective

This last section aimed at the examination of the perspective of the physical consumer in a chiefly business to business environment. The field is blurred and uncertain, as most of the implications are on a social level.
An important viewpoint is the comparison with the release of 3G and 4G. The long-term perspective is that, due to this proactive and push approach, the release of 5G is indeed surrounded by uncertainty. But now, with both 3G and 4G, there are millions of applications used at a consumer's level. And this will happen with 5G as well, probably in combination with augmented reality.

DATA ANALYSIS

Taking the findings into consideration, the analysis aimed at the fulfilment of both research questions.

The **first research question** is responded with the qualitative description of the strategy of a connectivity provider for the connection of a smart factory.

The strategy is displayed in the following table:

5G technologies	**Factory progress**
Node-centric networks and mmWaves	Low latency and unrestricted network due to a different frequency
Process virtualization	Creation of the digital twin and better representation of the physical process
Edge computing	Facilitation of the information flow among the machines and avoidance of a Cloud overload
Servitization of the infrastructures	Lower costs and more sustainable business model for manufacturing companies
Enhanced wireless connection	More mobility of the factory components and higher flexibility of the product development phase
Low packet loss rate	Higher reliability and less faults in the autonomous production

The **second research question** was divided into two answers. The first one concerns the moving sequence of all the technologies involved in the ecosystem.
The term “moving sequence” is intended as when the four groups of technologies (Augmented and virtual reality, Cloud and Edge computing, 5G networks and Artificial Intelligence) will be implemented in the market at a business level, meaning that they will be used by innovative companies for their businesses. Within the synergies incurring among these technologies (e.g., how a new augmented reality tool could upgrade a smart robot), there is always a technology that innovates before another.
Such sequence is thereafter exhibited:

Year	**Technology**	**Moves’ dynamics**
2018	Cloud and Edge computing	The technology is already here

2022	AR/VR	Embedding the technology in common glasses; acceleration in process components to increase the cost reduction; easier product development phase
	5G networks	Diffusion of commercial licenses; availability of the spectrum for wholesale companies; protocol switching in all the adaptable LTE devices
2023	Cloud and Edge computing (re-adaptation)	Adaptation of the Edge architecture to the Small Cell technology brought by 5G
2026	Artificial intelligence (machine learning)	Definition of a market for AI; price reduction of autonomous robots; diffusion of more algorithms for robots' management
	Artificial intelligence (machine to machine)	Creation of algorithms that allow the machines to take decision autonomously; creation of an architecture for the communication among the machines

The second answer concerns the comprehensive value chain of the smart factory ecosystem, and takes into account the value chain repercussions described in the Empirical Findings as well as the organizational and business considerations.

A further dissertation should be done to define the value created. The project Smarta Fabriker has the sole intention to create knowledge and word of mouth about the smart manufacturing world. However, the purpose of the research is to generalize the concept behind Smarta Fabriker to the future smart factories, that will have the creation of tangible products through autonomous processes as a value proposition.
Therefore, the value chain considers the aspects that are typical of the Smarta Fabriker project (e.g. the support of the government and the education system, the presence of a consultancy company for the Cloud platform) and transfers them to a generic smart factory ecosystem that aims at the development of a smart production system.

The value chain is depicted in the graph below.