Trabajo de Grado para optar al título del Negociador Internacional.

Characterization of the Industry 4.0 and its applicability in Medellin

Handed in by

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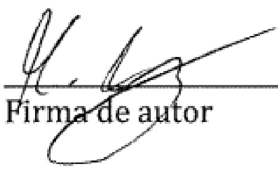

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1. General Introduction

The term "industry 4.0" was created by the German government in the second decade of the 21st century, and forms together with the so called project of the future "Industry 4.0" below the new high tech strategy for Germany, apart from other technological projects. It was selected thanks to the fact that the economy is on the threshold of the fourth industrial revolution, in which the real – physical- world and virtual world unite in a system, a so called **Cyber Physical-System**(CPS). This is only possible through the **Internet of Things** (IoT), which is a "new concept completing the evolution of communication and informatics, applying them to the objects, which allows a better interaction between them. It refers to a net of daily things interconnected through the internet" (Molano, 2014).

CPS are:

> "Integrations of computation, networking, and physical processes. Embedded computers and networks monitor and control the physical processes, with feedback loops where physical processes affect computations and vice versa. The economic and societal potential of such systems is vastly greater than what has been realized, and major investments are being made worldwide to develop the technology. The technology builds on the older (but still very young) discipline of embedded systems, computers and software embedded in devices whose principle mission is not computation, such as cars, toys, medical devices, and scientific instruments. CPS integrates the dynamics of the physical processes with those of the software and networking, providing abstractions and modelling, design, and analysis techniques for the integrated whole" (Asare, Broman, Lee, Torngren, & Sunder, 2012).

The characteristics of the industrial production in the future, first of all, come with a product individualisation, meaning that the mass production needs to be highly flexible. Secondly, the integration of clients and partners in business processes and with products and services of high quality result in hybrid products. (Bundesministerium für Bildung und Forschung, 2014a, p. 16)

On the other hand, optimization is requiring in the following points

- Standardization and reference architecture
- Control of complex systems
- Internet infrastructure and coverage
- Security
- Organization and design of work
- Training and application of studies
- Legal conditions
- Resource efficiency

In order to achieve the objectives and strategies of CPSs you need to realise the following characteristics of the Industry 4.0: The vertical integration over value added networks, the digital generalisation over the whole supply chain and the vertical integration with the connected production systems. (Promotorengruppe Kommunikation der Forschungsunion Wirtschaft – Wissenschaft, 2013, pp. 6–7):

1.1. Problem Statement

The reasons for the upcoming revolution are the challenges ahead, but who is playing a key role and why in its inducement? To answer that you can take a look at the share of manufacturing value added of the emerging countries compared to the traditional industrialised ones. Whereas in 1991 their share was at 80% it continued to decrease and in 2011 was at a shocking rate of 59 %.

However, emerging countries especially Asian frontrunners, excluding Japan, more than quadrupled their share to 31%. The whole market share nearly doubled within this period from 3.45 billion to 6.58. This explained why European and North American Governments and industries invest the most in the realisation of this differentiating, advantage gaining revolution, in order to keep their industry competitive, leading and regaining share and advantage over emerging countries. (Blanchet, Rinn, von Thaden, & de Thieulloy, 2014, pp. 2–3).

1.2. Background information

> “The production is on the threshold of the intricacy to the complexity. It would not be possible to describe all products and processes exactly. Mankind will get into a complex field, which won’t be describable nor predictable. Companies therefore must work on its flexibility and mutability in order to adapt quickly and economically to the changes ahead” (Bauernhansl, 2014, p. 13).

Why is it important to investigate this topic? The industries are proof in themselves. For example, nearly all of German suppliers have seen the importance of topics related to industry 4.0 in 2015: A study realized by the Bundesvereinigung Logistik shows that all the important topics of 2015 are already part of the transition process towards the Industry 4.0. In fact, 31 % already see the importance of digitalisation, a main issue to the Industry 4.0, as core topic within their business. (Statista GmbH, 2015). The potential of the German economy in reference to the industry 4.0, particularly referring to all products and services needed in technology and communication until 2020, have a potential of 10.9 million Euros according to market analysists of the Experton Group. These scientists referred to a study of the German government saying that the German gross value added would gain 1.7 % per year thanks to the upcoming revolution. (Pütter, 2014)

1.3. Questions

The two main questions to be answered within this work are:

- "What is the Industry 4.0?
- "Is it likely to be implemented in Medellin?"

Supportive questions are:

- What is the environment of the Industry 4.0 and what are the reasons and motivations for its implementation?
- What are the basic theories about industry 4.0 and what exactly do they consist of?
- What are the differences among selected world regions in terms of the demand, fomentation and implementation of the Industry 4.0?

1.4. Objectives

The two main objectives of this work are:

- Describe the characteristics of the Industry 4.0.
- Analyse its applicability in Medellin.

Specific objectives are

- Identify and describe the environment of the Industry 4.0 together with its principle reasons for its implementation
- Describe the basic theories of the Industry 4.0.
- Identify the requirements and differences of the Industry 4.0 in different world regions.
- Analyse the applicability and necessity of the Industry 4.0 in Medellin.

1.5. Methodological approach in the practical phase

This work is based on two investigation types: The first part, the characterization of the Industry 4.0, is descriptive, as the objectives are "observing and describing the behaviour of a subject without influencing it in any way" (Shuttleworth, 2008). However, the second part, the investigation of the applicability, is explorative as "there do not exist previous investigations about a topic or one's knowledge of this topic is vague and imprecise, which forces one to extract more provisional conclusion about what aspects are relevant and which not" (Universidad Nacional, 2012).

The methods used in this work is inductive as within this method "one intents to arrange the observation trying to extract conclusions of universal character from the accumulation of particular information." As well the deductive method will be used as "from the general beginning and, with the help of a series of rules of inference, a few theorems or secondary beginning are demonstrated" (Centro Aragonés de Tecnologías para la Educación, 2012).

In order to obtain the results for the second, exploratory part interviews and questionnaires will be used. The information obtained from this method will be analysed and presented in the last part of this work.

1.6. Tentative description of final report

In the following the concepts of the Industry 4.0 are explained, covering the description of the historical industrial revolutions, related investigation topics, elementary parts, basic technologies, introduction to companies and the benefits and outlook of an implantation. The third chapter deals with analysing the fomentation in selected world regions and the fourth discusses the possible implementation in Medellin. Following the synthesis, an annex contains additional figures.

2. Industry 4.0 Concepts – The fourth industrial revolution

2.1. Industrial Revolutions

As mentioned in the introduction, the term Industry 4.0 refers to the fourth industrial revolution. That following section will describe the first three industrial revolutions and the reasons for the fourth.

2.1.1. The first three industrial revolutions

The first industrial revolution started around 1750, driven by the evolution of the steam engine. Labour and Combustion engines made industrialization possible and contributed greatly to the fact that in those times no structural related famine emerged in the countries characterised as industrialized. However, this caused an explosive increase of the population in those countries due to the supply of clothes and food that became possible through the improvement of the transportation system, and the improvement of the productivity and production of basic supply goods. Of course all kinds of revolutions have effects on society: The manpower in classical crafts and agriculture were severely reduced and two social classes emerged: The factory workers and owners. The latter profited plenty from the industrial added value, whereas the former were exploited in the beginning. Even though the working conditions were extremely bad, more and more people moved into the cities, which invoked structural poverty: pauperism. This development lead to a bourgeois revolution during the transition to the second industrial revolution. (Bauernhansl, 2014, p. 5)

The second industrial revolution was characterized by labour divided mass production, with the help of electric energy, it was also characterized by an organization driven revolution highlighted by the assembly line developed by Henry Ford and the scientific management by Frederic W. Taylor. At the same time electric drive and combustion engines were developed. In particular, the electrified drive systems made it possible to decentralize combustion, so that each labour engines could be driven individually. Furthermore, the importance of crude oil increased as raw material of the chemical industry, and it consequently became a new fuel for mobile systems, especially for automobiles. Due to this development, large-scale industrial mass production progressed in the chemical and electrical industry as well as in mechanical engineering and automobile industry. On the other hand, the population continued to grow and it became clear to society that factory workers could not be exploited and that instead, prosperity needed to exist in order to lower social tensions. The need could be satisfied with the big industries' mass production, which made it possible to produce very cheap products because of Economies of Scale. During the transition from the first to the second industrial revolution the social democracy arose and the ideas of communism spread. In those days the seeds for our consumer-orientated affluent society were sewn. (Bauernhansl, 2014, pp. 6–7)

Interrupted by two world wars, the third revolution continued in the beginning of the 1960s. This revolution was first characterized by electronics and later, information and communication technology, which facilitated the automation of the production processes. Therefore, on the one hand the resources were rationed and on the other hand the varied serial production was enabled. Due to the fact that the basic need of the affluent societies in the 1980s were satisfied, markets were saturated, producing a change from seller's to buyer's markets - meaning that it was no longer about producing and selling all products: The client's needs were more and more differentiated and their wishes became more and more individual. This meant selectively paying attention to quality and individuality, resulting in the increasing importance of serial production until mass customization. Simultaneously the market economy has been developing further due to the information and communication technologies and later, through the internet, into a global availability of knowledge. Furthermore, the industrialized societies began to live beyond their means and in the 1970s and 1980s first indications of economic debt appeared. Since the fall of the Iron Curtain globalization has advanced unhindered. We are currently still in the same phase: Labour is more and more divided in the world and globally distributed production is the main choice. (Bauernhansl, 2014, p. 8)

2.1.2. The importance of the industry in economies

Around the end of the twentieth century, economists believed that the industrial sector would follow the same decrease like the agricultural sector as its share on the gross domestic product was at that time dwindling. It was assumed that its share would be below 10 percent. This development has been observed in industrialized countries like England, France and the United States of America. An exception here is Germany as it has achieved to maintain its industrial share around 25 percent since the reunification in 1990s. Many German neighbours pitied Germany being the “sick man” in the region and criticized its inability to change into a service and knowledge-based society and sticking to its high industrial share, old fashioned financial economy, “*Mittelstand*” structures and the legally relatively strongly anchored social benefits. But the upcoming crises showed the importance of the industrial sector. (Bauernhansl, 2014, pp. 7–8)

It has been ascertained, that developed economies need a high industrial share in order to be successful. (Manyika et al., 2012, p. 5) There exist three main reasons: productivity, innovation and export.

Productivity: This can be explained by the possibility of rationing industrial production. A service arises through the interaction between humans, whereas industrial production always arises through the interaction between human and machine. Through the given possibilities a higher productivity gain can be expected and this one precipitates in the growth of an economy.(Bauernhansl, 2014, p. 8)

Innovation: A mayor share of the investments in innovations come from industry. If a country has a low industrial share, then this contribution to innovation is missing and a renewal of the economy will not occur as it does in higher industrialized countries. (Bauernhansl, 2014, p. 8)

Export: Economies with lower industrial share and therefore a lower export rate do most probably have a negative trade balance, which hastens the occurrence of debt. (Bauernhansl, 2014, p. 8)

Some developed countries have taken counter measures: For example, the United States of America want to establish a share of 20 percent for the industrial sector, through a devaluation of the US-Dollar and incentives to invest in application-orientated research. In addition, the United Kingdom launched a "High Value Manufacturing" programme and Europe is currently trying to reach a minimum level of 20 percent. (Bauernhansl, 2014, p. 8)

Asia on the other hand, especially China, is watching this development critically. These countries quickly undergo the developments of the second and third industrial revolutions and build on the industry to create prosperity. (Bauernhansl, 2014, p. 9)

2.1.3. Change in production factors

In order to equalize sustainably demand and supply, a change in the production factors is required. This especially refers to the factors energy, material, staff (knowledge) and capital: (Bauernhansl, 2014, p. 11)

Energy change forces a significant change in energy policy. "The term encompasses a reorientation of policy from demand to supply and a shift from centralized to distributed generations[…], which should replace overproduction and avoidable energy consumption with energy saving measures and increased efficiency" (Saad, 2016, p. 49). The change referred to is the transition to a smart grid.

Material change concerns the solution to the closure of recycling circuits, the efficient use of renewable resources, evasion of creation of waste or prejudicial emissions and in context to that the integration of the process of value creation.(Bauernhansl, 2014, p. 12)

The staff change focusses on the demographic changes and skill shortages primarily in developed countries, but also in the developing countries. This means that today one needs to plan, how to extract the waste out of the processes, including waste of human resources. However, it is necessary to create a working environment which enables the employees to develop all skills, to stay motivated and to proportionally work productively over a long period of time. (Bauernhansl, 2014, p. 12)

The change in capital, as well as the economic and corporate approaches to financing need to be reviewed as they recently caused several crises. These days' factories are organized and leadership systems need to be altered. (Bauernhansl, 2014, p. 12)

The change in the production factors will lead to satisfaction of the demand side through greener value creation chains and without any problem creation on the supply side. Information and communication technologies will be the enabler of the changes. (Bauernhansl, 2014, p. 12)

2.1.4. Complexity: The motor of the fourth industrial revolution

The extent of the complexity can be easily seen in one's everyday life: Back in the old days one ordered a simple coffee, as there was only one option. Now one has to choose between a "Chilli Spice Latte" or a "Caramel Whipped Mocha". Another good example would be the car industry: BMW offers 10^{20}, or 100.000.000.000.000.000.000 or 100 quintillions (or however many theoretically possible) of combinations and configurations of "new" cars. (Danne, 2012, pp. 6, 8)

2.1.4.1. Complexity – What is that?

"The complexity is the characteristic of systems, which is defined through the number of elements of the system and the number of relationships between elements. The bigger the number of relationships between elements, the higher the grade of complexity" (Danne, 2012, p. 11). Changes, diversity and networking are three characteristics of the complexity of system. Through the increase of those characteristics, the complexity rises and through a rising complexity it is more difficult to describe systems, observe states of systems, forecast correctly the impacts of changes to the system and to control the system.

2.1.4.2. Complexity in the production - history

> "The production is on the threshold of the intricacy to the complexity. It would not be possible to describe all products and processes exactly. Mankind will get into a complex field, which will not be easily described nor forecasted. Companies therefore must work on their flexibility and mutability in order to adapt quickly and economically to the changes ahead" (Bauernhansl, 2014, p. 13).

The following figure 1 shows the development of the production since the 1850s regarding product variety, shown on the x-axis, and product volume per variant, shown on the y-axis.

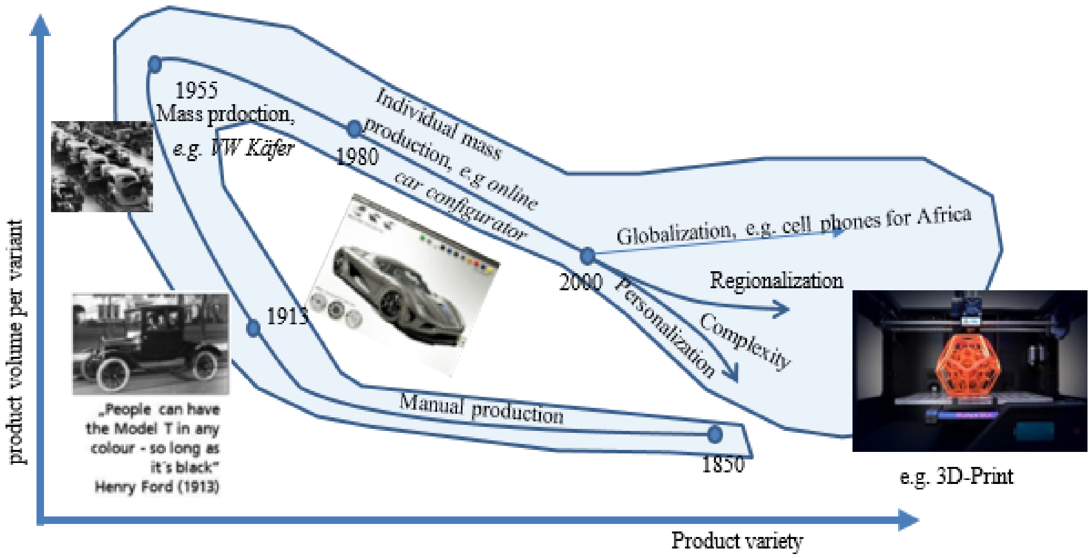


Figure 1 - History of the production (Bauernhansl, 2014, p. 13; Koenigsegg, n.d.; NDR Media, n.d.)

In 1850 production started with a high variety as it was done manually and at low volume per variant, until 1913, when Henry Ford said "People can have the model T in any colour, so long as it's black". Then the variety of the products decreased and the volume per variants increased steadily until this development reached its peak around 1955 with mass production. One of the best examples of this was the Volkswagen Käfer (Beetle). Around that time the volume per variant started to drop and the variants increased as the products needed to be individualized with the market changing from a seller's changes to a buyer's market. That is the point when, for example the automobile industry started the customer's configuration of their cars. Since the end of the millennium the range of product variety and volume per variant increased as at that time new trends like globalization., regionalization, complexity and personalization became prevalent. This caused a huge increase in the complexity of the markets, leading to a new production paradigm, which has to allow for a sustainable added value and at the same time it has to satisfy demands for personalization, regionalization and globalization. The growing lack of transparency and the dynamics in the market will amplify at a large scale the competitiveness of many companies. (Bauernhansl, 2014, p. 13)

2.1.4.3. Complexity in the production - the dilemma

In the diagram below, the dilemma of the companies is shown: The outer complexity rises, the functionality of the efficiency and its diversity, the demand regarding delivery capability and availability increase, along with the price elasticity and compatibility or reliability of products drive complexity. Producers have to be flexible regarding the variants, maybe including personalization, meaning that there is no 100 percent reliable forecast available. Crises will always exist, which can lead to a rise or fall in demand, new power centres like the BRICS are arising. Companies have to change in order to match the complexity and, according to W.R: Ashby, complexity can only be bypassed with an adequate complexity level. (Bauernhansl, 2014, pp. 14–15)

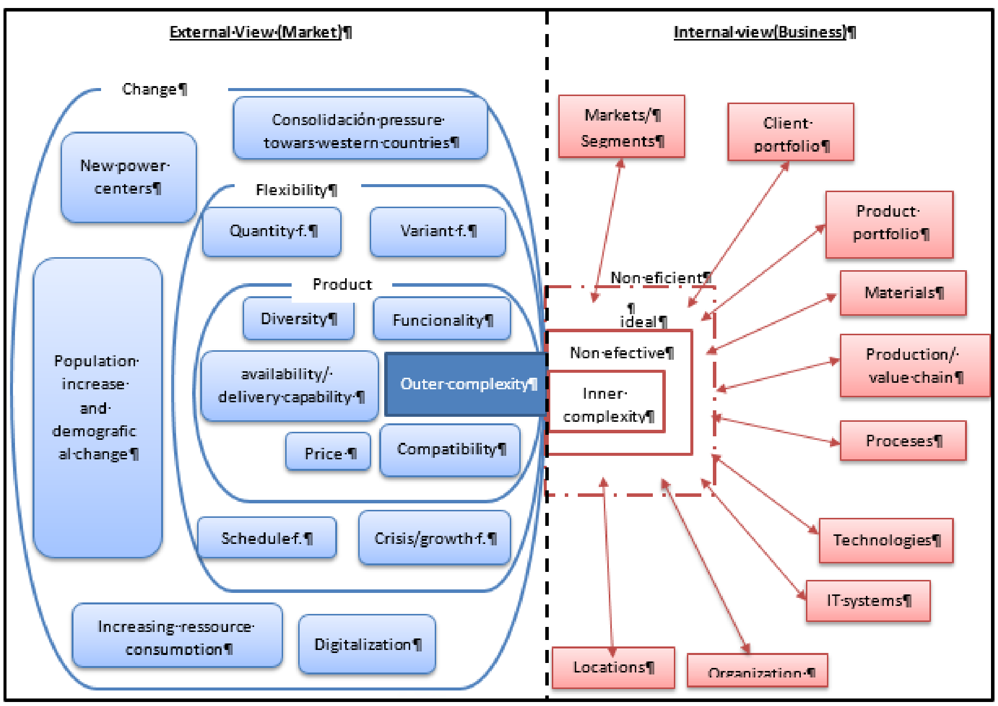


Figure 2 - Comparison of internal and external complexities ©Fraunhofer IPA (Bauernhansl, 2014, p. 14)

2.1.5. The transition phase

Even though there exists a clear line and difference between the third and fourth industrial revolutions, the industry has already moved on the current stage which can be described as industry 3.5 or transition phase. At this transition phase, the following are already in use: communication networks, optimization systems and data bases which increase productivity, reduce costs and make use of digitalization. The next step is the achievement of a total decentralized control, use of Internet of Things and Services, and so on which will be described in the next topics. (Venturelli, 2014)

2.2. Related investigation topics

Already there have been many studies connected to the Industry 4.0 and as well studies about the Industry 4.0 itself as is it highly promoted by European and North American governments, and these will also be mentioned in later chapters. The studies related to Industry 4.0 can be divided into three main groups, which are (Brettel, Friederichsen, Keller, & Rosenberg, 2014, p. 41):

- The individualization of the production
  - Mass customization
  - Modularization
  - Flexible and Reconfigurable Manufacturing Systems (FMS & RMS)
  - Distributed control
  - Self-optimization
  - Rapid Manufacturing
  - Cloud Computing
- Horizontal integration in collaborative networks
  - Collaborative Networks
  - Distributed Manufacturing
  - Supply-Chain Flexibility
  - Supply-Chain Visibility
  - Internet of Things and Services
- End-to-End digital integration
  - Virtualization of the process chain
  - Individualized Traced Data
  - Real-Time Operating Systems
  - Simulation and Modelling of products and processes
  - Simultaneous planning of products and production processes

2.3. Elementary parts of the Industry 4.0

2.3.1. Drivers of the Industry 4.0

2.3.1.1. Industrial Developments

The following three technologies and trends are substantial drivers of the Industry 4.0:

1. The use of productive intelligent embedded systems, mobile services y ubiquitous computing: Some embedded systems are already operating as closed, cooperative and networked systems. Especially in the automotive and aviation industry already there are localized and progressively mobile sensors, regulation and control services. Through increasing open networking, interaction, cooperation and usage of services from the network there will be new options and exploitation potential in many scopes of application and living areas. (Geisberger & Broy, 2012, p. 20)

2. The use of the internet as Business Web, a platform for economic cooperation with two complementing, but different characteristics, especially in trade and logistics but also in the scopes of application such as remote maintenance of equipment or intelligent, networked and sensor-equipped components, e.g. RFID technique, are used. Progressively there will be observation of state and environment as well, and the “memory” of the digital components, also for networked control, coordination and optimization will be used. You can find examples in flow of goods, maintenance processes or fleet management. As well clients will increasingly be able to track the status and the interaction between things and services through the internet and also be able to intervene actively. The other characteristic is the outsourcing of classical IT, administration, distributed coordination, operation and billing tasks towards the cloud, to worldwide distributed external service providers, meaning that it´s operation is independent from localized Data Centres. The Business Web permits the depicture of abilities and services in the internet and with that the possibility of the usage of internet services. This forms the base for integrated web based business models. (Geisberger & Broy, 2012, p.20)

3. The use of the semantic web and methods of the Web 2.0 and the interactive arrangement of integrated services, through the possibilities of a user determined interaction and a corresponding structure of knowledge and communication networks. Social communities in the internet also allow for a huge amount of data and information to be used for the targeted addresses of potential clients. Especially in the scope of auto-organized specialist, application and interest groups new requirements and inquiries for new services, integrated solutions and services arise. As well as this, it applies to B2B applications and business corporations. A huge contribution to those innovations are made by development communities. Those are organized in development platforms, which normally are open source initiatives. Other self-organized communities are specialized to a specific field of application and are driven by a specific problem and clients and users or subject specific social networks. (Geisberger & Broy, 2012, p.21)

Through the reciprocal effect between these trends, especially through the evolutionary dynamic of the open interaction between users and clients, new huge potentials for innovation and future added value arise. The consequences are dynamic, but there are also disruptive changes of markets, industry and business models. On the technology level two things occur: on the one hand the networked and increasingly intelligent RFID and sensor technologies are developed, creating the so called Internet of Things. On the other hand, the internet of services is extended. (Geisberger & Broy, 2012, p.22)

2.3.1.2. Moore’s and Metcalfe’s Law

Other drivers for the fourth industrial revolution are the Moore’s and the Metcalfe’s Law.

In order to obtain advantageous characteristics in the microelectronics industry the in 1947 invented solid-stated drives kept shrinking (or in technical jargon scaling) and this fact together with the invention of the planar integrated circuit granted an unprecedented explosive growth. By scaling solid-state devices cost, performance improved and granted a competitive advantage in the market. (Thompson & Parthasarathy, 2006, p. 20) "As a result, the microelectronics industry has driven transistor feature size scaling from 10 µm to ~30 nm during the past 40 years. During most of this time, scaling simply consisted of reducing the feature size. However, during certain periods, there were major changes as with the industry moved […] finally to complementary metal-oxide-semiconductor (CMOS) planar transistors in the 1980s, which has remained the dominate technology for the past two decades" (Thompson & Parthasarathy, 2006, p.20).

> "Moore's law is the empirical observation that component density and performance of integrated circuits doubles every two years. […] The key driver behind these trends is economics, as pointed out by Moore in 1965. According to Moore, integrated circuits and scaling are "the cheap way to do electronics". Even with large increases in lithography tool cost to fabricate nanoscale CMOS transistors (for example, the cost of lithography steppers increased from $0.01 to $35 million), which has led to modern factories costing $2-3 billion, the cost per transistor has decreased by seven orders of magnitude during the last 40 years and is likely to continue to decrease for another decade. However, CMOS transistor scaling must inevitably slow down and finally halt, at least in the traditional sense, as the lithography scale approaches atomic dimensions" (Thompson & Parthasarathy, 2006, p.21).

It is precisely the fact that CMOS will be much cheaper that makes the change to the Industry 4.0 possible, affordable and reachable in the near future.

The other important law, the Metcalf's law says that the benefit of a communication system grows with the square of the number of its participants. This law refers to communication systems, as CPPS can be understood as a communication system, meaning that the more we connect, including communication across companies, the greater the networking worth of the value network becomes, will also be reflected in its competitiveness. (Bauernhansl, 2014, p. 18)

2.3.2. Challenges

The upcoming chance to the „Industry 4.0" open up next opportunities, risks and challenges as well. The most important risk is the lacking velocity regarding the advances in the implementation or in other words the omission risk. (Kelkar, Heger, & Dao, 2014, p. 11)

Big chances obviously come along with challenges, and for the Industry 4.0 this includes first of all IT-security, high investment costs, missing technical solutions, break-up established structures and processes, management of resulting complexity, unified semantics for communication between machines and as well missing standards, legal insecurities and inadequate employee skills as it can be seen in the following graphic:

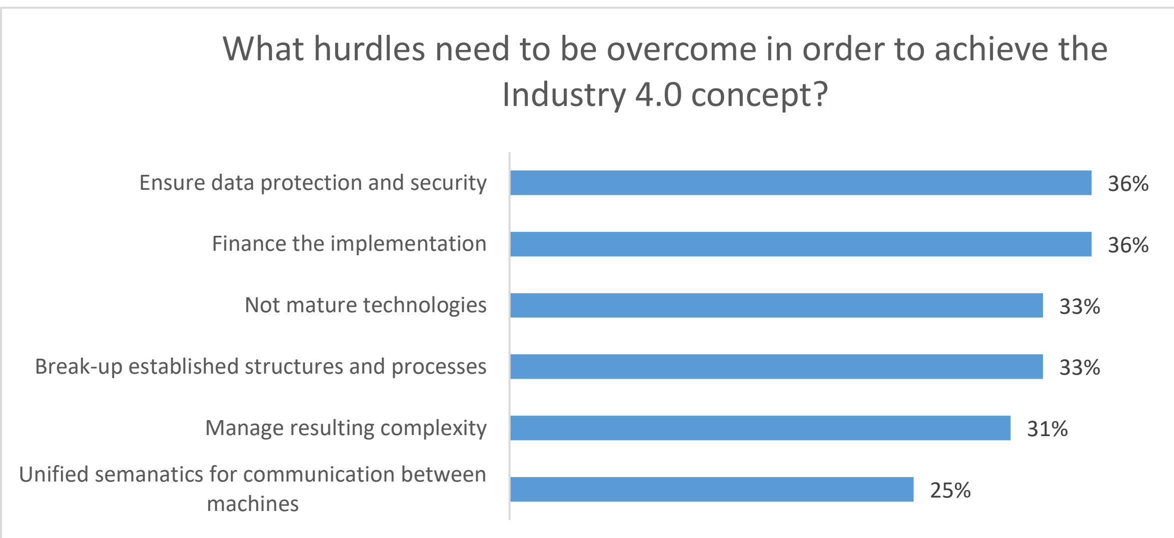


Figure 3- Opinion of companies in a poll to determine the most seen hurdles (Labaca Castro, 2012)

This graph shows the opinion of companies participating in an IDC (International Data Corporation) poll about the Industry 4.0 concept and their opinion about the hurdles that need to be overcome. Especially data protection and security, and the financing of it are seen as main issues, followed by still not mature technologies, the breaking up of established structures and processes.

2.3.2.1. IT-security

The networking of machines opens unknown possibilities and this includes “hackers” as well. It is only a question of time until a cyber-attack will cause a standstill of the production or the piracy of products. That is why IT-security has to be redefined. (Wirnsperger, 2015).

One example would be an attack to the sensors, so that a product would be fabricated in a different size than requested. The most important fact is that companies have to act now and take care of this issue before going from the transition phase to the fourth industrial revolution in order to prevent any attack: Today’s numbers of attacks are low, but with the rise of the fourth revolution and the digitalization will occur increasingly more often. The protection begins with the understanding of being a potential victim, which is missing to most of the companies. Especially interfaces between different softwares, like office, production and control programmes are most vulnerable, that is why a protection for the whole system is needed. (Wirnsperger, 2015)

In recent years, there have been attacks on critical infrastructure with different purposes: sabotage, stealing high-sensitive information for industrial espionage, and so on. Below two of these big cases that got lots of attention in the last few years, although many more have occurred, are mentioned:

- 2010: Win32/Stuxnet

> “Two of Stuxnets goals were to locate systems with Siemens Step 7 software – the industrial control systems that operated the centrifuges used by uranium-enrichment plants – and to change the speed of rotors periodically, which compromises the equipment by causing vibrations that can lead to physical damage and thus negatively affecting the enrichment process” (Wirnsperger, 2015).

- 2012: Win32/Flamer

> "Flamer, sophisticated modular malware that has many similarities with Stuxnet, implements complex logic, and some parts of the main module use the same source code as Stuxnet. However, at 20 megabytes, it is several times larger than Stuxnet (less than 1 MB) – and parts of additional operations in its code was written in Lua, a scripting language normally used by game developers; other differences made Flame a unique piece. Some researchers even claimed that it was the most complex malware ever seen" (Wirnsperger, 2015).

Besides of having IT Security laws that protect critical infrastructure for example, there are some measures to be taken regarding how the security of the information exchanged in the factories will be managed. One fundamental principle in the Industry 4.0 is the "smartization" of the Industry, which involves creating smart products and processes followed by storage and processing of large amounts of information. That infrastructure should be carefully designed to support the full availability of this "smartization" without compromising the data. Endpoint protection, authentication methods and encryption will probably be some of the major topics considered over the next few years to help this emerging industry become the Secure Industry 4.0. (Wirnsperger, 2015)

2.3.2.2. High investment costs

A recent study realized by PWC about the opportunities and challenges of the industrial internet showed that companies would be willing to invest 3.3% of their annual revenues in industry 4.0 solutions. (Koch, Kuge, Geissbauer, & Schrauf, 2014, p. 17).

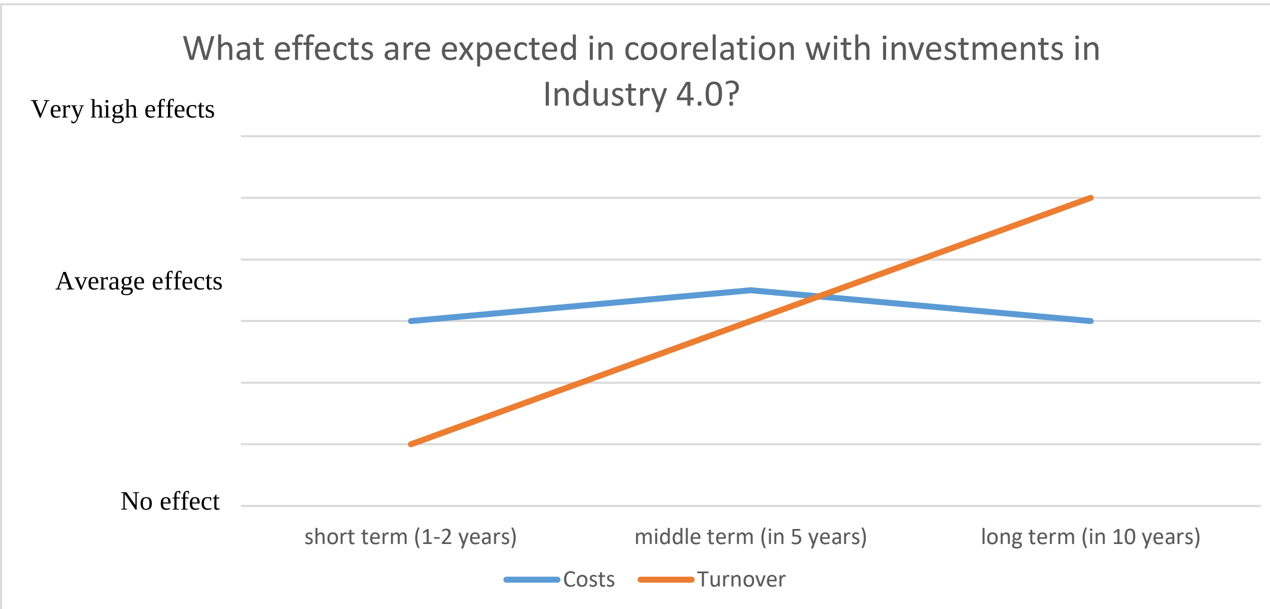


Figure 4 - Expected effects in correlation with investments in Industry 4.0 (Wischmann, Wangler & Botthoff, 2015, p. 12)

Another study realized by the German Ministry for Economy showed that the question of the economic efficiency of the required investments in particular is turning out to be one of the greatest obstacles. From the few studies which not only examine the economic growth potential but also the investment costs that are needed for this, it becomes evident that most German companies estimate the investment costs to be higher on a mid-term basis than the expected company growth. It is probable that many companies, especially in the SME segment, hesitate because of the relation – mostly negative - between the predicted high demand for investments and the resulting sales growth. Meanwhile, however, according to our current survey, the expected income exceeds the costs after about six years so that increased investments in Industry 4.0 can be expected in the near future. The evaluations show consistently positive expectations regarding the economic and business effects that are being expected through Industry 4.0.

However, it also shows that many companies still act hesitantly at present. It is recommended to discuss and apply valid business models to be able to prove the benefits of investments in Industry 4.0. Furthermore, there is a need for a detailed analysis of the hitherto underestimated positive network effects which result from the digitalisation that accompanies Industry 4.0. (Wischmann et al., 2015, p. 12)

2.3.2.3. Preservation of company secrets

Company secrets are non-obvious internal processes, whose holder intents secrecy, based on an economic interest worthy of protection. (Berwanger, Meckel, Wichert, & Bartsch, 2013, p. 431) Already data, including each date, is seen as a central economic good, which are being produced exponentially in the digitalised economy and society and which will be new, economically relevant resources. All these are as well company secrets but could be more easily accessible by externals.

2.3.2.4. Missing standards

A key aspect, in order for the fourth industrial revolution are international standards. Therefore, appropriate standards will have to be developed that deals with structural principles, interfaces and data exchange. With digitization of industrial production, it is essential for extremely divergent systems from various manufacturers to interact reliably and efficiently. (Deutsche Kommission Elektrotechnik (DKE) & Deutsches Institut für Normung e.V. (DIN), 2016, p. 7). An architecture reference base is built as a unique structure for concepts and methods to create a common structure and language for the uniform description and specifications of concrete systems in architecture to be applied. For this aim, a cooperation over sectorial and branch borders is needed.

Research should be done in the area of structural principles, interfaces and data exchange formats needed to support the “Industry 4.0”. This has to be made in international and industrial teams, in order to make the results acceptable between multiple and not only within one company. Some international standards, of great interest, already exist. These should be revised and their role for "Industry 4.0" confirmed. Other standards will have to be developed in order to fill gaps not yet covered.

Deeper knowledge concerning structural principles, interfaces and data exchange formats are needed to support "Industry 4.0" and upon new or partly existing international and industrially accepted standards for Industry 4.0 should be agreed upon. (Widforss, n.d.)

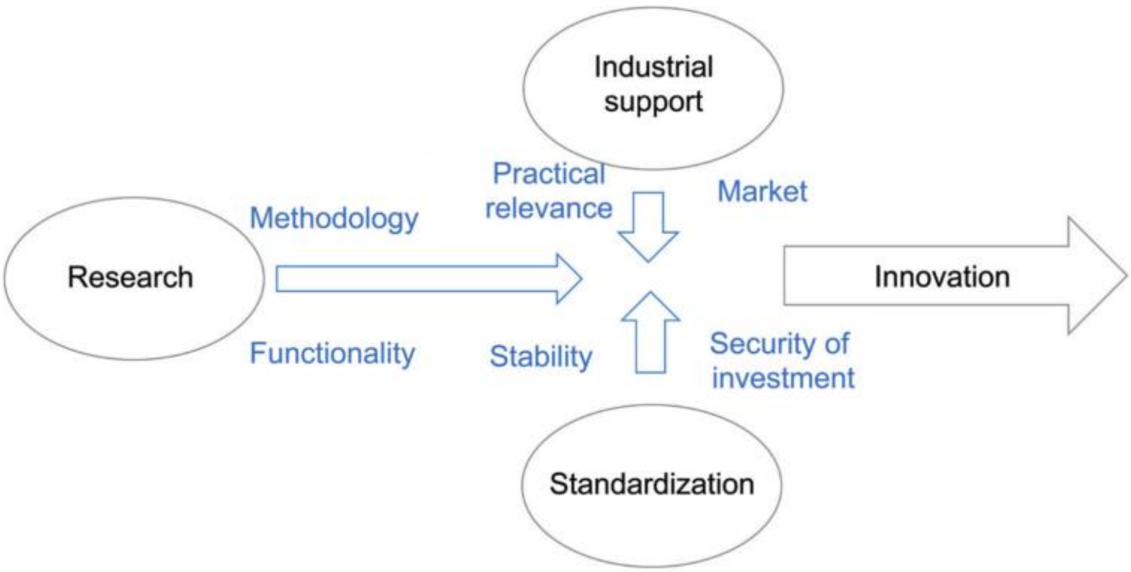


Figure 5- Innovation by standardization (DKE & DIN, 2016, p. 15)

> "Standards and specifications represent an effective instrument for putting the results of research into practice in a rapid and user-friendly manner, and by doing so promoting rapid access to the market for innovations. They thus secure a broad acceptance for the implementation of new concepts and technologies in industrial practice, create confidence and trust among manufacturers and users, and provide the necessary security for investment.

> Development phase standardization therefore makes a fundamental contribution to the utilization of research results. It plays a decisive part in making the traditional standardization process more dynamic, and comprises all activities which are aimed at detecting the standardization potential of strategic, fundamentally innovative products and services, systems and basic technologies, at as early a stage as possible" (DKE & DIN, 2016, p. 15).

The central importance of standardization in the digitization of industrial manufacturing is now becoming apparent outside Germany in a large number of activities. There are for example standardization initiatives at ISO, IEC, ISO/IEC JTC 1 (ISO/IEC Joint Technical Committee for Information Technology), W3C (World Wide Web Consortium), ITU-T and IEEE (Institute of Electrical and Electronics Engineers), and also initiatives such as the Industrial Internet Consortium (IIC).(DKE & DIN, 2016, p. 21)

In order to support the vision of "Industry 4.0" as well as possible at the International Organization for Standardization (ISO) and to deal with the topic of standardization in a concerted and all-encompassing manner, the German Institute for Standardization (Deutsches Institut für Normung or DIN) has initiated a strategic advisory group at ISO on "Industry 4.0", which aim is to organize the contribution to be made by ISO and in that way support a common procedure, especially together with the International Electrotechnical Commission (IEC) and the International Telecommunication Union sector for technology (ITU-T). The focus of the strategic advisory group is on the Strategic and conceptual development of "Industry 4.0" at ISO, the identification of needed standards and specifications, the establishment of implementation strategies and recommendations for "Industry 4.0", the Coordination of the standardization activities on the international level , the establishment of early coordination across the various committees and organizations and the cooperation with further organizations on the national, European and international levels, with great importance attached to cooperation with IEC and ITU-T. The report to the Technical Management Board is planned for September 2016.(DKE & DIN, 2016)

2.3.2.5. Legal issues

Most non-personal-data produced by machines and devices containing no information about persons are not regulated by law. There, indeed partly exist legal protection, like for example the data bank copyright and data bank manufacturer protection in German law as well as the legal protection for company secrets. Even though it should be separated from premature legal regulation and first of all let the companies have the rights of use through contractual designs. If the distribution of data usage through private autonomous instruments be insufficient, then it can be corrected afterwards and as well monopolistic constructions should be intervened by the cartel office. Approaches which guarantee the data protection through technical design, like for example “Privacy by design” will be core elements. Considering the current Safe Harbor ruling by the European court of justice, it is important to set up reliable regulations in the international data interchange. (Plöger et al., 2015, p. 12)

The same publication experts were surveyed about the situation of legal framework in Europa and in the world, shown in the following figure:

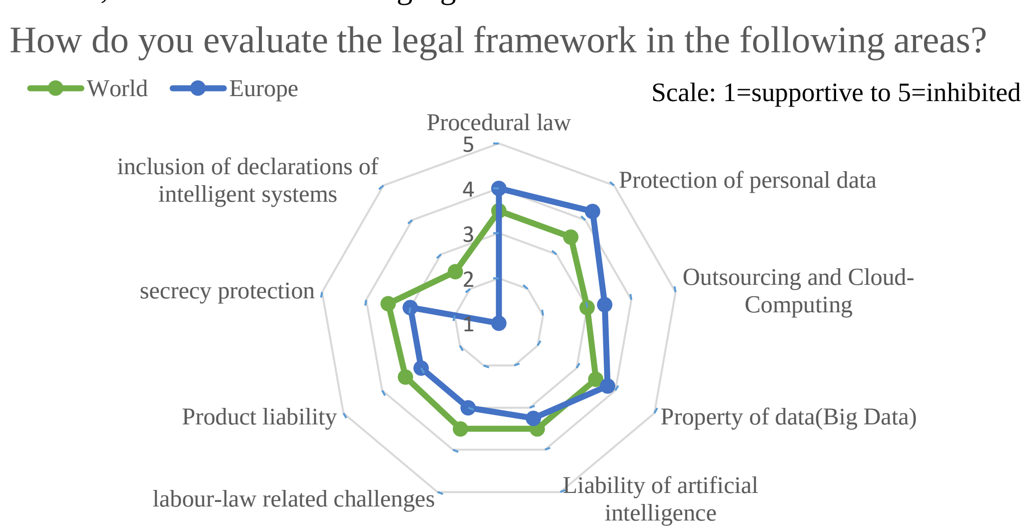


Figure 6 - Legal Framework Evaluation in Europe and rest of the World (Plöger et al., 2015, p. 8)

Most of the questioned saw the most obstacles in Europa in the protection of personal data and cloud computing. In most of the areas the rest of the world shows to have less obstacles regarding the lower regulation intensity outside Europe. The only exception is the procedural law, as outside of Europe the different regulated Anglo-American procedural law is more common, where companies should be prepared for arbitration, where “discovery processes” or “requests-for-documents” are permitted. As well should be noted the companies see less need for action in the property of data, due to a certain scepticism against a rash regulation.(Plöger et al., 2015, p. 8)

2.3.2.6. Inadequate employee skills

The qualification of the employees is a very important topic for the whole industry. The digital change will alter the requirements over the whole value chain. Processes and business models will become more agile and data intensive and require a whole bunch of new abilities and qualifications. As well the demand for software developers and data analysts will rise significantly in the next five to 10 years. (Koch, Geissbauer, Kuge, & Schrauf, 2014, p. 37)

As well it has to be mentioned that for small and big companies, it will be critical to find the right partners with the necessary expertise as well as the use of new services and provider models like Software-as-a-Service. (Koch et al. , 2014, p.5), to which industry analysts are prognosticating rising growth and turnovers. SaaS refers to the provision of standard software solution through the internet, where the supplier is responsible for the operation and maintenance of the multi-tenant software, and does not earn value through licensing as the clients pay a fee for its components and services. (Buxmann, Hess, & Lehmann, 2008, p. 1)

2.3.3. The developments towards the Factory of the “Future or Industry 4.0”

There have been many movements towards the Factory of the future or in other words “Industry 4.0” starting with Numerical-Control Technology (NC), industrial robots and application technologies followed by the first ideas of flexible manufacturing systems as you can see in the following timeline:

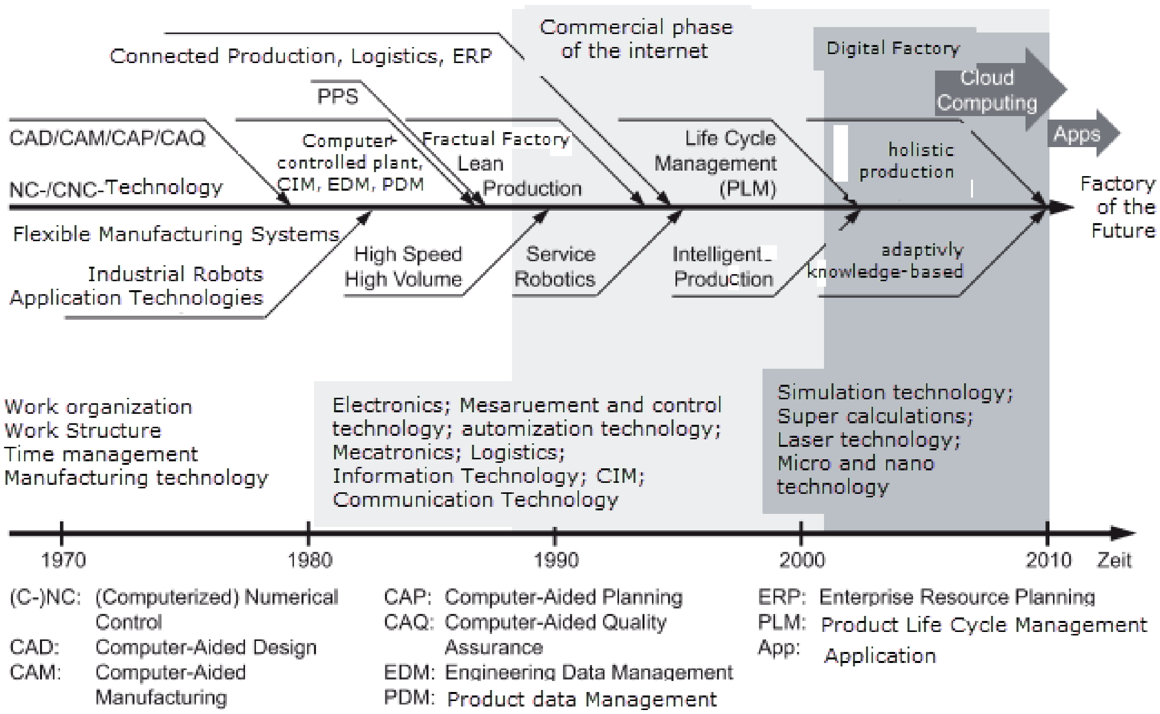


Figure 7- Engineering developments in context to the "Factory of the Future" (Westkämper, Spath, Constantinescu, & Lentes, 2013, p. 87)

In the following two main concepts Computer Integrated Manufacturing and Lean Management will be described shortly.

2.3.3.1. Computer Integrated Manufacturing

The basic idea of the connecting the production through IT techniques is not new: Already in the 80s the idea has come up in the computer integrated manufacturing (CIM).

CIM is a collective term for various activities in a company which can by supported by IT-systems, which are bundled below the term “CAx” (short for computer aided …), whereas the vision behind CIM is the holistic consideration of the output creation of goods and service supported by it systems. The CIM philosophy includes the full automation form the planning until production, where everything should be controlled by computers. However, the human factor fell in to oblivion and CIM failed due to the inexistence or economically inefficiency of required data systems, sensors and data transmission techniques - an overbred, expensive, nearly incontrollable production had been created. (Soder, 2014, p. 85)

In the mid-70s the Americans Wisnosky, Shunk and Harrington received by the American Air Force the order to develop new methods, processes and tools to efficiently support the necessary integration tasks in the Air Force production companies, which they named Integrated Computer Aided Manufacturing(ICAM). They were the first that understood that a network of technical and informational interaction needs to be taken into account in order to manage a successful integration of the production tasks. With the aim of clarifying appropriation, they created the in the following shown “wheel” to exemplify on the one hand the architecture and on the other hand the dependence of the to be coordinated different elements of the integration task.(Westkämper et al., 2013, p. 51)

The below depicted ICAM wheel shows that back in those days data management received a special attention and that as well the four main functions product development, production planning and management as well as plant automatization had to be analysed and newly conceived, so that in the end the key figure productivity is, in principle, connected to the data management and the above mentioned four functions and the co-workers to be integrated, computer technologies to be applied and together with the training and further education. (Westkämper et al., 2013, p. 52)

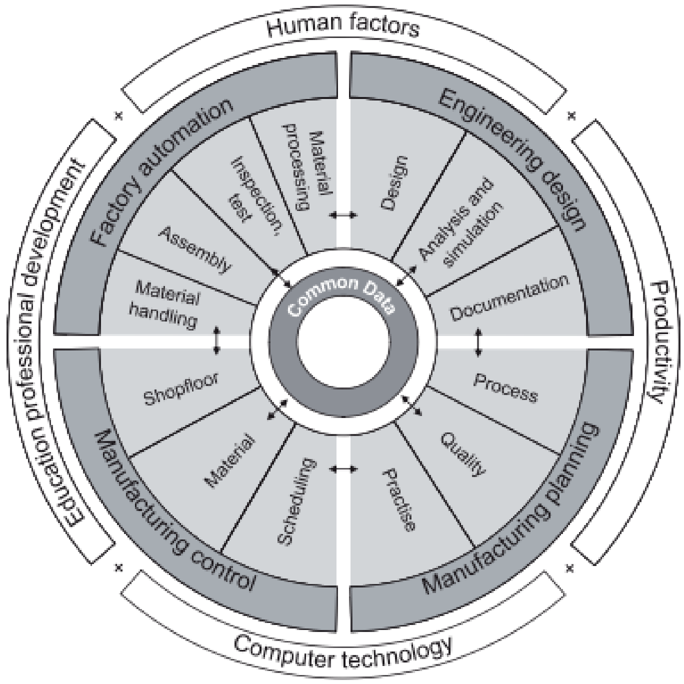


Figure 8 - ICAM Wheel (Westkämper et al., 2013, p. 52)

2.3.3.2. Lean Production

The term Lean Production had been marked within the scope of the International Motor Vehicle Programme (IMVP) and a study realized from 1985 to 1990 by the Massachusetts Institute of Technology (MIT) in the automobile industry. (Womack, Jones, & Roos, 1990, p. 90) This organization and production model of Japanese origin supports the management of a company regarding its quality, productivity, flexibility and employee motivation. As well wastes of all kind, e.g. buffer stock or excess capacity, are evited and the clients moves into the middle of all endeavours. (Syska, 2006, p. 84)

The origins of Lean Production go back to the 50s, in which days the Japanese automobile industry was confronted with competing European and US-American companies. (Mählck & Panskus, 1993, p. 24)Four main conditions forced them to make changes: Firstly, the domestic market was very small and demanded a product range. Secondly the Japanese employees were not willing to be treated as variable costs or replaceable parts and therefore enforced their tenure and profit sharing. Thirdly the by the war destroyed Japanese economy had few capital and Forex so it was impossible to invest in the newest western production installations. Fourthly, many foreign automobile producers were eager to open up production plants in Japan in order to defend themselves against Japanese exports. (Syska, 2006, p. 85)

Due to these condition Toyota was forced to develop a new production system, which could compete with the West's "tailored" mass production and the result was the Toyota Production System (TPS), which thanks to the above mentioned MIT study gained a high recognition. (Syska, 2006, p. 85)

Lean production focuses on key words like team work, continuous improvement process (CIP or KAIZEN), Just in Time (JIT), pull production and the main aim to create a value chain orientated enterprise configuration.(Soder, 2014, p. 87) It stands for the avoidance of waste of the resources in use for the value creation, for an effective flow of material instead of high inventory, for the avoidance of mistakes instead of sophisticated and cost intensive rework and for competent, rich in substance and responsible work in self-monitoring instead of heteronomy and monotony.(Syska, 2006, p. 85)

Processes and procedures shall be optimized in order to archive the following main goals (Mählck & Panskus, 1993, p. 22):

- Quality improvement: Zero mistake strategy, Development quality, Product and process quality
- Time reduction: shorter processing time, reliable processes, avoidance of waste
- Cost reduction: efficient value creation, avoidance of overhead costs, lower production costs

2.3.3.3. Industry 4.0

The next important building block of the factory of the future is the “Industry 4.0” which will be described in the following chapters.

2.4. Basic Technologies

Generally, it is assumed implicitly that "Industry 4.0" is a technological topic and application examples implement technical complexity that has never existed, which is a fundamental misunderstanding: Many basic technologies like **Internet of Things**, **Auto-ID**, **embedded systems** or **broadband, wireless networks** have been available since quite a time and have been developed constantly. As well in the areas of **industrial communication** and **control techniques** with **Ethernet based fieldbuses**, **OPC UA** and **Soft-PLC**, technology standards exist, which are a good basis for the implementation for intelligent facility performance. (Schlick, Stephan, Loskyll, & Lappe, 2014, p. 59)

2.4.1. Existing Technologies

2.4.1.1. Internet of Things

Internet of Things (IoT) is going to connect more than 50 billion things in the next years as the experts of the International Institute of Electrical and Electronics Engineers (IEEE) estimate. They even go further and say that around 100 billion things will be connected until 2020. Not only humans, using the technology will be connected, the term things refers itself to machines, vehicles, building technology, referring to illumination, televisions, computers, fridges, freezers, goods packing, sensors of all kinds, cameras, basically everything imaginable. (Andelfinger & Hänisch, 2015, p. 9) The miniaturization of electronical components, which especially has been hastened through the development of the smartphone, made it possible to connect all things, which should be networked, through the equipment with sensors and tiny computer components and for example Wi-Fi antennas and RFID tags. (Andelfinger & Hänisch, 2015, p. 9) The Internet of things is seen as a market worth billion by experts: Rob Lloyd, president of CISCO, numbers the business possibilities until 2020 to 14,4 trillion US Dollar.(Paul, 2013)

2.4.1.2. Auto-ID

> "Automated identification systems which involve the automated retrieval of the identity of objects are becoming a reality for monitoring items moving through the manufacturing supply chain. Automated identification enables accurate, timely information about a specific item to be stored, retrieved and communicated. This information can be used to assist in automated decision making and control functions relevant to that item" (McFarlane, Sarma, Chirn, Wong, & Ashton, 2003, p. 1).
>
> "Automated identification systems have been used industrially for almost 20 years. More recently the aim of the work of the "Auto ID Centre" has been to develop standards and network infrastructure for enabling unique, item- level identity and related product information to be uniformly available to enhance production, distribution, storage and retail processes in the supply chain" (Sarma, Brock, & Ashton, 2000).

The centre is also helping to bring the price of the automated identification process down so that it becomes feasible to consider the automated identification of everyday retail items. The initial systems being developed draw heavily on past and current developments in the area of radio frequency identification (RFID). RFID provides a simple means of obtaining unique, item-level identity data, increasingly at a reasonably low cost. (Sarma, 2001) These systems can be coupled to networked databases which enable additional data about the item to be kept.

2.4.1.3. Embedded Systems

Embedded systems are information processing systems which are integrated in superordinate systems, which execute special, dedicated tasks and functions in those superordinate systems and which are only developed for these functions. Embedded systems are note the main part, but indispensable. These systems can be found in mundane things like transport vehicles (drive control, climate control, breaking systems, navigation systems, ABS, autopilot, and so on), medical device like tomographs or pacemakers, production facilities (conveyer control), processing technology and so on. (Lange, Bogdan, & Schweizer, 2015, p. 1) The trend of miniaturizing embedded systems and their penetration into all living and working environments can be summed up into three main terms: Ubiquitous Computing, Pervasive Computing and Ambient Intelligence. The first one ubiquitous computing refers to the availability of information at all times and all places, the second one focusses on practical devices being controlled or regulated by embedded systems in order to communicate to the user. Ambient intelligence means the use of highly intelligent chips in our immediate environment, like clothes, buildings, medical utilities. Entertainment, etc. (Lange et al., 2015, pp. 2–3)

Embedded systems can be classified into 5 groups(Lange et al., 2015, p. 3):

- Hidden systems: Embedded systems performing controlling or regulation tasks, not having any open control interfaces with the user
- Devices requiring control by specialists, helping with the control of complex tasks
- Data terminal devices being controlled by specialists and connected by a central computer, most of the times as well to a data base
- Self-service devices being used by the layman
- Mobile portable devices for private and business use, with and without wireless connections to bases stations or servers.

2.4.1.4. Broadband, wireless networks

Broadband is part of the Information and Communication Technologies (ICT), which have as the same main base the semiconductor technology, and is a telecommunication service under which the analogue and digital transmission of data over a corresponding network infrastructure are summed up. Here broadband comprehends a number of electronical communication technologies, which enables the on the internet protocol(IP) based data, to be received and sent. (Bach, 2008, p. 11) For IP-based data transmission, the velocity of transmitting data over the internet is distinguished between narrowband and broadband, whereas the transmission rate of a ISDN-Primary Rate interface should be over 1.5 Mbit/s (Megabyte per second) as the International Telecommunication Union (ITU) stated it in its Guideline I.113 from 1997. (International Telecomunication Union, 2003). Wireless networks are local radio networks like WLAN/WiFi (Wireless Local Area network/Wireless Fidelity; IEEE standard 802.11x) or WiMax (Worldwide Interoperability for Microwave access; IEEE standard802.16y)(Engineers Garage, 2012), mobile radio networks like second generation or 2G GSM(Global System for Mobile Communications; 9,6 kBits/s; ETSI(European Telecommunications Standards Institute) Standard TS 102 128 TR 145 926and), 2.5G or GPRS (General Packaged Radio Service; 115 kBits/s; ETSI TS 155 919 and so on), 2.75G or EDGE (Enhanced Data Rates for GSM Evolution; 236 kBits/s; ETSI TS, 3G or UMTS(Universal Mobile Telecommunication system; 384 kBits/s; ETSI 3GPP 25.-series), 3.5G or HSPA (High Speed Down Link Packet Data; 14,4 Mbit/s; 3GPP 25.-series) and the newest standard LTE(Long Term Evolution; ETSI TS 133 969 and so on) or 3.9G(150 Mbit/s), 4G(LTE-A; 600 Mbits/sec and 4.5G(LTE-AP; 1 GBit/s). (Elektronik-Kompendium.de, 2016)

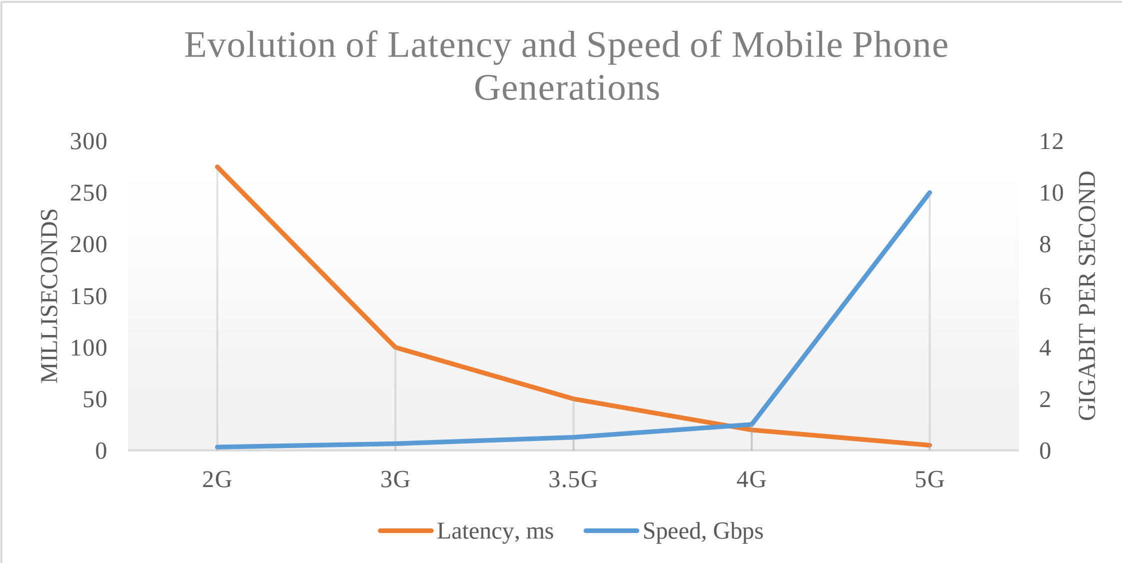


Figure 9 - Evolution of Latency and Speed of Mobile Phone Generations (The Economist Newspaper Limited, 2016)

In the above figure you can see the evolution of latency and speed of the second till the current fourth generation and an outlook of the next already in tests existing generation, which decuples the speed to nearly 10 GB per seconds and lowers the latency to nearly zero milliseconds.

2.4.1.5. Industrial Communication/Control technology standards

Due to the development in the micro- and optoelectronics, there are new structures based on serial communication, which divides the automation systems in several hierarchical levels as you can see in the figure 9. Through the implementation of microcontrollers in intelligent automation control devices, on the one hand their functionality of those can be drastically expanded and on the other hand the reliability can be optimized through a number of Eigen- and diagnostic functions. (Schnell & Wiedemann, 2008, p. 101)

Serial Communications are accepted at field level, which serves as connector between the production facilities in the sensor and actor level, close to the processes, as it can be seen in the figure below:

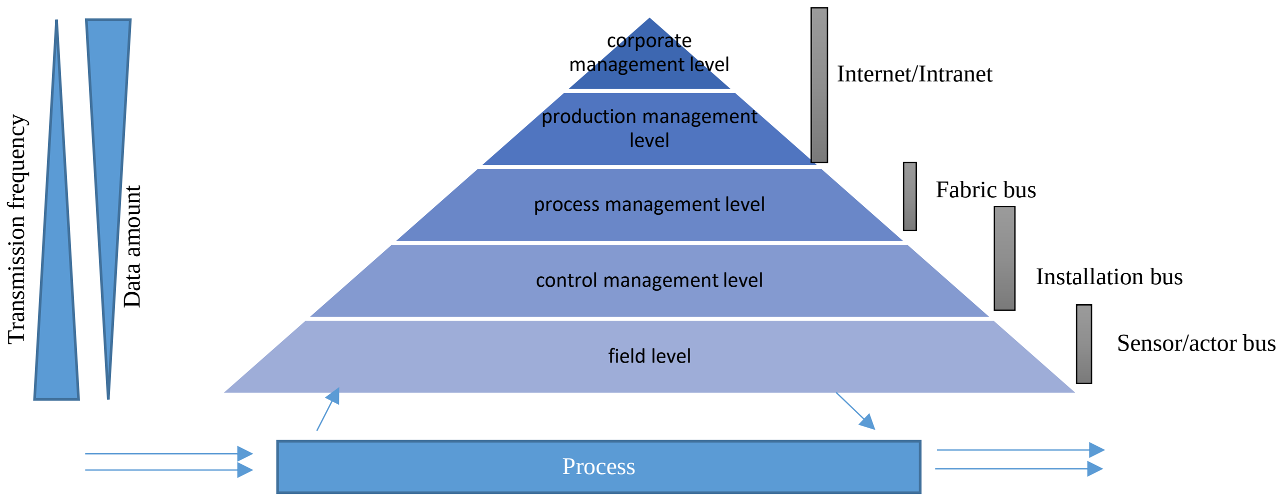


Figure 10 - Model of levels for categorization of bus systems in automation systems (Schnell & Wiedemann, 2012, p. 117; Schumacher, Form, Leohard & Varchmin, 2006, p. 10)

The requirements for such bus systems are real-time capability (using the determined access method), high transmission velocities, reliability (incl. if necessary error tolerance), low disruptive sensibility (EMC or electromagnetic compatibility), comprehensive topology, flexibility, installation- and mounting technology (Sensor/actor area) and profitability (Low cost solutions). (Schnell & Wiedemann, 2008, p. 102). These requirements result in a hierarchical communication structure in the form of a multilevel fieldbus network, which are going to be in great demand (Kriesel, Gibas, Riedel, & Blanke, 1990, pp. 150–153) and necessary for "Industry 4.0" as they offer a high flexibility, free eligible topology, projectable reliability through a balanced redundancy and connected to that, an customizable real-time capability.

2.4.1.6. OPC UA

OPC stands for OLE (Object Linking and Embedding) for Process Control and refers to a new industrial interoperability standard for the interchange of data between different components in the automation technology and is being maintained by the OPC-foundation to which more than 200 enterprises belong. The OPC specifications itself are based on Component Object Model (COM), which is the main technology for the support of distributed systems. COM is competing with CORBA (Common Request Broker Architecture) for UNIX (Uniplexed Information and Computing System) based systems, but all or nearly all computer solutions in the automation world are based on Microsoft Windows and use existing Microsoft Windows technologies like DNA (Distributed interNet Application), ODBC (OLE DataBase Connectivity) and OLE as mentioned above are based on COM. (Schumacher et al., 2006, p. 151). In many industrial firms, process data are captured and processed through the above mentioned many levels, but are being complicated by the lack of a uniform interface standard between the field and control management levels while each automation equipment manufacturer uses own methods and protocols. This is where OPC is supposed to intervene and unify everything regarding the communication.

2.4.1.7. Soft-PLC

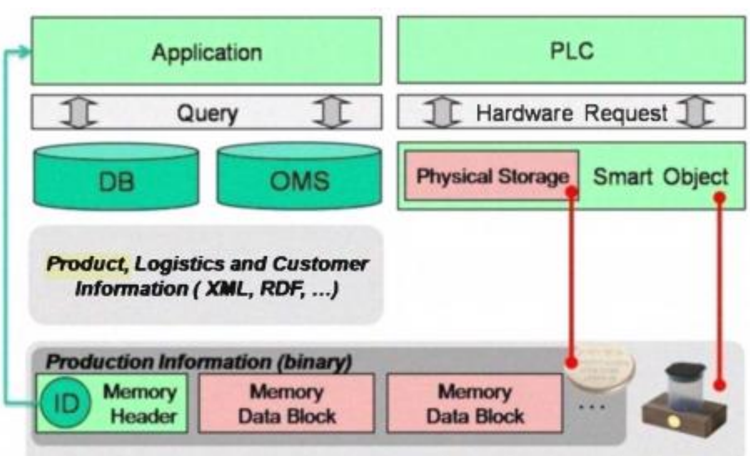
The Programmable Logic Control (PLC) has its task to control or regulate single operations of a machine or facility after a predefined functionality process depending on sensor signals.(Kaftan, 2016, p. 13) PLCs are produced in a series and primarily do not have any task. All logical elements, storage functions, times and so on are integrated by the manufacturer and are connected through the programming to a functioning controller. Further, Soft-PLC, is the reconstruction of a PLC in a software.(Bayer, 2009, p. 7) Nowadays, Soft-LPX can run on Linux, any microcontroller platform or even without an operation system(OS). Advantages of such system are a fully graphical user interface, high user comfort and easiness of use; the hardware and operation system are standardised and widespread and the final advantage is that a file system, network connection, efficient CPU and large storage already exist. (Bayer, 2009, p. 8) Whereas the disadvantages are that the OS only have a real time capability to a limited extent (<10 ms) and that the system is dependent on the reliability of the OS:(Bayer, 2009, p. 9)

2.4.2. Core contents of the Industry 4.0 in the production

The core content of “Industry 4.0” applications is the exploitation of current and future optimization potentials in information processing, with innovation following the connection of many sources of information that are not yet connected, as well as the improvement of technical and organizational processes Technology itself is the mean to the end which has to be adjusted the circumstances.(Schlick et al., 2014, p. 59) In the production the will exist three main components, the **intelligent product**, the **intelligent machine** and the **assisting operator**.

2.4.2.1. The intelligent product

The intelligent product is a metaphor for the reduction of the media disruption with reference to the intelligent product. The disruption leads most of the times to waste and less productivity. Information like the product itself, production parameters or needed configuration for facilities are at the right place at the right time and can be processed digitally. A new, additional feature will be the option to store and trace all historical information about each product itself, like for example the applied processes or its unique characteristics. This can be called Digital Object Memory(DOM), according to Stephan et al. (Stephan et al., 2009, p. 200 et sqq.), of which an example design can be found in the following figure 11.



An intelligent pr … e Logistics area like

Figure 11 - Hybrid Architecture of the DOM with physical on-product storage and off-product database (DB) and! or object memory server (OMS) referenced by an ID.(Stephan, Meixner, Koessling, Floerchinger, & Ollinger et al., 2009, p.210)

flexible production or flexible outer logistics. But as well it has to be mentioned that if the product needs to be intelligent it needs to have enough physical space for an electronical component, especially for liquid or small products. Another option is the partly intelligent product using for example auto ID in order to identify a product with less physical space occupying technologies, but this does not mean the unintelligence of the product just that the information will be provided in time at the right place.

2.4.2.2. The intelligent machine

Whereas the intelligent product has one level of application the machine has to be distinguished in **5 phases**: planning, assembling, start-up operations, operation and reconfiguration.

The objective for the **planning, assembling, start-up operations and reconfiguration** lays in the achievement of getting through an efficient function orientated rough planning to a functional machine. It is important to note that "mechatronization" of particular components in connection with a model based projection of the system control, and other factors could be potentially harmful rudiments.(Ollinger & Zühlke, 2013, p. 1444) For the integration of each mechatronic component, an industrial Plug&Play plays a very important role, which covers the integration of the modules in different fieldbus systems right up to the integration in the IT systems of the production. (Schlick et al., 2014, p. 61)

The aims in the **lifecycle** phase of the facility are more diverse and ranging from the technological processes transparency, quality optimization, and maintenance support to the tolerance optimization of the production characteristics in the whole process chain or the utilization maximization of a whole machine park.

In order to achieve these aims four different levels of artificial intelligence are needed as it can be seen in the following figure 12:

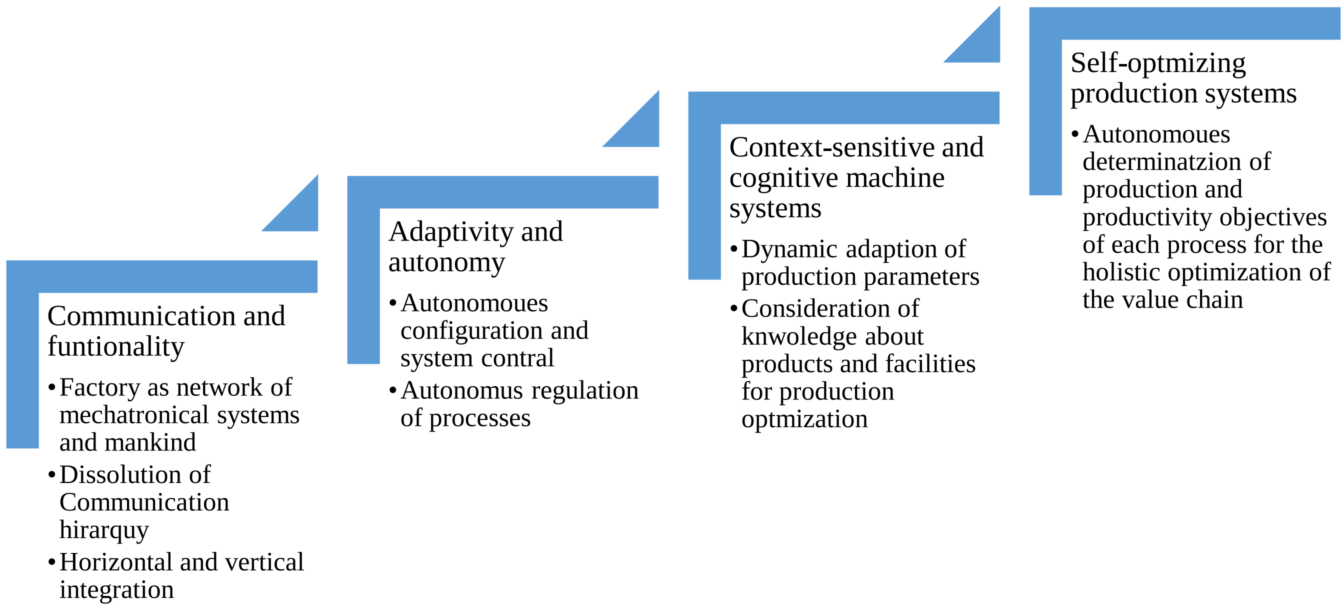


Figure 12 - Steps of intelligent behaviour of production facilities (Schlick et al., 2014, p. 62)

The first step, in which most of the factories are still in, is the implementation of a better communication and functionality, the adaption and implementation of autonomy, context-sensitive and cognitive machine systems and finally, reaching the last step of self-optimizing production systems. (Schlick et al., 2014, p. 61)

2.4.2.3. The assisting operator

Intelligent products and machines will deliver a huge amount of information, which need to be filtered depending on the situation so that mankind can receive the information at the right time at the right place and exactly the information needed in order to comply with the task. This information is diverse and has various sources like the sensor system and other company IT systems. The most important issue is the **man-machine interface**: For example, mobile tablets offer possibilities as they are portable, connectable and communicable via image as well – making reference to augmented reality applications. (Schlick et al., 2014, p. 62)

2.4.3. Production Automation and CPSs

Two core elements of this industrial revolution is the continuing automation of the production and the implementation a cyber-physical systems(CPSs). Especially in decision-making processes with for example 150 machines in a factory, for resulting an issues comes up to a scope of 10^{8160} possible solutions. This is why processes need to be automatized and connected through CPS to facilitate such solutions. (Schuh, Potente, Thomas, & Hauptvogel, 2014, p. 286)

2.4.3.1. Production Automation

Production automation "can be defined as a technology concerned with the application of mechanical, electronic, and computer-based systems to operate and control production" (O'Sullivan, 2009, p. 9). The automatized production design requires the joining of the main innovations: from technology developments, customer requirements and from suppliers in order to find a holistic solution. (Büttner & Brück, 2014, p. 127) Modern production methods and processes have to be more efficient and as well resource and energy saving. Flexibility must also be improved, and the availability of production means must be both increased and sustainable. (Hoppe, 2014, p. 249) Products need to be traced through their life cycle and the production hast be freely scalable. These new technologies in particular shall enable the factory to produce mass products and individual products (batch size 1) at the same time within the same infrastructure The engineering has to be automated and information need to be securely, horizontally and vertically interchangeable through standardized interfaces. Other core requirements for the production are self-optimization, condition monitoring and track and trace. (Hoppe, 2014, p. 250) Two core elements is the batch size 1 as mentioned above and the possibility of data mining. "Industrial companies are increasingly developing data warehouses to collect business data. Data-mining algorithms can not only extract the static patterns in data, but can also discover dynamic trends" (Kusiak & Smith, 2007, p. 147)".

> "There are two general classes of data mining, **descriptive** and **predictive**. The goal of descriptive data mining is to discover patterns, e.g., product configurations formed in mass customization applications. The predictive data mining aims at building models to determine (predict) an outcome, e.g., a stock level. Since the expanse of data analysed by the data-mining algorithms is essentially unlimited, the patterns discovered are usually not anticipated and are of interest to different users" (Kusiak & Smith, 2007, p. 148).

Data Mining within the production comes along with three core principles: the watchdog principle, the drill down principle and the object identification principle.

> "The objective of the watchdog program is to automatically discover "meaningful" item sets from a large number of service reports. The "meaningful" item sets are worth probing further to prevent quality problem epidemics. This intelligent program supports the quality engineers in taking actions of quality improvement before the experienced service technicians make a report" (Hori, Taki, Washio, & Motoda, 2002, p. 19).

Another principle are the drill down, where through predefined evaluating structures, detailed in-depth information can be found and analysed. (Verl & Lechler, 2014, p. 141) The last important principle of data mining is the identification of objects and workplaces with instant display of known object and life cycle data. (Verl & Lechler, 2014, p. 141)

2.4.3.2. Cyber-Physical Systems

In 2006 Hellen Gill of the US-American National Science Foundation first made the term "cyber-physical-systems" apparent, which derives from "cybernetics", a term being invented by the US-American mathematician Norbert Wiener in 1948 (Wiener, 1948). In his vision cybernetics was the conjunction of control and communication, where control is a closed-loop feedback: Control logic is first driven by measurements of the physical processes, and subsequently drives the physical processes. Nowadays cybernetics is understood as the conjunction of physical processes, computation and communication. (Lee & Seshia, 2015, p. 9)

As it is mentioned in the introduction, CPS are:

> "Integrations of computation, networking, and physical processes. Embedded computers and networks monitor and control the physical processes, with feedback loops where physical processes affect computations and vice versa. The economic and societal potential of such systems is vastly greater than what has been realized, and major investments are being made worldwide to develop the technology. The technology builds on the older (but still very young) discipline of embedded systems, computers and software embedded in devices whose principle mission is not computation, such as cars, toys, medical devices, and scientific instruments. CPS integrates the dynamics of the physical processes with those of the software and networking, providing abstractions and modelling, design, and analysis techniques for the integrated whole" (Asare et al., 2012).

But what are CPSs based on, what is their evolution and development? The development is shown in the following figure 12. We already know embedded systems and some of them are already connected to the internet, but the next step is the managing the change from fractal systems to CPSs through the most important term in CPSs: **COMMUNICATION**. These systems will be capable of communicating through a net, even internet and use all its services. They can capture immediately the environment with appropriate sensors, analyse it with global available data and services, save them and influence the physical world with the help of actors.

This is why in the in the end, with the use of the three types of internet - Human internet, IoT and IoS - decentralized, fast and real-time solutions can be applied.

The final stage of Cyber-Physical Systems would be a System-of-Systems(SoS) as it is described in an overall topic for funding projects of the European Commission. SoS describe the large scale integration of many independent self-contained IT systems to satisfy global needs from citizens, taking into account multi-system requests. (European Commission, 2015b)

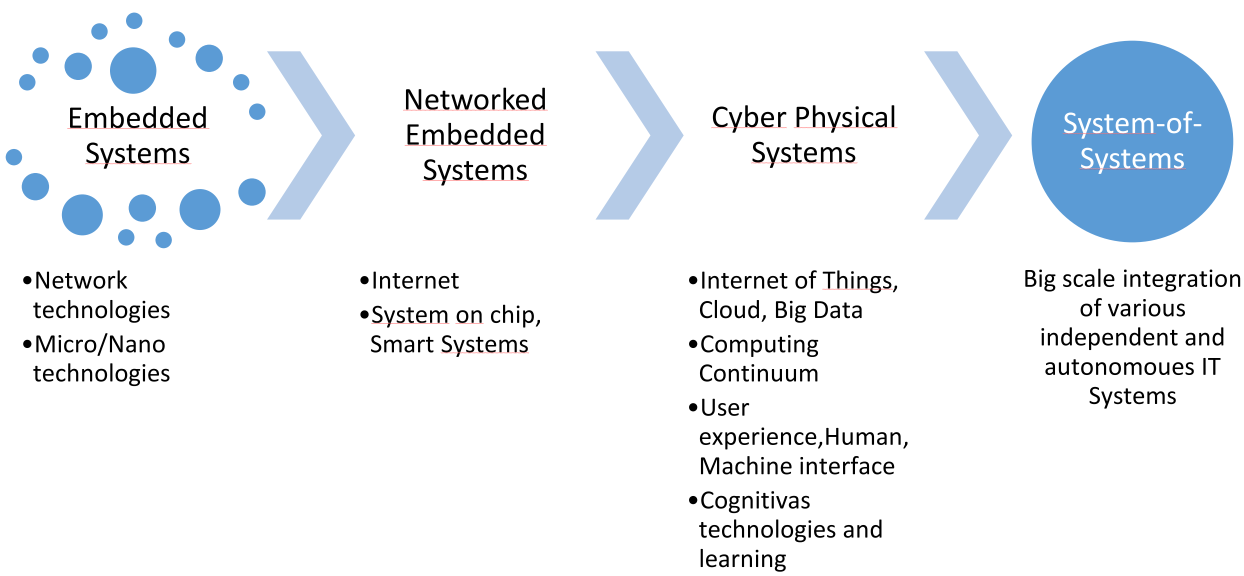


Figure 13 - Evolution and development of CPSs – own creation, in the style of (Laka, 2010, p. 5)

Design and deployment of CPSs can be based on a **5C** architecture as it can be seen in the below shown figure, where the functions are shown in the pyramid and the attributes on the right hand side: In the **connection** level the devices can be designed to self-connect and self-sense for its behaviour through examples like Plug&Play, tether free communication and a sensor network. In the **conversion** level, the data of devices can be self-related and can sensor measure the features of critical issues with self-aware capabilities. Machines can use the self-aware information in order to self-predict their potential issues. In the c**yber**-level, each machine can create its own "twin" by using instrumented features and even characterize the health model of the machine, based on a time-machine methodology. The twin created in the cyber space can function as self-comparison for peer-to-peer performance for further synthesis. In the **cognition** level, the results of a self-assessment and self-evaluation will be presented to users of the system in order to show potential issues. In the **configuration** level, the machine or the production system can be reconfigured based on priority and risk criteria to achieve resilient performance.(J. Lee, Bagheri, & Kao, 2015, p. 19)

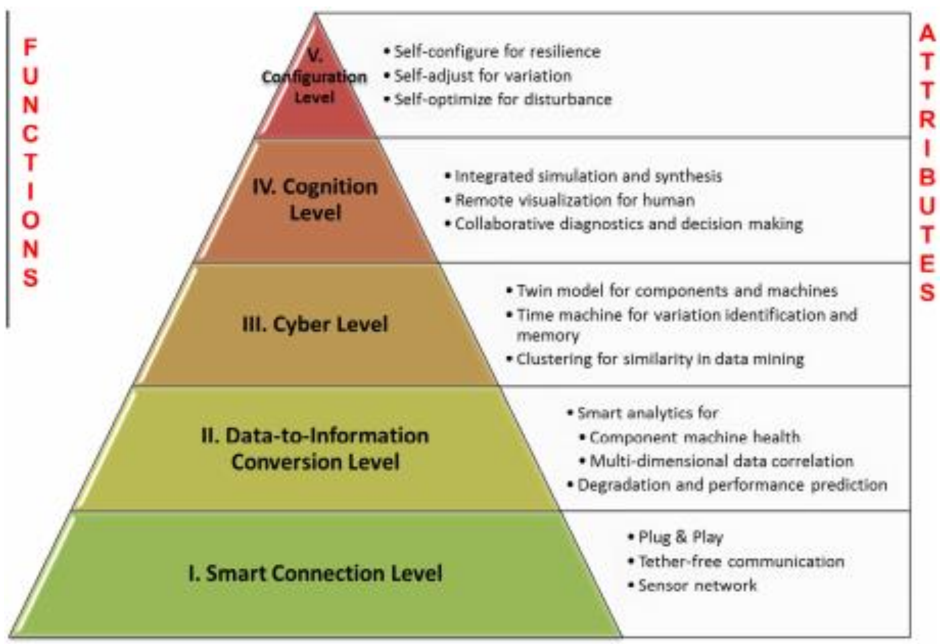


Figure 14- 5C architecture for implementation of Cyber-Physical System.(J. Lee et al., 2015, p.19)

The system itself creates its value added through communication through intelligent subsystems, which consist of sensor, Hardware(HW)/Software(SW) Controls and HMI(Human-Machine-interface) actors and communication. A CPS might include a cloud service to improve total communication and include services (IoS).(Laka, 2010, p. 7)

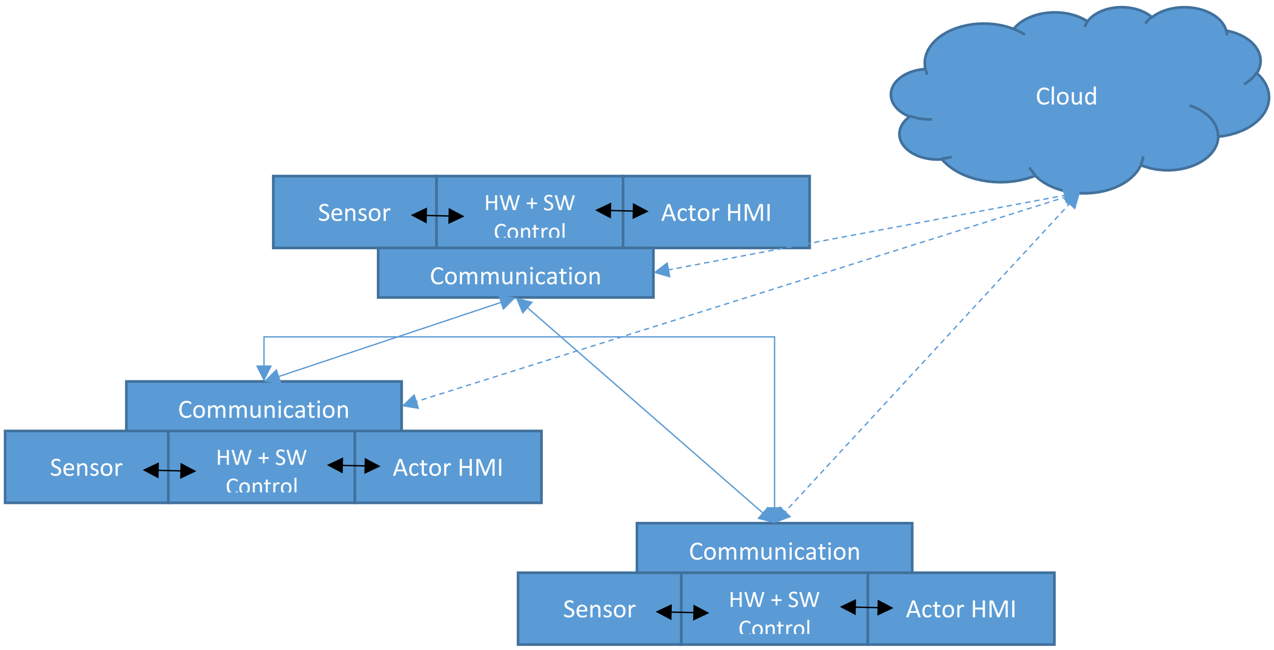


Figure 15 - CPS components (Laka, 2010, p. 7)

One core reason for the intelligence of CPSs is **Metcalfe's Law:** Robert Metcalfe(*1946) is the inventor of the Ethernet-LAN-technology and in 1970 he made the assertion that the value or the performance of a network increases exponentially depending on the number of its members and makes reference to the possible returns of scale while widening its number.(Laudon, Laudon, & Schoder, 2010, p. 223) This means the more intelligent subsystems there are in a CPS more intelligent the whole system is.

2.4.4. Vertical and horizontal integration – Value chain integration

One of the main changes in Industry 4.0 environment is that production systems will be connected vertically with all business processes within the company and horizontally with the value chain networks and that these connections/systems can be controlled in real time.

Requirements for this network are a permanent broadband connection to process all data, standardized services and applications and efficient structures. It should be kept in mind that data has to be stored safely, but always accessible externally.(Kempermann & Lichtblau, 2014, p. 8)

The vertical integration includes the extensive networked communication within a business: Different IT-systems will be connected and harmonized, regardingless its hierarchy level. All elements communicate and control optimizing and control processes in real time so that the production and resource usage will be more efficient.(Kempermann & Lichtblau, 2014, p. 8)

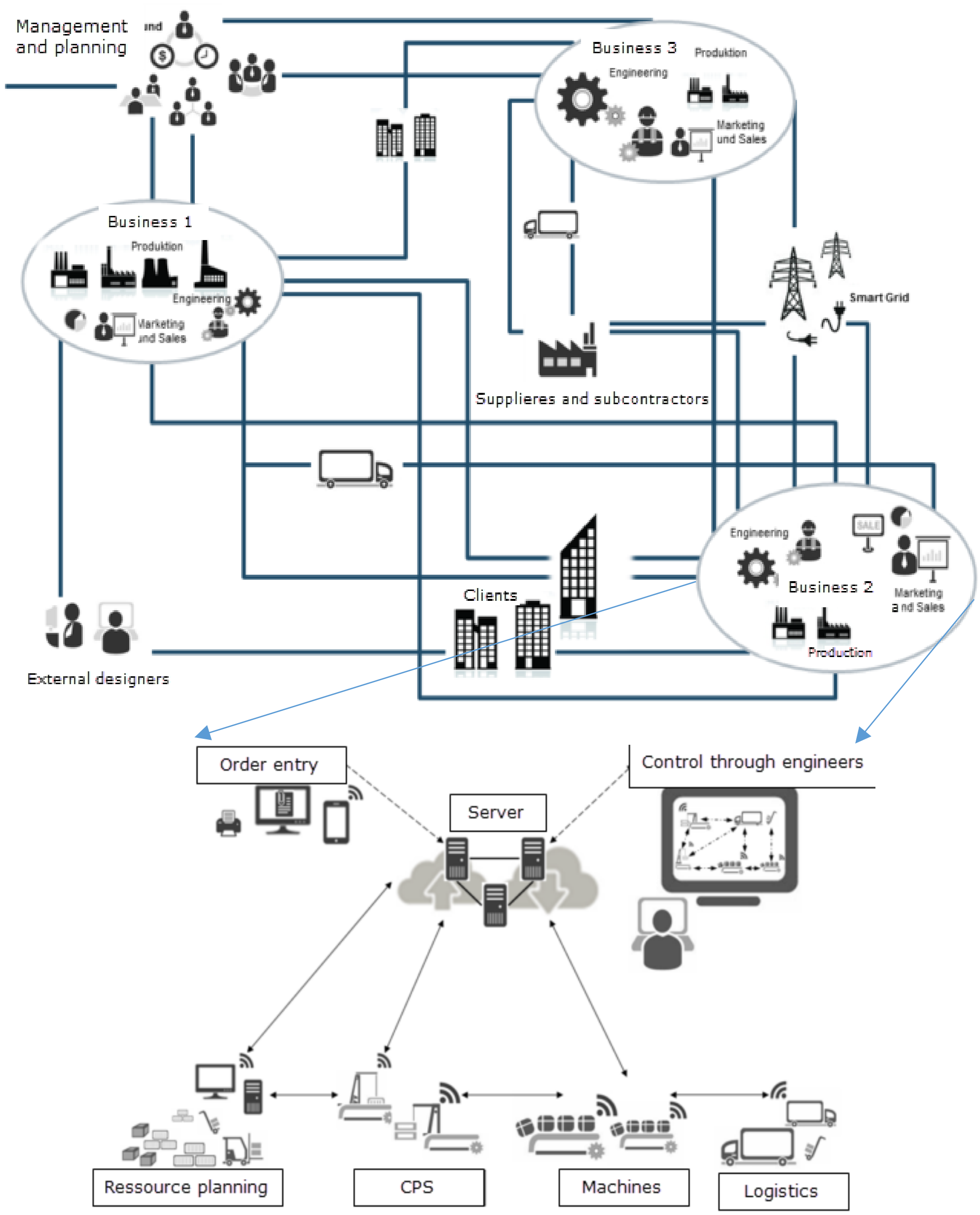


Figure 16 - Horizontal integration above and vertical below(Kempermann & Lichtblau, 2014, p. 8,9)

The horizontal integration builds up upon the vertical, where technical processes can be integrated in super ordinated, which are synchronized with other participants of the value chain grid in order to create an adaptive logistic system (Kempermann & Lichtblau, 2014, p. 9)

2.4.5. Security and Safety

The connection of many IT systems creates different security requirements as each component has different characteristics, which creates new vulnerabilities and possibilities to attackers to intrude into systems and with that as well cause damages to the physical world. Examples would be that computer viruses could spread over to the production facilities and liberate remote maintenance for machines.(Fallenbeck & Eckert, 2014, p. 397) Classical security technologies like Virus Scanner, firewalls, VPNs or SSL/TLS encoded communication between browsers and serves are not suitable for some components due to its easy, resource-saving structure and characteristics. They are also unable to identify themselves, detect manipulations and communicate safely. Required are new safety techniques like **trustworthy kernels** for limited components or lightweight, strong security mechanism to prevent manipulations or render them as harmless manipulation.(Fallenbeck & Eckert, 2014, p. 398) In addition, the time windows for decoding and encoding data or authentication by users and equipment are tiny, so it is also necessary to develop a **security concept for all levels**, which includes for example the user rights management (Fallenbeck & Eckert, 2014, p. 398) Another hurdle is the amount of date created, meaning **Big Data**, which has to be controlled as well.(Fallenbeck & Eckert, 2014, p. 399) Big Data are data, which, with regard to the amount, heterogeneity and frequency/process velocity of data, otherwise known as the 3Vs – Volume, Velocity and Variety – are huger than the "normal".

2.4.6. Man-Machine-Interaction

The evolution leads to flexibility, but as mentioned in the introduction a high complexity. This as well changes the role of the people in the company, because the huge amount of data cannot be reviewed, nor the autonomy of processes can be overseen by the personnel and the knowledge about such could easily get lost so that they cannot react effectively and fast to any issue. Until now production facilities used classical evaluation systems resulting in manual creation of tables, graphics, lists or 2d images, where the staff needed to gather and understand all information on their own according to their knowledge. In the future this data will be available in real-time and displayed immediately on mobile devices. It is important that for incentives to be created in order to improve the staff's knowledge about the facility and its processes and allow them understand and comprehend such. After mastering the collection of all this information, the question of how the personal can interact with the system, arises.

One way of visualizing massive amount of information is the **3d process data visualization**. But so far it has not gained that much acceptation. It would offer the advantages that more information con bi displayed in a smaller room. As well Pantförder (2009) showed in one of his empirical studies that 3d process data visualization on the example of hydraulic presses showed a higher error recognition as conventional 2d visualization, especially with complex problems, where it showed a big advantage. (Pantförder, Vogel-Heuser, & Schweizer, 2009) The recent studies show that a 3d visualization of process data is a technology for better controllability of the extremely high amount of data that will be connected in the future. (Mayer & Pantförder, 2014, p. 483)

But how can workers easily control machines and understand 3d process data visualization? The answer lies in the consumer electronics: **Multitouch-displays**. Within the industry most of the touch panels which has already been used are a one-to-one implementation of the conventional usage. Now you will be able to save time in the process control through **finger gestures**. As well the implementation of portable devices will enhance the production process.(Mayer & Pantförder, 2014, p. 485)

This leads to an extended use of mobile devices, the **Augmented Reality(AR)**, where the build.in camera comes in to use. The image transmitted, the reality, is enhances/augmented by additional information on the devices screen. This is not only useful for local usage, but also with the connection to the internet of things and services, making it for example possible to use video stream all over the world and do remote maintenance. (Mayer & Pantförder, 2014, p. 488) A further possible implementation is the use of smart glasses and using voice control.

Figure 17 - An example of AR on an assembly robot(top) (Iconics Germany, 2015) *and AR on a wearable(Bottom)* (Critical Manufacturing, 2016; SAP, 2013)

Furthermore, **Social Networks** or third-party **Information systems** can be used to share information with other companies.

2.5. Introduction to companies

The Frauenhofer Institute developed a 7 step introduction process to industry 4.0 for a company, how they can approach the topic and how the concepts and technologies can be implemented in their value chain process, especially in the production system. (Bildstein & Seidelmann, 2014, p. 588) With the help of this method companies can evaluate the use-of-potential different Industry 4.0 aspects and the implementation of concepts can be planned and if such is the case, implemented systematically. The seven steps can be cover three main aspects: Redaction and analysis of the processes, investigation of Industry 4.0 readiness and implementation planning.

First step

The first step included the participation at information events, workshops with specialized executives, the visit to other companies and continues interchange with platforms at research institutes, such as the “Platform / 4.0” for the Frauenhofer Institute. This first step has the main objective of gain understanding, knowledge and commitment. (Bildstein & Seidelmann, 2014, p. 588)

Second step

This step includes the decentral development of use cases within the company, whereby the focus should be placed on real-time, decentralization and software services. As well a first rough cost and use-of-potential analysis should be performed. The main objective of this step is the gaining of use cases. (Bildstein & Seidelmann, 2014, p. 588)

Third step

The third step is the participation of executives in workshops in order to decide upon use case with the best cost and use-of-potential analyses and the lowest implementation risks. The objective is the shortening of the use cases and the development of a project plan. (Bildstein & Seidelmann, 2014, p. 588)

Fourth step

This step focuses on the communication and integration of and between employees, council, clients and suppliers in order to be able to start off with the implementation and to gain commitment. (Bildstein & Seidelmann, 2014, p. 588)

Fifth step

The fifth steps include the implementation of use case in pilot projects using of the 80/20 rule (80% of output/20% of input), the evaluation of costs and use, and as well the realization of workshops to develop new use-case ideas. The overall aim is the evaluation of use cases and gain of implementation experiences. (Bildstein & Seidelmann, 2014, p. 588)

Sixth step

This step is about the definition of a roadmap to roll out successfully evaluated Industry 4.0 use cases throughout the whole company and the creation of a program for the pilot implementation of new use cases. Mile stones are the implementation roadmap and evaluated new use cases. (Bildstein & Seidelmann, 2014, p. 588)

Seventh step

The final step includes the roll out over the whole company with continuous evaluation and the implementation of Industry 4.0 principles in the production system with the overall gain to achieve an Industry 4.0 production system. (Bildstein & Seidelmann, 2014, p. 588)

2.6. Benefits and outlook

As the value added will increase immensely, despite of the high complexity - as it must be controlled, through the decentralization, autonomy, high transparency, knowledge availability, efficiency, productivity, time efficient, and so on which are al success factors of the Smart Factory. But where does this lead to? Mainly in the business world, everything is measured not only by quality, which will increase obviously, but also by how times can be shortened and, last but not least, by costs. The latter especially will decrease as shown in the following table, which shows that all costs in all areas decrease, in the indirect costs, especially there is a huge potential.

Costs	**Effects**	**Potential (%)**
Inventory	Security Stock reduction Avoidance of Bullwhip and Burbridge effect	-30 to -40
Production	OEE improvement Process regulation circles Vertical and horizontal staff flexibility improvement	-10 to -20
Logistics	Augment of automation (Milk Run, Picking, …)	-10 to -20
Complexity	Performance range improvements Less trouble shooting	-60 to -20
Quality	Real-time quality regulation circles	-10 to -20
Maintenance	Optimization of spare parts stock Condition orientated maintenance Dynamic prioritization	-20 to -30

Figure 18 - Estimation of cost reductions (Bauernhansl, 2014, p. 31)

Inventory costs can be reduced by 40 % through a reduction of the security stock, due to real rime planning, which as well diminishes the Bullwhip and Burbridge effect in the supply chain.

The production costs will decrease through the Overall Equipment Efficiency (OEE), process regulation circles and vertical and horizontal staff flexibility improvement of up to 20 %.

Logistics costs could decrease about 20 % as the processes, for example milk run or picking, will be more automated.

Complexity costs mark the highest potential of up to 60 % reduction through improvements in the performance range and the nearly inexistence of issues as nearly all waste is avoided.

Quality costs could decrease about 20 % due to real-time quality regulation circles.

Maintenance costs could decrease about 30% as the spare parts stock is optimized, allowing maintenance, with regard to the condition, to be dynamically prioritized.

In general, it can be said that a huge use potential exists! All industrial experts doing research in this area confirmed a productivity increase of up to 50% depending on the production complexity.(Bauernhansl, 2014, p. 32)

3. Industry 4.0 Context – Fomentation and Development of the Industry 4.0 in selected regions

As many industrialized countries lose their share in the market - as mentioned in the above chapters - especially those should invest in the possibilities of giving their industry incentives to stand out in innovation in order to be more competitive. Whereas the runner up countries should do that in order to maintain the gain in the market share. In the following chapters some governmental incentives in Europe and the Americas will be briefly explained.

3.1. Industry 4.0 in the European Union

The European Commission has the objective of supporting and strengthening the European Union(EU)in the topics of research and development. Therefore, many different promotional tools exist: The main instrument for promoting the European research sector is the framework programme for technological development, which currently is the framework programme number 8 or the current used term Horizon 2020. One part of it is the EUREKA programme, in which 39 European states and the EU encourage cross-border projects.(Geisberger & Broy, 2012, p. 210)

3.1.1. Horizon 2020

> “Horizon 2020 is the biggest EU Research and Innovation programme ever with nearly €80 billion of funding available over 7 years (2014 to 2020) – in addition to the private investment that this money will attract. It promises more breakthroughs, discoveries and world-firsts by taking great ideas from the lab to the market. Horizon 2020 is the financial instrument implementing the Innovation Union, a flagship initiative aimed at securing Europe's global competitiveness” (European Commission, 2016).

The programme is divided into 10 different programme sections: Excellent Science, Industrial Leadership, Societal Sciences, Spreading Excellence and Widening participation, Science with and for society, cross-cutting activities, Fast track to innovation pilot, European Institute of Innovation and technology, Euratom and Smart Cyber Physical Systems. As read in above chapters Industry 4.0 is affecting all of them, but not in all sections exist funding projects.

The European Technology Platform MANUFUTURE Platform originated the European Factories of the Future Research Association, briefly EFFRA, which is an industry-driven association, promoting the development of new and innovative production technologies through pre-competitive research within the European Research Area(ERA). EFFRA is the representative in the European public-private partnership formed under the Horizon 2020 framework Factories of the Future. In October 2015 it opened calls for research funding of 278 million in advanced manufacturing. One of the focus areas is the IoT in order to "foster the taking up of IoT in Europe and to enable the emergence of IoT ecosystems supported by open technologies and platforms" (Ibanez, Riemenschneider, DG Communication Networks, & European Commission, 2015, p. 7) and "It will be addressed through a complementary set of activities structured around Large Scale Pilots"(European Commission, 2015a, p. 91), like for example wearables for smart ecosystems or autonomic vehicles in a connected environment (European Parliament, 2016, p. 41)

"Other key support measures for Industry 4.0 research include the **Future and Emerging Technologies** (FET) Programme under the current EU managed Framework Programme Horizon 2020. This is a funding line that supports "radically new lines of technology through unexplored collaborations between advanced multidisciplinary science and cutting-edge engineering". Under Horizon 2020, FET actions have been allocated a provisional budget of EUR 2696 million. This does not exclusively apply to Industry 4.0 but research under this area is likely to qualify as FET projects can be funded under three broad themes:

- FET Open funds projects on new ideas for radically new future technologies, at an early stage when there are few researchers working on a project topic.

- FET Proactive funds emerging themes that aim to establish a critical mass of European researchers in a number of promising exploratory research topics. This covers areas that are not yet ready for inclusion in industry research roadmaps, but with future potential.

- FET Flagships are EUR1-billion, 10-year initiatives that focus on solving an ambitious scientific and technological challenge" (European Parliament, 2016, pp. 41–42).

The following figure shows the roadmap framework of the European Parliament in order to fund and support the Factories of the future programme under FET.

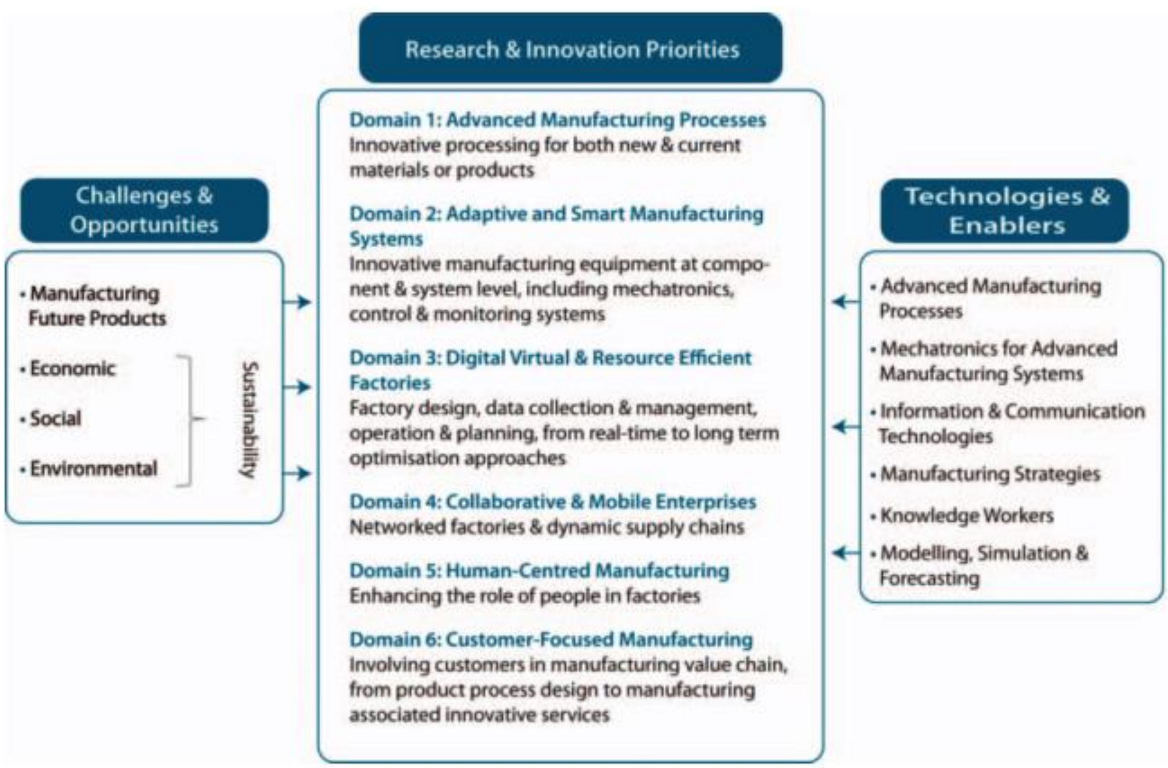


Figure 19 - The Factories of the Future roadmap framework (European Commission, 2013, p. 12)

The Factories of the Future Private-Public-Partnership (PPP) is divided in six research and innovation domains, whose activities "should focus on a concrete and measurable set of target, described as manufacturing challenges and opportunities", which is the core objective of the PPP. In order to archive this a public funding budget of 500 million euros per year is required. The private sector is devoted to an equivalent contribution in kind. The total funding size of the Factories of the Future programme under Horizon 2020 will result in 7 billion euros. (European Commission, 2013, p. 12)

3.1.2. EUREKA

The **Eu**ropean **Re**search **C**o-ordination **A**gency is an initiative, which supports cross boarder European research cooperation's – between SMEs, research centres and universities for industrial innovations - through particular programmes focusing on one specific thematic priority. Within these programmes bids for projects are published and these are revised through a European evaluation committee. If a project is approved, it will be given a programme identification according to the type of project. The awarding of financial means is done by each country, meaning that the financing is not covered by a central budget but through national or regional financial instruments of the member nations. Eureka programme enable application-orientated, cross boarder research and development projects for civil purposes, without the necessity of being aligned to a substantial strategy, which makes them highly flexible and decentralized. (Geisberger & Broy, 2012, p. 2013)

EUREKA created additional turnover and jobs for European companies and supported the internationalization of businesses with innovative ideas since its foundation in July 1985. One important tool are the so called **clusters**, long-term and strategically significant initiatives to develop key technologies for the European competitiveness, being an "engine" for industrial innovation and economic growth. (Eureka Network, 2015)

Half of the current 8 clusters are related to Industry 4.0:

- Catrene (**C**luster for **A**pplication and **T**echnology **R**esearch in **E**urope on **N**ano-**E**lectronics), having the goal to develop a complete ecosystem around the semiconductor industry,
- Celtic Plus - mutual research projects in the area of telecommunications, new media, future Internet, and applications & services focusing on a new "Smart Connected World" paradigm
- Europides[2] catalyses the generation of innovative, industry-driven, pre-competitive R&D projects in the area of Smart Electronic Systems and is the innovation hub for smart sensors, smart power modules, electronic hardware platforms and more generally electronic product integration and embedded systems for automotive, aeronautics and space, security, medical electronics, smart everywhere (cities, home, wearable) and industrial electronics.
- ITEA 3 - supporting innovative, industry-driven, pre-competitive R&D projects in the area of Software-intensive Systems & Services (SiSS)
- PENTA - micro- and nano-electronics that will support the vision, strategy and planned implementation contained in the European Industrial Strategic Roadmap for Micro- and Nano-Electronic Components and Systems as prepared by the Electronic Leaders Group.

3.2. Germany

On March 13, 2015, Federal Minister of Research, Johanna Wanka reported to the German Handelsblatt that Industry 4.0 was Germany's economic future. She maintained that, although the country's economy was prosperous, with an education system that was working well and investment levels for R&D that had reached international competency levels, it would be a fatal error for Germany to continue in that holding pattern. She mentioned as well that Germany, being an advanced industrial nation, had to make use of this situation by feeling the pressure und using it to design a digital revolution together with its European and international partners, taking on a leading role in this area. The Federal government supported the development of Industry 4.0, with the understanding that economists and scientists would work together on a research strategy for projects promoted by the Federal Republic. In order to be successful the Industry 4.0 has to count on the German “Mittelstand”. It must be focused on upholding the “Made in Germany” reputation and reaching a higher performance. (BMBF, 2015)

The in the introductory chapter mentioned German High-tech Strategy had been introduced to the public in 2006 as a national concept by the German ministry of education and research (BMBF) with the aim of supporting innovations in different technology areas. Within this concept the three main goals are (Geisberger & Broy, 2012, p. 207):

- Setting priorities and creation of lead market in the for Germany important technology areas
- Stronger connection between industry and science in order to promote innovation
- Improvement of framework conditions for innovations in the industry

The in 2014 revised strategy identified five areas of needs and 27 fields of innovation in total below them:

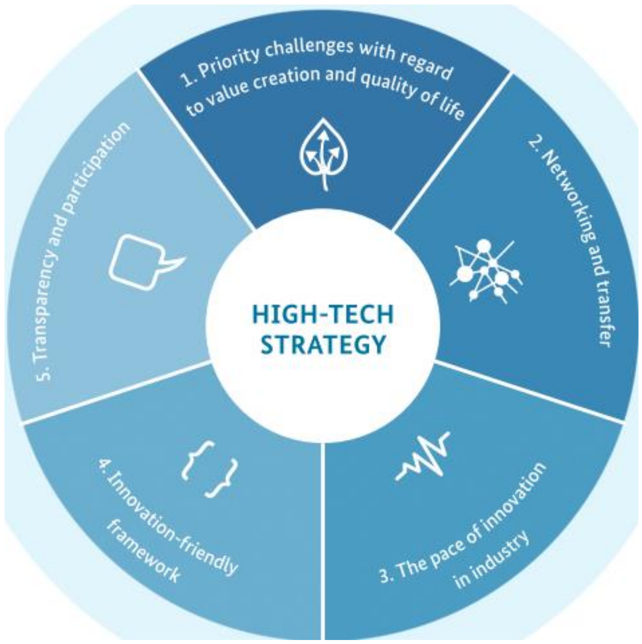


Figure 20 - core elements of the new German High-Tech Strategy(BMBF, 2014, p. 4)

Especially the first „Priority challenges with regard to value creation and quality of life, with its onnovation field „The digital economy and society“ focuses on the Industry 4.0 itsself and connected topics like Smart services & data, Cloud computing, Digital networking & science & education & live environments and touches other fields like siustainable economy and enrgy, inovative wold of work, intelligent mobility and civill security. The second element “Networking and transfer” focusses on networking and transfering in the fields of innovation in order to serve the German economy internationally. “The pace of innovation in industry” is the third element and focusses on the implementation of key technologies, SMEs & start ups and srenthening weak reagions. The fourth field can be connected to the Industry 4.0 as is focusses on the creation of a innovation friendly framework. The last element is the streghening, promiting and expanding of “transparency and participation in innovation”. (BMBF, 2014, pp. 14–47)

One source states that Germany had already around 500 million in the research for Industry 4.0.(Temperton, 2015) Besides there exist private rersearch in this field like for example its`s OWL: “a network of 180 businesses, universities, research institutes and other organisations called Intelligent Technical Systems OstWestfalenLippe which is collaborating on working on projects worth EUR 100 million” (European Parliament, 2016, p. 42).

3.3. Industry 4.0 in the United States of America

Rockwell Automation, a leading US-American supplier of industrial automation and information products criticized the US Government for the shift of federal funding away from applied research, which is essential to manufacturing innovation. This research dropped more than 40 percent from 1990 to 1998, whereas before 1990 funding for applied and basic science research had been equal. The in 2014 current funding for applied research was 30 percent lower than funding for basic science, which gap of $10 billion US-dollars, regarding to Rockwell Automation, remains expanding. (Rockwell Automation, 2014, p. 6)

3.3.1. National Science Foundation

The Directorate for Computer and Information Science and Engineering (CISE) and the Directorate for Engineering (ENG) of the National Science Foundation (NSF) initiated a common initiative and research programme called Cyber-Physical-Systems. This initiative supports three main topics: Basics, research for methods and tools, components, running time substrates and systems. (Geisberger & Broy, 2012, p. 214) There exist three types of support:

1. “**Breakthrough** projects must offer a significant advance in fundamental CPS science, engineering and/or technology that has the potential to change the field. This category focuses on new approaches to bridge computing, communication, and control. Funding for

Breakthrough projects may be requested for a total of up to $500,000 for a period of up to 3 years.

2. **Synergy** projects must demonstrate innovation at the intersection of multiple disciplines, to accomplish a clear goal that requires an integrated perspective spanning the disciplines. Funding for Synergy projects may be requested for a total of $500,001 to $1,000,000 for a period of 3 to 4 years.

3. **Frontier** projects must address clearly identified critical CPS challenges that cannot be achieved by a set of smaller projects. Funding may be requested for a total of $1,000,001 to $7,000,000 for a period of 4 to 5 years" (National Science Foundation, 2016a).

Currently there exist 276 support project with a total reward of $142.882.216. (National Science Foundation, 2016b)

3.3.2. Defense Advanced Research Projects Agency

The Defense Advanced Research Projects Agency (DARPA) supported 13 projects within its META programme, which forms part of its Adaptive Vehicle Make (AVM) programme, which ended in end 2014. Its goal was

> "to substantially improve upon the existing systems engineering, integration, and testing process for defence systems. META is not predicated on one particular alternative approach, metric, technique, or tool. Broadly speaking, it aims to develop model-based design methods for cyber-physical systems far more complex and heterogeneous than those to which such methods are applied today; to combine these methods with a rigorous deployment of hierarchical

abstractions throughout the system architecture; to optimize system design with respect to an observable, quantitative measure of complexity for entire cyber-physical systems; and to apply probabilistic formal methods to the system verification problem, thereby dramatically reducing the need for expensive real-world testing and design iteration.

The year one META effort was organized into multiple, independent technical research paths:

- Metric of Complexity: a practical, observable metric for cyber-physical systems to enable design trades, cyber-vs-physical implementation trades, and to improve parameterization of cost and schedule
- Metric of Adaptability: a quantitative metric measuring the ability of a system to change easily, quickly, and inexpensively (i.e., with minimum incurrence of cost and degradation in performance) in response to a wide spectrum of anticipated and unanticipated perturbation events exogenous or endogenous to the system
- Metalanguage for System Representation: a maximally expressive yet formal language applicable across a broad range of heterogeneous constituent components that is capable of characterizing software and electromechanical components
- Design Flow and Tools: a novel design flow that employs hierarchical abstraction and model-based composition of electromechanical and software components to achieve designs that are ultimately verifiable--at least in a probabilistic sense

> Verification Flow and Tools: a verification approach and enabling tools that generate probabilistic "certificates of correctness" for entire large-scale cyber-physical systems such as ground combat vehicles, airplanes, or rotorcraft based on stochastic formal methods, scaling no faster than linearly with problem complexity" (Defense Advanced Research Projects Agency, 2016).

3.3.3. Networking and Information Technology Research and Development

The primary governmental mechanism for coordinating the investments in R&D, not being part of a secret connection nor information technology is the Networking Information Technology Research and Development (NITRD) programme, to which 14 research promotion organizations and other agencies belong to. These work together, offering a bright spectre of advanced networking and IT capabilities and the development of leadership in science, technique and technologies as well as the economic competitiveness of the United States of America. Total efficiency and productivity are increased, developing the economy's strength, avoiding duplications and improving interoperability and networking of IT products. (Geisberger & Broy, 2012, p. 215) Nowadays the NITRD programme is focussing on 12 research areas, of which one of them are CPSs. Within this area a Senior Steering Group(SSG) coordinates programmes, budgets, policy recommendations for CPS research and development by "identifying and integrating requirements, conducting joint programme planning and developing joint strategies"(Networking Information Technology Research and Development, 2016).

3.3.4. Smart Manufacturing Leadership coalition

SMLC was founded in 2010 and incorporated as a Non-Governmental Organization in 2010, to overcome the costs and risks associated with commercialization of Smart Manufacturing (SM) systems. SMLC has developed an implementation agenda for building comprehensive, scaled infrastructure to support commercialization of SM systems, including a prototype platform suitable for use in test bed trials of SM systems. (Smart Manufacturing Leadership Coalition, 2016b) **Its vision is to create an**

> "Open Smart Manufacturing Platform and Marketplace enabling manufacturing companies of all sizes to gain easy, affordable access to modelling and analytical technologies that can be tailored to meet cross-industry business-case objectives without having to retrofit existing systems. The concept of an open architecture enables the ability to access and contribute to a marketplace of industrial applications, including commercial and open-source technologies. Manufacturers will have access to endless possibilities through connecting new and existing architectures, talent and solutions. Similarly, solution providers, software vendors and entrepreneurs will have access to a broader manufacturing community and will be given a huge opportunity to innovate further" (Smart Manufacturing Leadership Coalition, 2016a).

The topics attended had generated a great deal of attention, especially since the Obama Administration announced a $500 million initiative on advanced manufacturing for PPPs. (Steering Committee of the Advanced Manufacturing Partnership 2.0 (AMP2.0), 2014, p. 85)

3.4. Industry 4.0 in the BRIC states and Asia

In the BRIC states (Brazil, Russia, India, China and South Africa) a huge number of activities important to the topic CPS are realized, mostly below different names or bigger R&D initiatives. The access to information is difficult, but the dynamics and support through government an funding agencies is given.(Geisberger & Broy, 2012, p. 216)

3.4.1. Brazil

The exist a lot of Brazilian projects supporting the possibilities being opened up through CPSs. For example:

- Agricultural industry: "Development of a prototype smart sensor CIBERFLORESTA. The sensor, in addition to performing all the functions of a data acquisition system has functions of intelligent real-time processing of an intelligent agent, whose database contains the expert knowledge of the behaviour of environmental variables of urban forest ecosystem. The system triggers events alerts to detect changes in behaviour that are risk or without risk in crop productivity" (Chase, de Almeida, Sampaio, & Brito-De-Souza, 2011).

- Intelligent Building: Nowadays house and building automation forms part of the standard for constructing.

- Energy consumption: The Project "Cidade Inteligente Búzios" is controlling intelligently the consumption of energy and besides will in include an automatic control of the energy network.(de Araujo et al., 2014)

3.4.2. India

The Indian Ministry of Communications & Information Technology started a project called Cyber-Physical Systems Innovation Hub in 2011. The researched areas are: Smart Grid Systems, Smart Cellular Networks, Green ICT, Smart Buildings, Smart Healthcare Systems, Humanoid Robots und Search and Rescue Robots. Apart from that, the ministries department of Information Technology is deals with the juridical framework for new technologies and besides developed a strategy for cyber security.("Cyber Security Strategy | Government of India, Department of Electronics and Information Technology (DeitY)," n.d.) Below the patronage of the IISC, Robert

Bosch GmbH founded a Centre for Research in CPSs in Bangalore, where as well top Indian research centres and the Frauenhofer institute take part. This project is funded with 22.8 million euros and prospectively supports future industry and science projects. (Geisberger & Broy, 2012, pp. 217–218)

3.4.3. Russia, China, South Africa

These countries do have active projects in the areas of CPSs, but there is no concrete information. In Russia exists the A.B. Kogan Research Institute of Neurocybernatics and in South Africa intelligent buildings are constructed. The School of Software of the Chinese Dalian Universality founded in 2009 a research group being connected to CPS, regarding research and implementation focusing of technologies like networks, protocols algorithms and software platforms and the domains are health prevention, energy, consumer electronics, transport, automation and education. (Geisberger & Broy, 2012, p. 217)

4. Applicability of the Industry 4.0 in Medellin

In order to analyse the applicability of the Industry 4.0 in Medellin two main formats were created: a questionnaire answerable by company experts and personal interviews with selected companies. First of all, it has to be mentioned that the lack of knowledge of the topic made it hard to find experts in answering the questionnaire and even harder to find interview partners. The help of national organizations was not given.

4.1. Methodological design

Two methods were chosen: a questionnaire and personal interviews.

4.1.1. Questionnaire

The questionnaire was created with Google Forms and made public though the same platform. (http://goo.gl/forms/jw32iO9NtY)

Figure 21 - Header of the Questionnaire made available on Google Forms

It consisted of 9 general and 17 Industry 4.0 specific Questions being divided in 4 chapters. Only experts, having received the password beforehand to avoid public inexperienced responses, could have answered it.

4.1.1.1. Preparation, publication and evaluating questionnaire

The preparation, publication and evaluation of the questionnaire consisted of 7 steps:

1. Decide on the information required:

   The aim of the questionnaire was to get a general answer if the industry knows about the Industry 4.0, if it has implemented it or related topics and where the public and governmental steps should be taken to promote it.

2. Define the target respondents:

   The target respondents were qualified and experienced people either in the industry or the academic or research sector.

3. Choose the method of reaching your target respondents:

   The method was an online, 24/7 available, self-explaining questionnaire, which was only accessible by a password present by email and mailing lists through university and company contacts.

4. Decide and develop on question content:

   The questions needed to be connected to the three aims of the questionnaire. Each one also needed to be in a specific type in order to achieve the aim.

5. Put questions into a meaningful order and format:

   Within each chapter/aim the questions needed to be organized in a wisely chosen order.

6. Check the length of the questionnaire:

   The length should not have exceeded a time limit of about 10 minutes in order to gain the full attention and specific answer of each person.

7. Pre-test the questionnaire:

   This pretesting has been done many times by the director, the writer of the thesis and some university students.

8. Publicising of questionnaire:

   Obtaining URL from Google Forms and sending it via emails and through mailing lists of others to the target group.

9. Defining Target Quantity:

   In regards to the small response, but highly professional response and after consultation with the director of the thesis the target quantity of answers needed to be over five in order to be significate.

10. Evaluation of Results:

    The evaluation was realized by using computer programmes IBM SPSS and Microsoft Excel thanks to the download option of Google Forms.

4.1.1.2. Questionnaire Contents

The questionnaire was divided in 4 chapters:

- Company classification: 6 questions
- Knowledge of Industry 4.0: 2 questions
- Industry 4.0 actions in the company and expected changes: 9 questions
- Implementation and support necessities: 8 questions

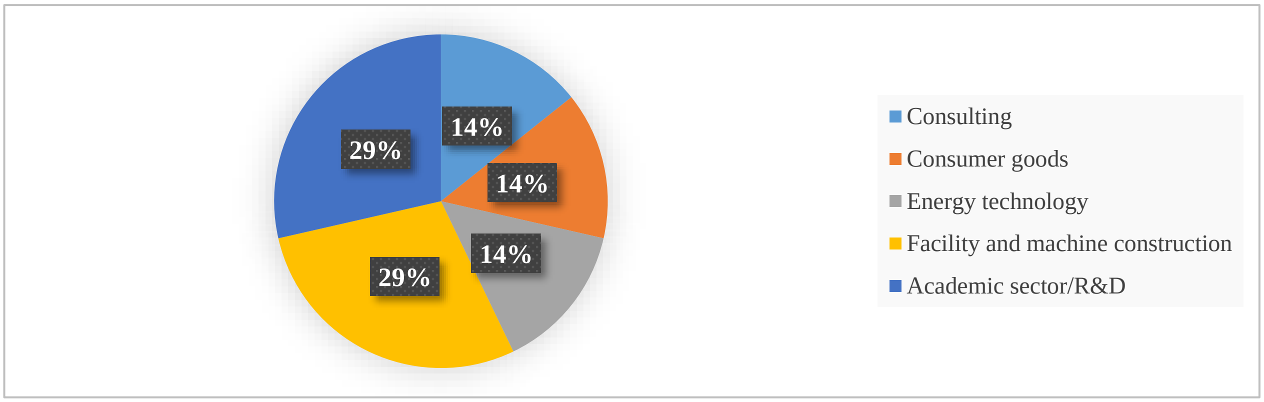
The first chapter intended to gather all the characteristic information from the surveyed and by that characterise and group the people. Besides its helped to statistically identify coherent answers. The only purpose of the second chapter was to find out if knowledge about Industry 4.0 existed and optionally give more information about it. The acquired knowledge of the Industry 4.0 concepts in the second chapter of this thesis was the basis for the third chapter in the questionnaire in order to find out possible applied concepts and expectations of the actions. Whereas the last question group is connected to the third chapter of this thesis asking about how well the implementation is promoted and what is needed to support the necessities of an implantation.

In the following the questions and answers are presented.

4.1.1.3. Questionnaire answers

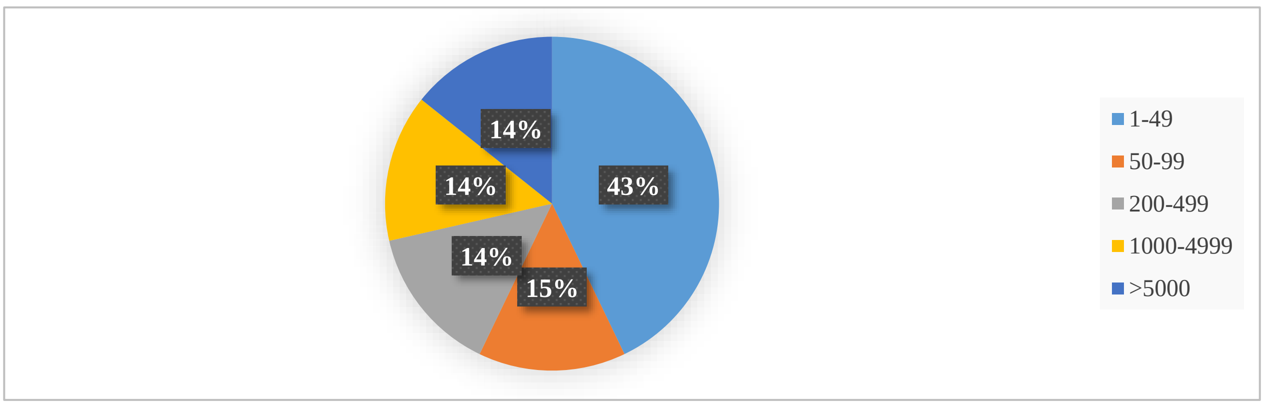
4.1.1.3.1. Company classification

1st Question: ¿In which economic sector is your Company principally located?



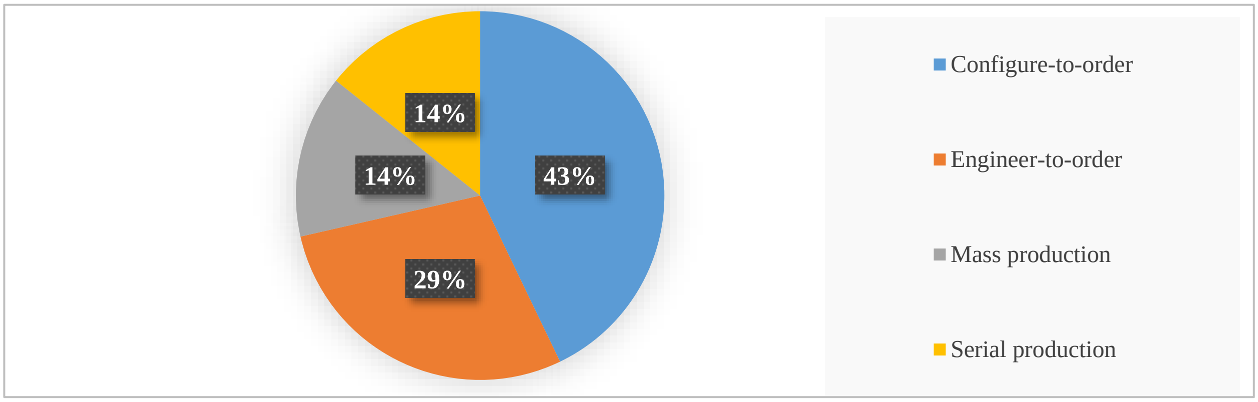
The distribution goes over various sectors being principally in the academic/R&D and facility and machine construction sector.

2nd Question: How many people are currently employed in your Company in Colombia?



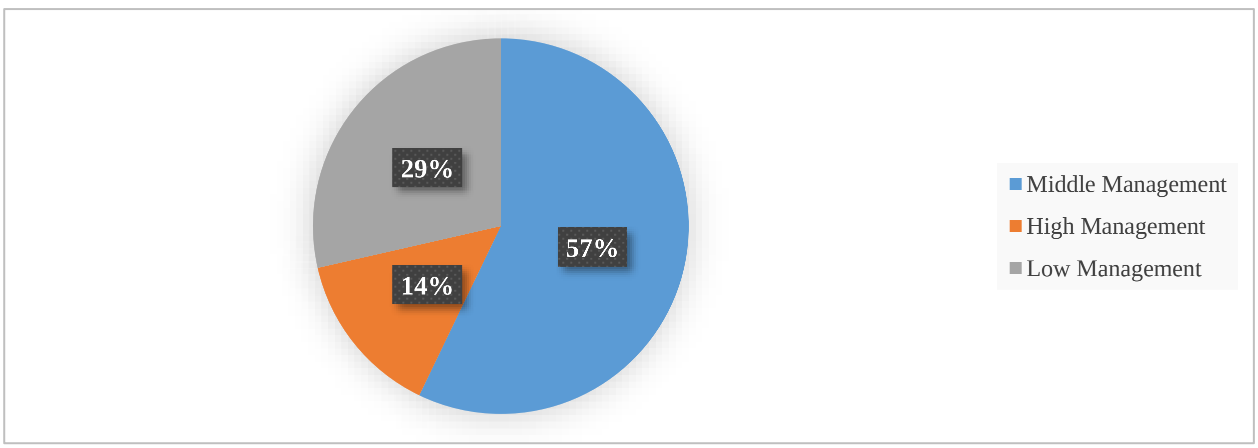
In most of the cases, the companies are small sized and employing less than 1000 people.

3rd Question: What is your main production type?



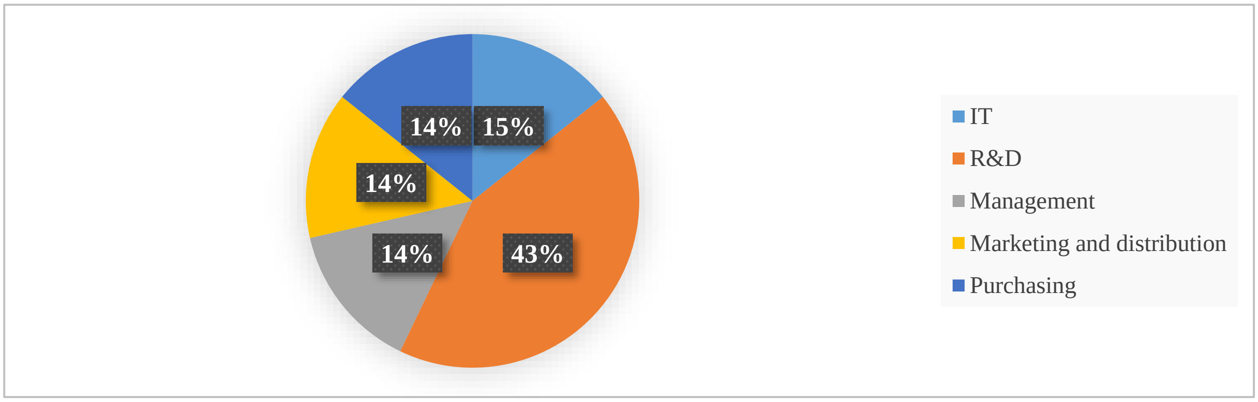
The main production type is configure-to-order, followed by nearly equal other types engineer-to-order, mass-production and serial production. One was dedicated to the creation of strategies for enforcing innovation in Medellin.

4th Question: What management level are you in?



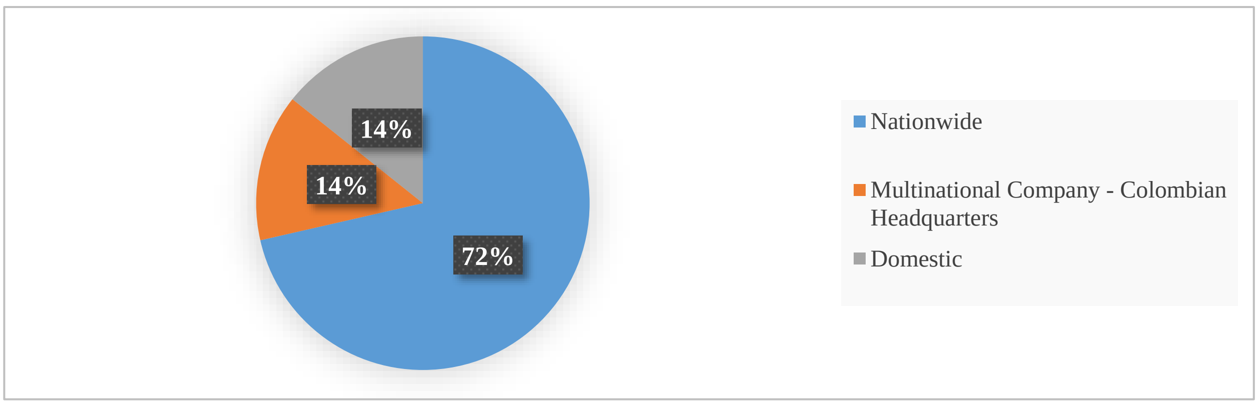
More than the half answering the questionnaire worked in the middle management, followed by 29% in the low management and only 14% the high level management.

5th Question: In what department are you working?



About 43% worked in the R&D department, followed equally by all others named: IT, Management, Marketing & Distribution, Purchasing.

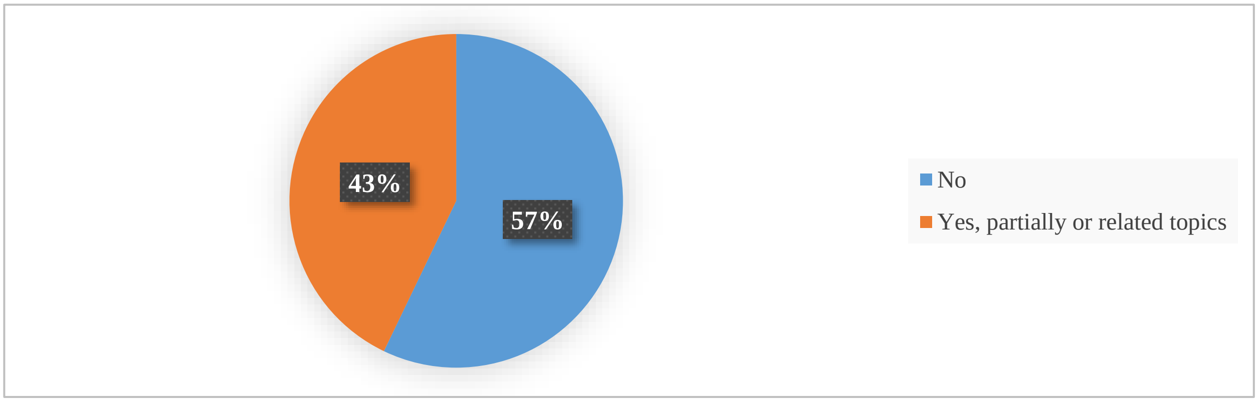
6th Question: What is the operation range of your company?



More than two thirds operate nationwide, the rest are multinationals and domestic companies.

4.1.1.3.2. Knowledge of Industry 4.0

1st question: Do you know about Industry 4.0?



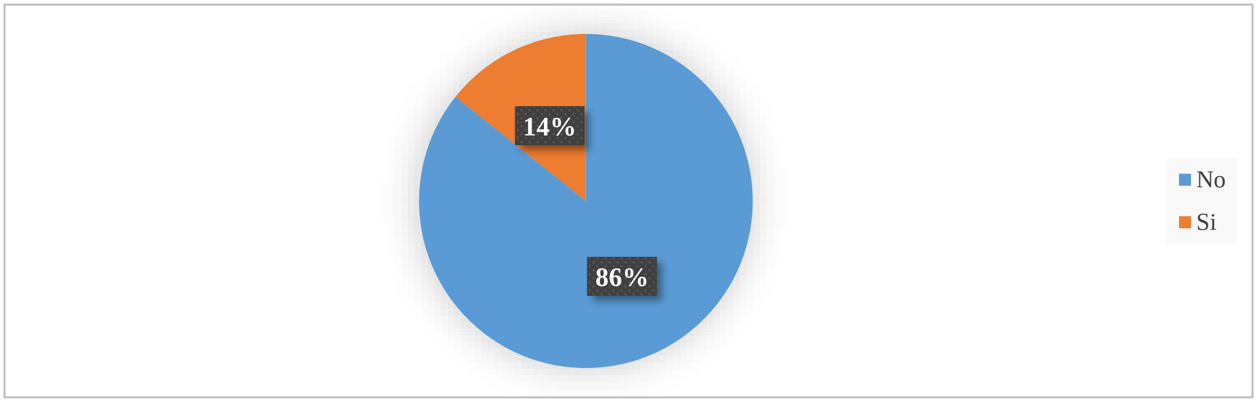
Nobody answered Yes, but a little bit less than the half answered knowing partially about Industry 4.0 or related topics and the rest nothing.

2nd Question: Do you want to know more about Industry 4.0?

Almost all of those questioned wished to know more about the topic itself, which was offered during the questionnaire with connected PowerPoint slides or videos in order to be able to answer the rest of the questions.

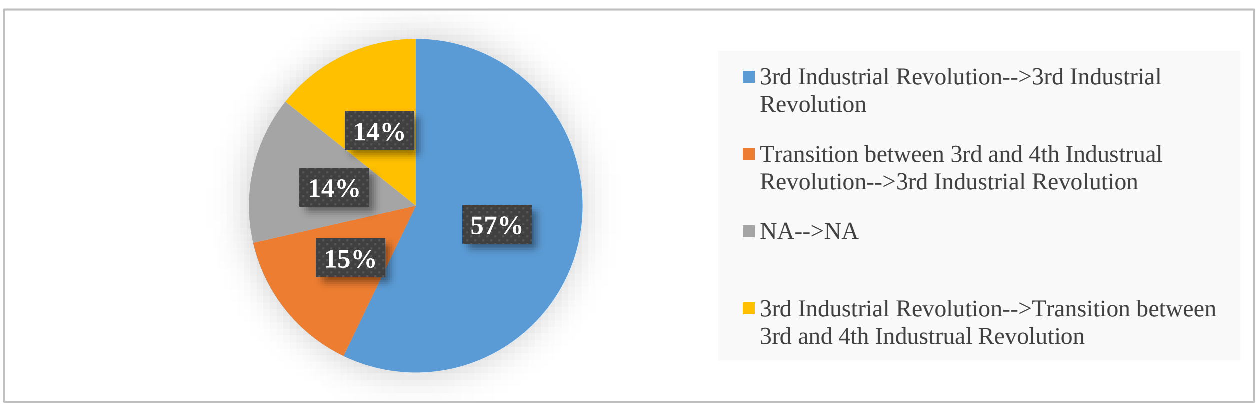
4.1.1.3.3. Industry 4.0 actions in the company and expected changes

1st question: Has your company planned or is it planning to implement any Industry 4.0 or related elements?



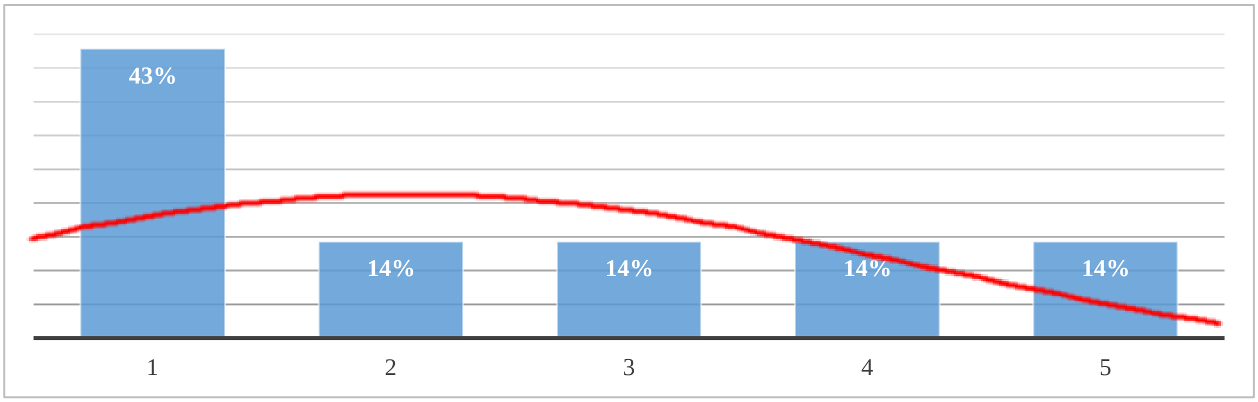
Nearly 90 percent answered not planning nor having implemented any industry 4.0 or related elements. The 14 percent have implemented or are planning elements in development projects or working with Industry 4.0 suppliers.

2nd & 3rd Question: Where do you think is Colombia and your company currently situated?



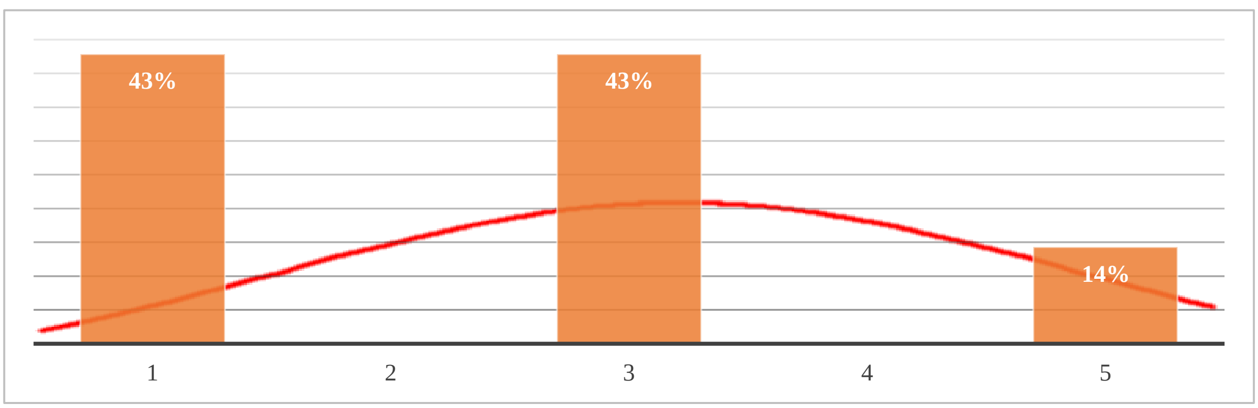
57% answered that Colombia and their company are in the third Industrial Revolution, only 14 percent observed Colombia in the third revolution and their company already being in the transition to the fourth. Nearly equally 14% observed Colombia being in the transition to the fourth and their company being in the third. The same amount did not answer either one of the questions. A total of around 71% saw Colombia being in the third revolution, equal to the one thinking this of their company.

4th question: How do you evaluate the importance of the Industry 4.0 in general? (One being very important to 5 unimportant)



Nearly half of the questioned saw a general high importance of the industry 4.0. The other half equally voted from important to no unimportant. The red line represents the standard normal distribution.

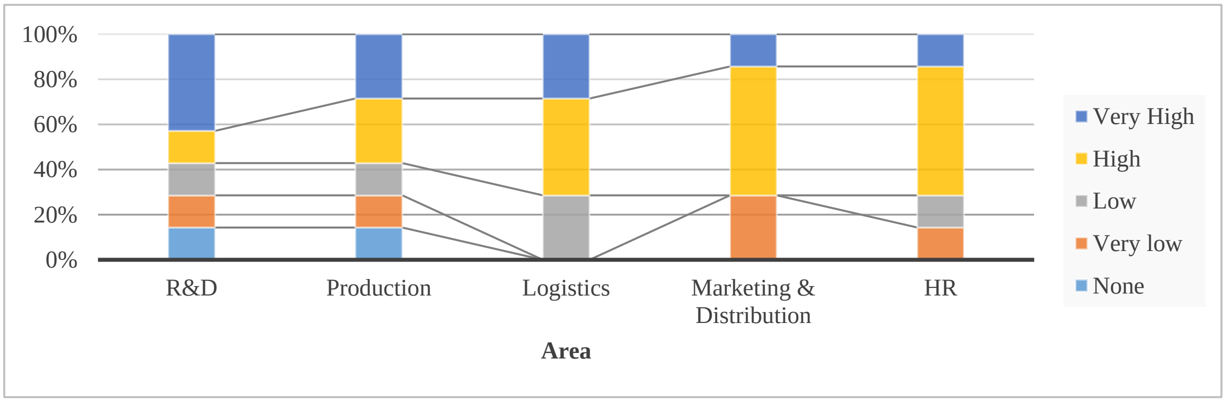
5th Question: How do you evaluate the importance of the Industry 4.0 in your company in the future? (One being very important to five unimportant)



This question clearly led to a different answer as 43 % still voted being very important and 43% showing a medium importance and 14% a low importance. If you analyse the answers it can be seen that all persons voting the importance at a general high also think so for their company. Whereas all the twos and fours moved to a medium importance. The unimportance stayed the same. The red line represents the standard normal distribution.

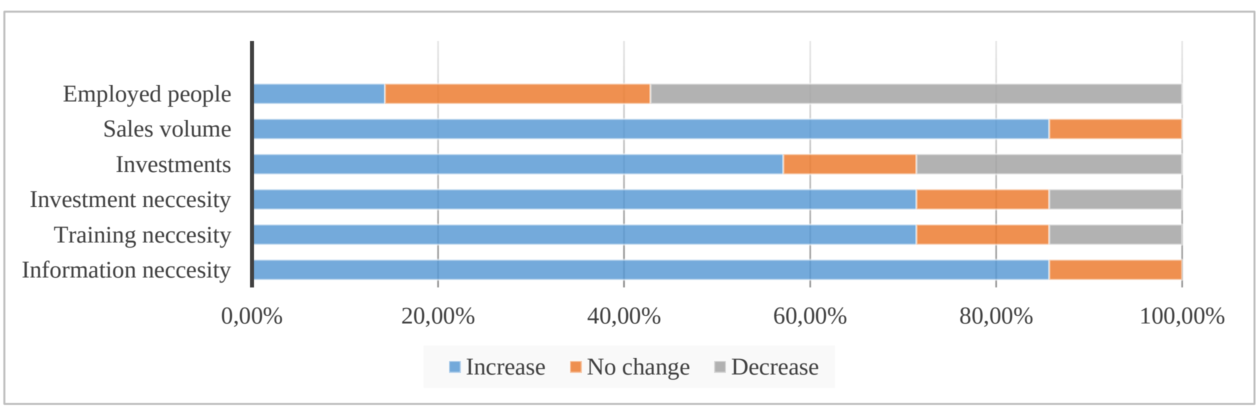
The **6th** question is omitted due to a lack of answers. This multiple choice question asked about the opinion of horizontal and vertical integration in IT systems nowadays and in five years. Overall they showed a high agreement upon increasing levels.

7th Question: How much is invested in each area in IT support systems?



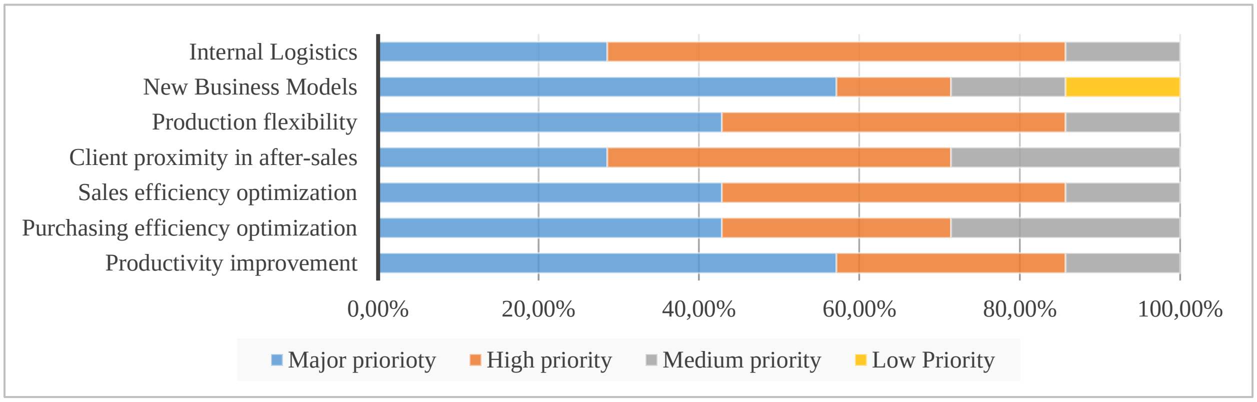
This showed mixed expenditures in the R&D department, higher expenditures in the production department, even higher expenditures in Logistics, Marketing & Distribution and Human Resources.

8th question: What impact are you expecting through the digitalization of business processes in each of the following?



First of all, it can be seen that most of those questioned regarding the number of employed people, expect a drop or no change at all. Regarding the sales volume nearly 90% expect a rise and the other 10% no change at all. Overall the investment necessity is expected to rise together with the number of investments. Also training is required and more information is needed.

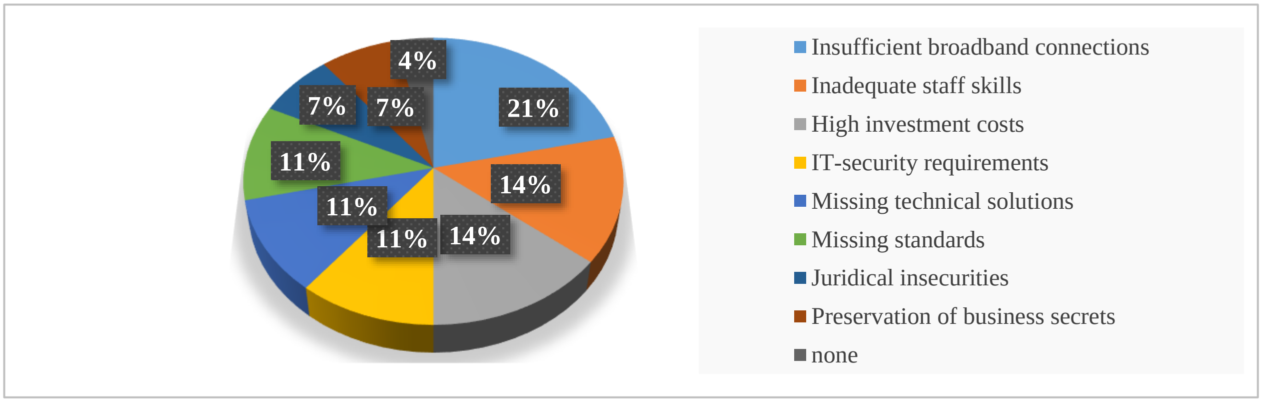
9th question: What priority does each topic have regarding digitalization and networking?



The clear focus here is on new business models and productivity improvement where 60 percent marked it as major priority for its business regarding digitization and networking. But new business models were the only category showing low priority as well. Around 45% showed high priority in production flexibility, sales efficiency optimization and purchasing efficiency optimization. Less high priority, around 30% was shown in internal logistics and client proximity in after-sales. But if you sum major priority and high priority internal logistics, production flexibility, sales efficiency optimization and productivity improvement sum up to around 85%.

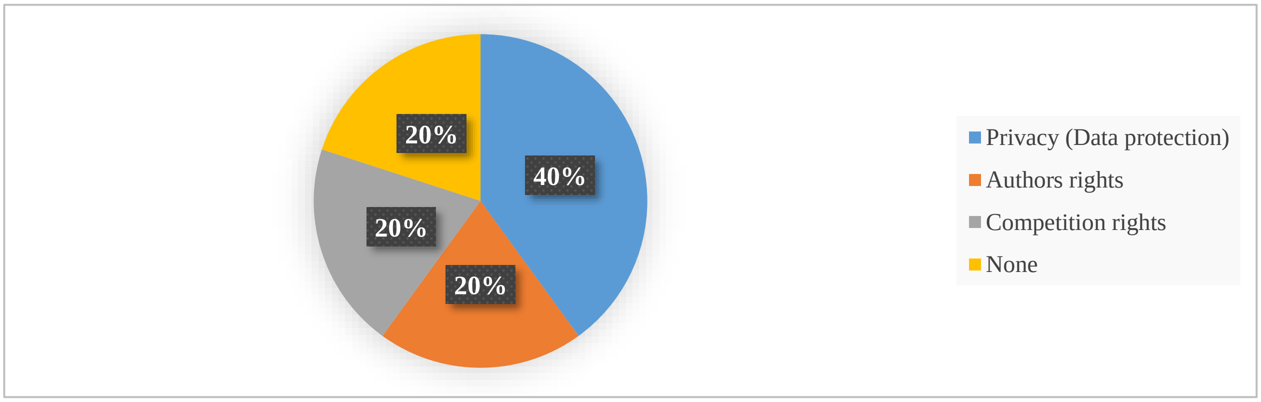
4.1.1.3.4. Implementation and support necessities

1st question: Where are you seeing obstacles for adopting to the digitalization trend? (multiple answer question)



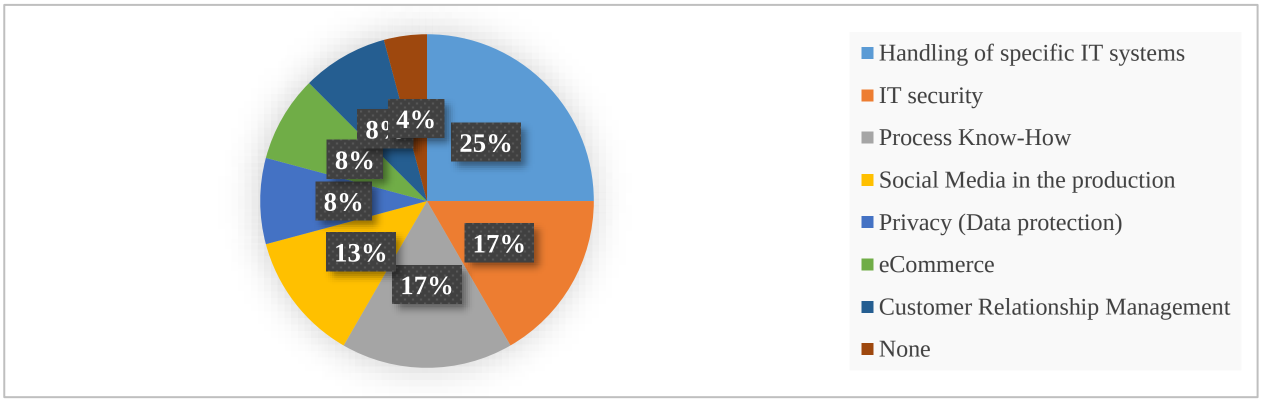
Clear obstacles for the implementation in Medellin are seen in insufficient broadband connections, followed by inadequate staff skills and the high investment costs. Missing technical solutions and standards and IT-security requirements were each around 11%. Those were followed by juridical insecurities and preservation of business secrets. 4% of the answers included no obstacles.

2nd question: Where are you seeing legal obstacles? (multiple answer question)



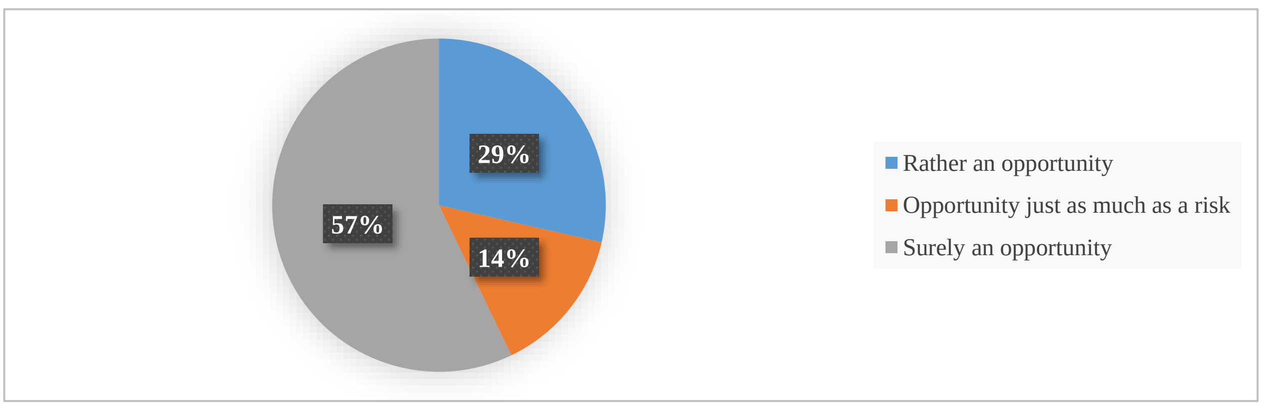
Legal obstacles are clearly seen in the Privacy or data protection with a share of 40 percent, followed equally by authors rights, competition rights and no obstacles at all.

3rd question: In what topics do you see the necessity of training your employees?



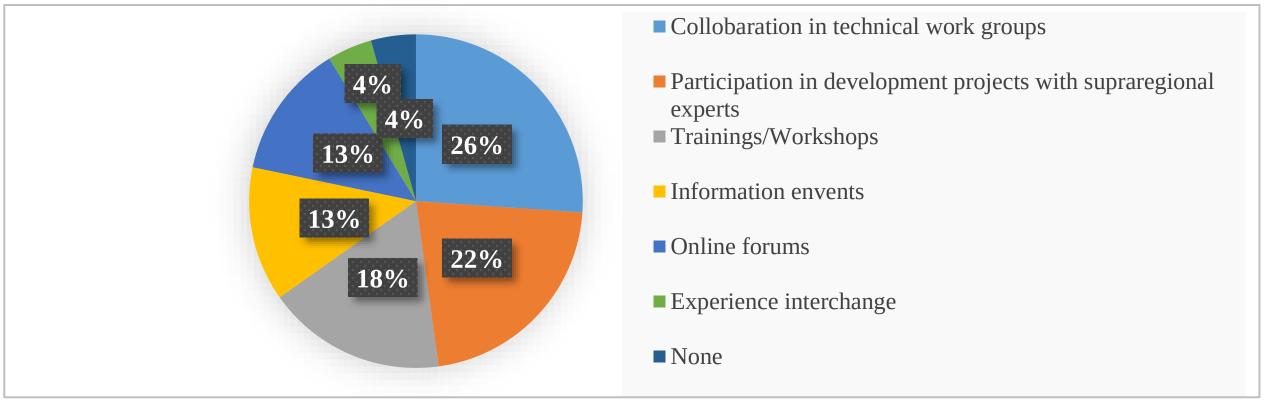
The handling of specific IT systems was mentioned the most times, around 25%, followed by IT security and process Know-How (17%). The social media in the topic is also seen as an issue (13%), trailed by Privacy (Data protection), e-commerce and Customer Relationship Management (each 8%). Also in 4% of the answers none was mentioned.

4th question: Do you think the industry 4.0 represents rather an opportunity or risk for the national industry?



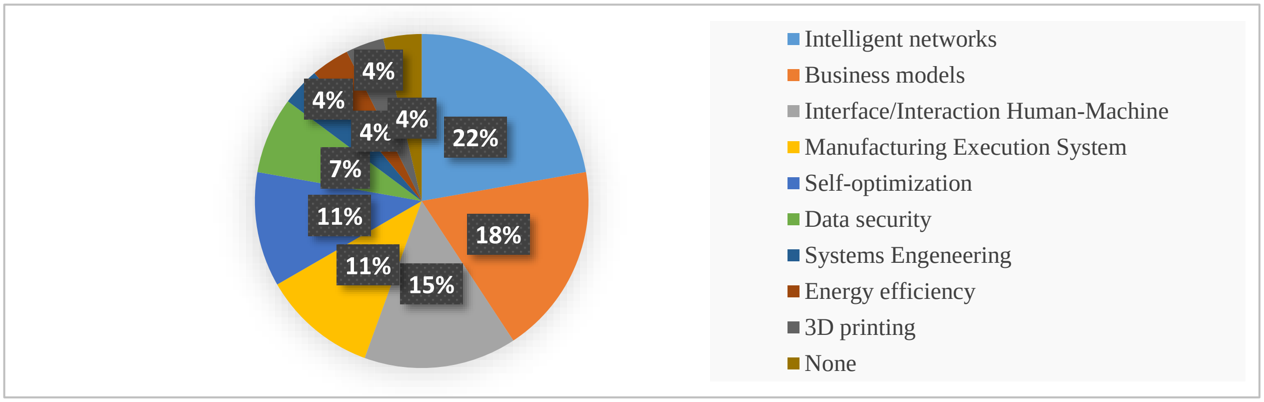
Around 57% see the Industry 4.0 surely an opportunity for the industry. 29% are more sceptical and see the Industry 4.0 rather as opportunity. 14% see the Industry 4.0 just as much as an opportunity as a risk.

5th question: What kind of support would you like to receive for implementing the Industry 4.0?



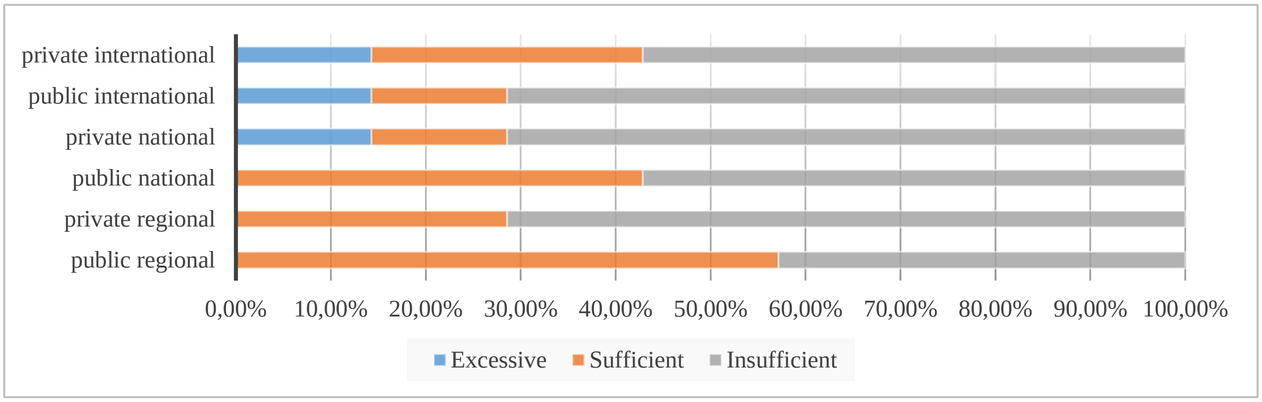
26% mentioned the collaboration in technical work groups, 22% the participation in developments projects with supraregional experts, followed by Trainings/Workshops (18%), information events (13%) and Online forums (13%). Less important was seen the experience interchange. Also in 4% of the answers none was mentioned.

6th question: In which transversal topics of the Industry 4.0 are you especially interested?



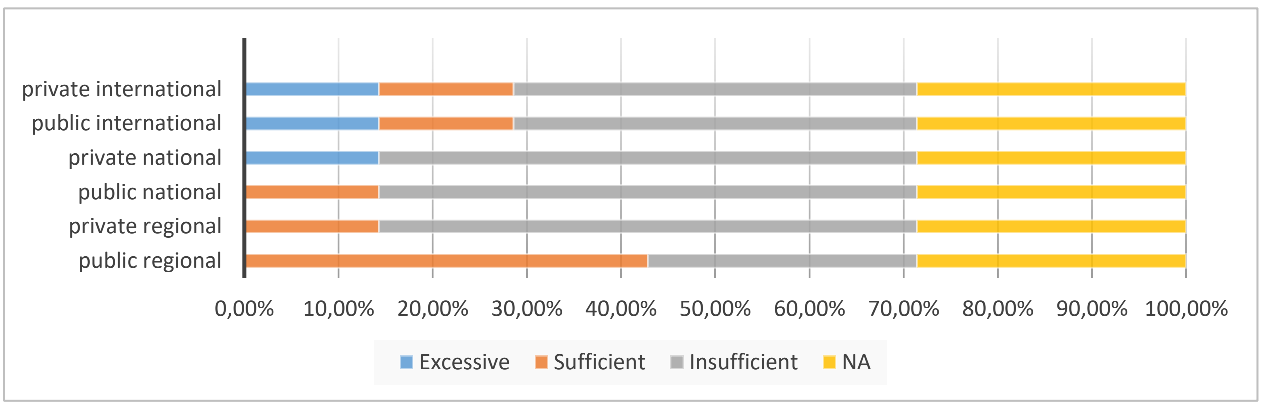
Frontrunners are intelligent networks (22%), Business models (18%) and Interface/Interaction between Human and Machine (15%). Also mentioned topics are Self-optimization (11%), Manufacturing Execution Systems (11%) and Data security (7%). Less mentioned topics were Systems Engineering, Energy efficiency and 3D printing (each 4%). Also in 4% of the answers none was mentioned.

7th question: How do you evaluate the support in the following levels for the industry in general?



Standing out is the figure of nearly 60 % seeing the public regional funding as sufficient. As well around 15% marked the private and public international spending as well as the private national spending as excessive, but as well in mostly all categories the spending was seen as insufficient (Average 60.1%).

8th question: How do you evaluate the support in the following levels for the industry 4.0?



Here the overall image looks a lot different, in the question before around 31% saw the funding as sufficient whereas here it dropped to the half. Besides the high figure of not applicable is with around 30% in average quite high.

4.1.2. Interviews

In order to gain a deeper insight and understanding of the applicability in Medellin, it was necessary to speak to experts explaining their point of view. A total of three interviews were held. The interviews were orientated on the answers given in the questionnaire and additional ones.

The term industry 4.0 had rarely been known, rather other connected topics like IoT and M2M. In the two companies there are not any projects of implementation, they even have only a few automated processes. The third company Ruta^n is a public cooperation supporting the economic evolution in the city of Medellin in science, technology and innovation. The information about Industry 4.0 related topic is developed in investigation groups and cooperatives. Regarding the obstacles for the implementation of the Industry 4.0, the collaboration between companies, organizations, etc. is the biggest issue, hindering the collective advancement in this topic. Another mentioned issue is the lack of knowledge of the firstly high investment cost but higher ROI. The interviewed answered that Colombian companies would be eager to change/invest when they see a sufficient ROI or high increase in competitive advantages. Another big issue is the insufficient internet connection. Everyone agreed on a necessary higher horizontal and vertical integration of IT systems. The only technologies used in these companies were automation and sometimes M2M. All companies agreed on national SME having bigger chances to implement Industry 4.0 or related topics as they are financially and decisively more independent than multinationals. (Gallon B., personal interview, 2015; Neumann Restrepo, personal interview, 2015; Urquijo Murillo, personal interview, 2015)

RUTA^n

Ruta^n was founded by Medellins city hall, Empresas Publicas Medellín (EPM) and UNE (Marca de productos de comunicación de EPM y Millicom International Cellular). It is an entity, in which distinct programmes are developed and its main task is the distribution of public resources in order to promote science, technology and innovation (CTi). (Ruta N & Alcaldia de Medellín, 2011, p. 5) Since Colombia and Medellin have found out an on-going way out of the violent, decades lasting conflict, Medellin has changed a lot in the last 20 years.

> "Medellin's homicide rate has plunged, nearly 80% from 1991 to 2010. The city built public libraries, parks, and schools in poor hillside neighbourhoods and constructed a series of transportation links from there to its commercial and industrial centres. The links include a metro cable car system and escalators up steep hills, reducing commutation times, spurring private investment, and promoting social equity as well as environmental sustainability. In 2012, the Institute for Transportation and Development Policy recognized Medellin's efforts with the Sustainable Transportation Award" (Morena, 2013).

Medellin even has been awarded the title City of the year 2012 , a programme developed by the Urban Land Institute, the Huffington Post and Citi. (Starkey, 2013) It continues seeking innovation and other competitive advantages with the help of RUTA^n and other initiatives.

Ruta^n wants to change the economic evolution of the city towards an intense business in science, technology and innovation in an inclusive and sustainable way. Its principle objective is the year 2021, when its wants to be Latin-America's most innovative city. (Ruta N & Alcaldia de Medellín, 2011, p. 3). In order to achieve this, it has developed a Plan of Science and Technology and innovation. This 10-year plan includes programmes and projects prioritised by two strategic objectives: Development of emerging businesses belonging to the sectors of energy, health and ICTs and Development of innovation capacities which contribute and strengthen efficiency and quality.

The current public investment in science, technology and innovation is 5% of the city's GDP – in 2014 equal to 1.51 billion USD - - and the companies of the high value added represent 75% of the city's productive sector.(Pineda & Scheel, 2011, p. 7)

There do not exist specific Industry 4.0 projects, but it supports many TIC projects like broadband connection, Cloud Computing, Big Data and mobile applications. As well few advanced manufacturing projects are realized.

4.2. Analysis of the information

The collected information showed that the Industry 4.0 as it is, is not very known in Medellin only by related topics. This does not depend on the company size nor its operation range or type of production, but the people having known about the topic are either in the high or middle management and work in the R&D department or management. All these knowing about it or related topics opine that the Industry 4.0 is important for the economy and the company itself. The people not having known about the topic before did not see a big importance in the topic.

4.2.1. Key obstacles

Until any pure project could be implemented the big obstacles need to be overcome**: Improving the broadband connections**, **training the personnel** and **seeing the importance of the change and possible ROI**.

4.2.2. Global Information Technology Report 2015

The main obstacles are also reflected in the Global Information Technology Report 2015 where Colombia scored a 4.1, being 7 the highest and by this representing the 64th rank of 143:

Its strongest points are in the **Readiness**, referring to **infrastructure** (4.3 - rose incredibly since 2012, internet bandwidth increased from 10 kb/s per user ca. 80!), **affordability** (5.9 - rose incredibly since 2012, fixed broadband internet tariff dropped by 50%!) and **skills** (4.9 – educational system and general skill of the people). The availability of latest technologies is pretty good at 4.6. But it lacked in the environment sub index (3,7- referring to **political & regulatory and business & innovation environment**) and the **economic impact** (3.2). It has also to be stated that the **business usage** still is quite low (3,5). Hampering the score is the **venture capital availability** at 2.6 and even worse, **knowledge intensive jobs** are at a decreasing rate at 16% of the workforce. Though it is worth mentioning that the **capacity for innovation**

(3.5) is continuously rising as it is the **intellectual property protection** (3.5). (Dutta, Geiger, & Lanvin, 2015, p. 144) Please see figure 24 in the annex for more specific information.

Indeed, the Global Information Technology Report refers to Colombia as a whole and it has to be assumed that numbers would vary in some categories, but in generally support the findings in Medellin.

4.2.3. Conclusion

This leads to the conclusion that the environment for an Industry 4.0 in Medellin, Colombia is given, as **technology is accessible and a juridical framework is given**. Its implementation is only **limited by the financial investment devotion and time to invest and install the technological environment, train skilled people and convince companies of its possible value creation**.

4.2.4. Recommendation

As nation and region wide funding and promoting is not a driver in the industry, this thesis is rather a recommendation for SME to gain interest in this topic and if the ROI would be positive, start investing to accomplish competitive advantages. A possible way of implementation is given within this work and benefits are outlined. All together Medellin is already going a good and stunning way regarding innovation and possesses already a general outline of a framework for the Industry 4.0. Besides the private engagement the city itself could invest more in establishing a basic functioning framework and promote components of the Industry 4.0 in order to be a nationwide leader of the fourth industrial revolution, which besides is resulting in an advantage bringing competitiveness and international attentiveness.

4.3. Mention: Approximation proposal SyncBox® App

SyncBox App is a group of solutions, focusing on different organizational areas. It constructs a clearer and objective administration with easy analysable information, not depending on the business model nor size. This system can help you analyse the complex data and processes collected in the factory with the main objective to support decision making in real time. Another aim is the value creation through a higher throughput, ROI and EBITDA and a lower inventory, operating costs and time.

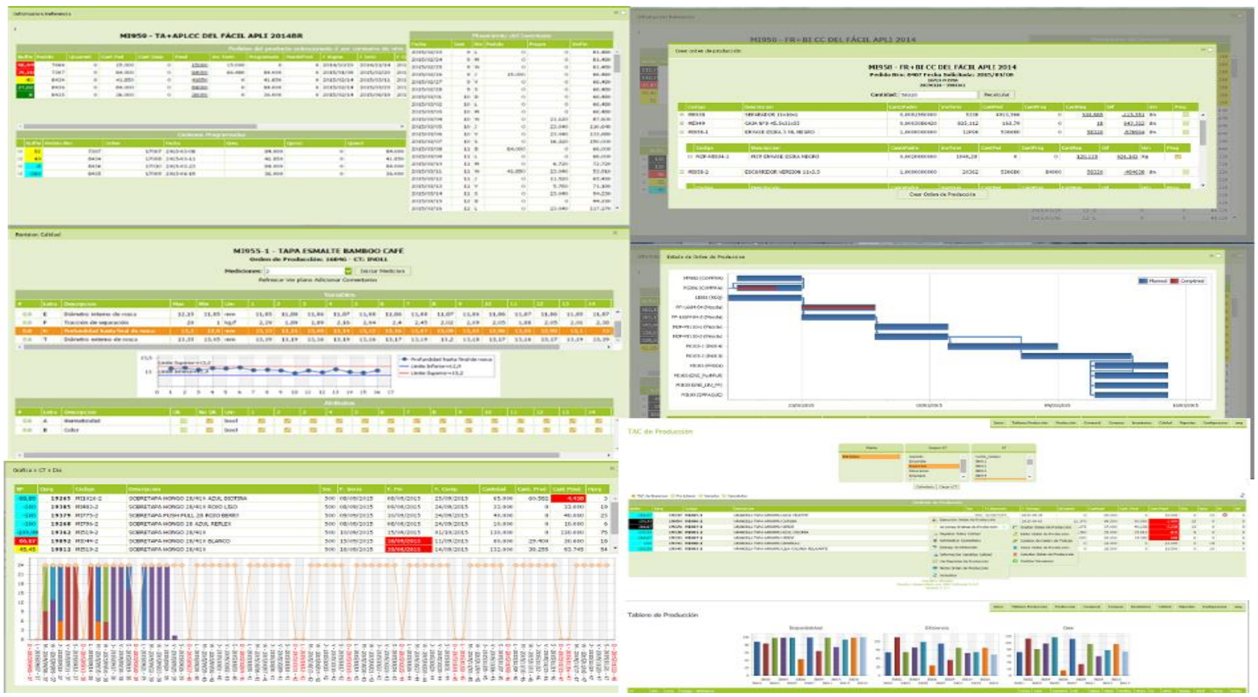


Figure 22 - Screenshots of different SyncBox App solutions (SMG Software S.A.S, 2016)

It offers four different solutions: RealTime, RealTime+, Pro and Ultimate. The basic solution offers signal detections of all equipment, jobcentres, machines and resources and analysing them in the software. With the sensors come a long new computer softwares, HMI on machines and direct communication between PLC and software. The RealTime+ solution offers a deeper look into the data connecting them to other data bases to plan the production automatically depending on the registered orders in the system. Ultimate adds the feature of a specified order planning. Pro adds the connection to other data bases like prime material and purchasing. Two additional options, Satellites and Services, offer identification techniques in real time, identification creation and identification itself and the services connected. Another product, projects offers project management.(SMG Software S.A.S, 2016)

Analysing the products offered it is an approach to an Industry 4.0. It captures real time data through sensors in order to enable a real time management. In order to develop it further to a smart factory, flexible and new production machines and techniques need to be installed, all internal systems, as well the suppliers and client's ones need to be connected in order to facilitate vertical and horizontal integration. A step further would be the completion to a full cyber physical system as described in earlier chapters.

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5. Synthesis

This thesis gives an understanding of the general theory of the Industry 4.0, its fomentation in different world regions and the possible implementation in Medellin, Colombia.

It has been explained the need of a fourth industrial revolution and its main components, which in some cases already exist in companies and in other topics are being researched and developed. The framework for its implementation is already being created in some countries, but lacks in others.

As explained in the problem statement the main motors of fomentation are the industrialized countries because of losing their share in the manufacturing sector. This is why these, especially Germany, invest in and support the revolution.

The last part analysed the possible implementation in Medellin through interviews and questionnaires and led to the result, that bypassing the named obstacles a step by step implementation in a relatively distant future - compared to other countries like Germany - is possible for a small amount of companies.

6. Annex

Priority challenges with regard to value creation and quality of life

The digital economy and society	Sustainable economy and energy	Innovative world of work	Health living	Intelligent mobility	Civil security
• Industry 4.0 • Smart services • Smart data • Cloud computing • Digital networking • Digital science • Digital education • Digital life environments	• Energy research • Green economy • Bioeconomy • Sustainable agricultural production • Assuring supply of raw materials • Future of building • Sustainable consumption • City of the future	• Work in a digital work • Innovative services for future markets • Competency building	• Fighting major diseases • Individualized medicine • Prevention and nutrition • Innovations in the care sector • Strengthening drug research • Innovations in medical technology	• Intelligent and capable transport infrastructure • Innovative mobility concepts and networking • Electromobilit y • Vehicle technologies • Aviation • Maritime technologies	• Civil security research • It security • Cyber security • Secure identities

Figure 23 - 1st element of Germanys high tech strategy (BMBF, 2014, pp. 14–17)

Networking and transfer

- Strengthening potential for innovation in science
- Strategically expanding universities‘ opportunities for cooperation with industry and society
- Closing gaps in commercialisation
- Promoting internationalisation

The pace of innovation in industry

- Use of potential key technologies for the benefit of industry
- Strengthening innovative SMEs
- Increasing the numbers of innovative start-ups
- Enhancing the innovation resources of structurally weak regions

Innovation-friendly framework

- Assuring the supply of skilled personnel for technical and innovation
- Better financing of innovations
- Enhancing the legal framework and standards in the technical sphere
- Providing more-efficient protection for intellectual property
- Promoting open innovation and making new knowledge available
- Developing strategies for open access
- Creating copyright laws that address educational and research needs
- Creating incentives via innovative public procurement

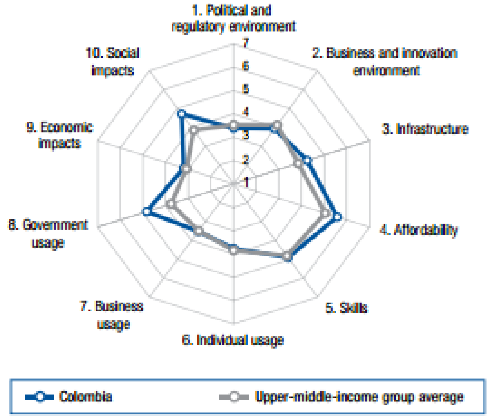
Transparency and participation Innovations

- Strengthening openness to technology, and creating opportunities for participation
- Promoting dialogue with citizens, and promoting citizen science
- Expanding science communication
- Agenda processes – en-route to the innovative society
- Creating transparency, strengthening strategic foresight

Figure 24 - 2nd until 5th element of Germanys High-tech Strategy(BMBF, 2014, pp. 18–47)

Colombia

	Rank (out of 143)	Value (1–7)
Networked Readiness Index 2015	**64**	**4.1**
Networked Readiness Index 2014 (out of 148)	63	4.0
Networked Readiness Index 2013 (out of 144)	66	3.9
A. Environment subindex	97	3.7
1st pillar: Political and regulatory environment	98	3.4
2nd pillar: Business and innovation environment	94	3.9
B. Readiness subindex	59	4.9
3rd pillar: Infrastructure	68	4.2
4th pillar: Affordability	55	5.6
5th pillar: Skills	77	4.9
C. Usage subindex	59	4.0
6th pillar: Individual usage	77	3.8
7th pillar: Business usage	81	3.5
8th pillar: Government usage	30	4.8
D. Impact subindex	52	3.9
9th pillar: Economic impacts	69	3.2
10th pillar: Social impacts	43	4.7



The Networked Readiness Index in detail

	INDICATOR	RANK/143	VALUE
	1st pillar: Political and regulatory environment		
1.01	Effectiveness of law-making bodies*	121	2.7
1.02	Laws relating to ICTs*	55	4.2
1.03	Judicial independence*	112	2.8
1.04	Efficiency of legal system in settling disputes*	91	3.4
1.05	Efficiency of legal system in challenging regs*	91	3.1
1.06	Intellectual property protection*	95	3.2
1.07	Software piracy rate, % software installed	42	52
1.08	No. procedures to enforce a contract	34	33
1.09	No. days to enforce a contract	134	1,288
	2nd pillar: Business and innovation environment		
2.01	Availability of latest technologies*	84	4.5
2.02	Venture capital availability*	82	2.6
2.03	Total tax rate, % profits	140	75.4
2.04	No. days to start a business	60	11
2.05	No. procedures to start a business	94	8
2.06	Intensity of local competition*	56	5.2
2.07	Tertiary education gross enrollment rate, %	60	45.0
2.08	Quality of management schools*	69	4.3
2.09	Gov't procurement of advanced tech*	50	3.7
	3rd pillar: Infrastructure		
3.01	Electricity production, kWh/capita	92	1,313.2
3.02	Mobile network coverage, % pop.	1	100.0
3.03	Int'l Internet bandwidth, kb/s per user	35	76.1
3.04	Secure Internet servers/million pop.	68	33.5
	4th pillar: Affordability		
4.01	Prepaid mobile cellular tariffs, PPP $/min.	82	0.30
4.02	Fixed broadband Internet tariffs, PPP $/month	64	31.41
4.03	Internet & telephony competition, 0–2 (best)	1	2.00
	5th pillar: Skills		
5.01	Quality of educational system*	90	3.4
5.02	Quality of math & science education*	109	3.3
5.03	Secondary education gross enrollment rate, %	60	92.8
5.04	Adult literacy rate, %	51	94.7

	INDICATOR	RANK/143	VALUE
	6th pillar: Individual usage		
6.01	Mobile phone subscriptions/100 pop.	87	104.1
6.02	Individuals using Internet, %	63	51.7
6.03	Households w/ personal computer, %	73	42.2
6.04	Households w/ Internet access, %	74	35.7
6.05	Fixed broadband Internet subs/100 pop.	67	9.3
6.06	Mobile broadband subs/100 pop.	77	25.0
6.07	Use of virtual social networks*	83	5.5
	7th pillar: Business usage		
7.01	Firm-level technology absorption*	89	4.4
7.02	Capacity for innovation*	85	3.5
7.03	PCT patents, applications/million pop.	64	1.3
7.04	Business-to-business Internet use*	67	4.8
7.05	Business-to-consumer Internet use*	62	4.7
7.06	Extent of staff training*	83	3.9
	8th pillar: Government usage		
8.01	Importance of ICTs to gov't vision*	42	4.4
8.02	Government Online Service Index, 0–1 (best)	17	0.79
8.03	Gov't success in ICT promotion*	57	4.4
	9th pillar: Economic impacts		
9.01	Impact of ICTs on new services & products*	51	4.6
9.02	ICT PCT patents, applications/million pop.	75	0.2
9.03	Impact of ICTs on new organizational models*	54	4.5
9.04	Knowledge-intensive jobs, % workforce	90	16.8
	10th pillar: Social impacts		
10.01	Impact of ICTs on access to basic services*	58	4.3
10.02	Internet access in schools*	82	4.0
10.03	ICT use & gov't efficiency*	61	4.2
10.04	E-Participation Index, 0–1 (best)	11	0.88

Note: Indicators followed by an asterisk (*) are measured on a 1-to-7 (best) scale. For further details and explanation, please refer to the section "How to Read the Country/Economy Profiles" on page 115.

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Figure 25 - Colombia's Country Profile in the Information Technology Report 2015 (Dutta et al., 2015, p. 144)

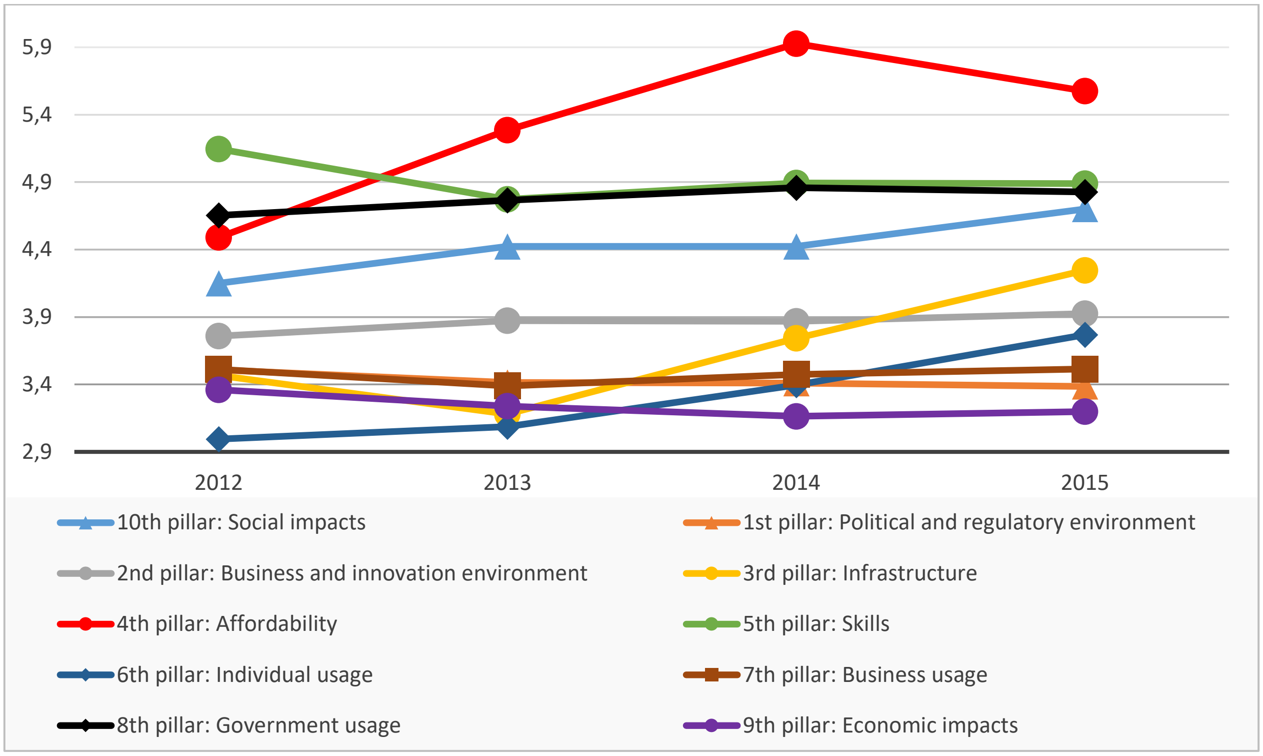

Figure 26 - Development of the pillars of the Information Technology Index from 2012 to 2015 (World Economic Forum, 2015)

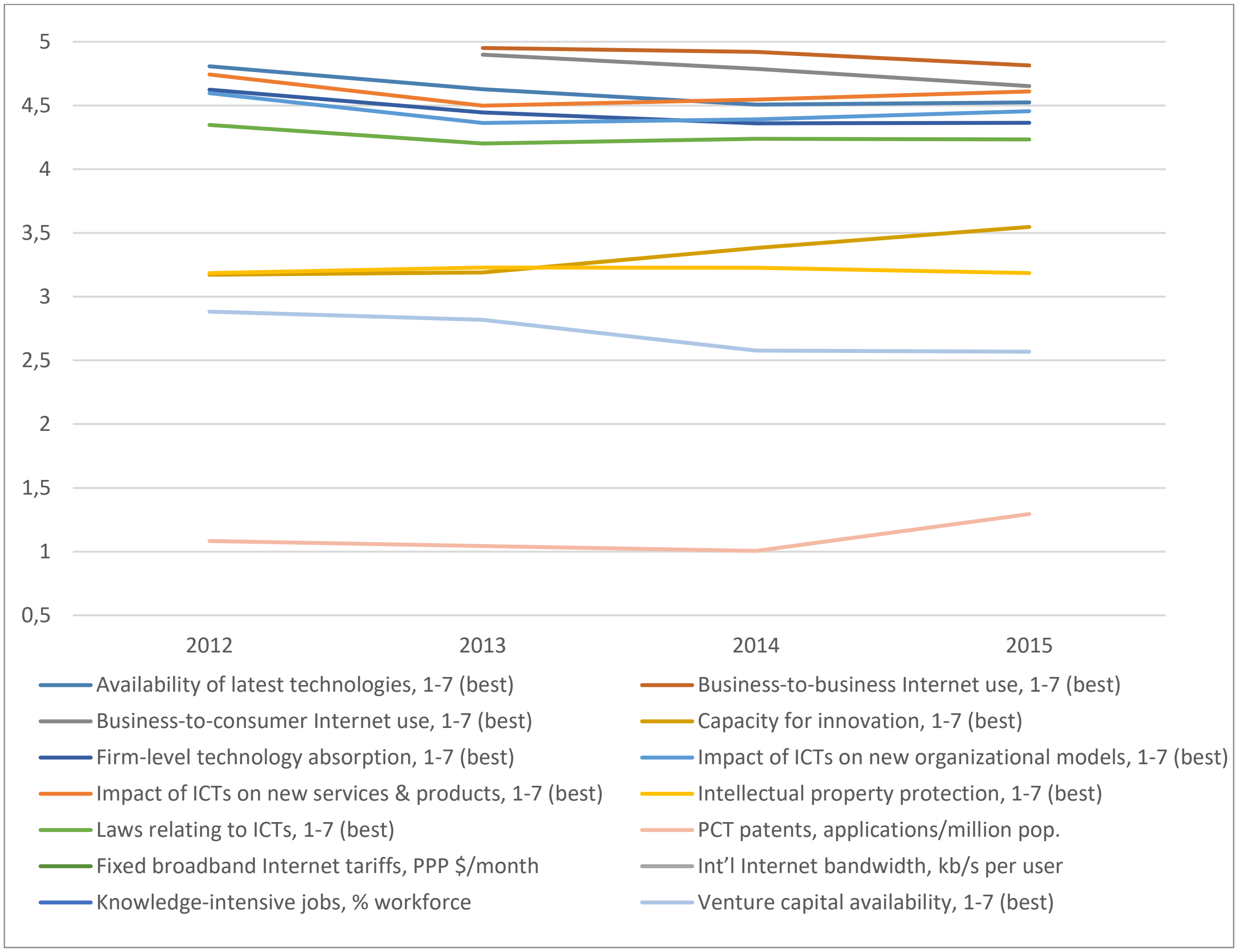

Figure 27 - Selected series of the Information Technology Index 2012-2015(World Economic Forum, 2015)

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