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How does Industry 4.0 technologies impact on performance objectives in the larger area of Upper Bavaria? – Results of an empirical survey in large enterprises and SME'S

Abstract

Implications of Industry 4.0 for enterprises in Upper Bavaria are still unclear. This working paper examines how key technologies of Industry 4.0 impact on performance objectives. The research methodology is based on a quantitative study carried out in in the larger area of Upper Bavaria with a focus on metal-mechanic and automotive sector. The results show which Industry 4.0 technologies have the highest implementation level and which technologies have the biggest impact on company performance objectives. Furthermore, the presented survey provides not only research on large companies, but analyze also micro, small and medium-sized enterprises in detail.







How does Industry 4.0 technologies impact on performance objectives in the larger area of Upper Bavaria? – Results of an empirical survey in large enterprises and SME'S

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1 Introduction

The present work aims to investigate the impact of industry 4.0 technologies on performance objectives in a company context. Of main interest for the present work is in the larger area of Upper Bavaria as an industrial location with a strong economic relevance. A carried out quantitative survey on the base of a questionnaire allows to work out differences between large companies as well as small and medium-sized enterprises (SME's for short). Furthermore, the authors examined existing differences within SME's by analyzing micro-sized, small-sized and medium-sized enterprises isolated from each other.

The realization of the present working paper is part of the project "industryNOW" at Technische Hochschule Ingolstadt (THI for short). "industryNOW" is funded by the Bavarian State Ministry of Science and Arts to expand existing research activities in Industry 4.0 and digitalization in production at THI. The interdisciplinary researcher's group of "industryNOW" follows a holistic approach to intelligently link information in the production area in order to make it available to the user in a context-related manner (see Figure 1).

The realization of the present working paper is also part of an international cooperation between the Universidade Federal Do Parana (UFPR for short) in Brazil and THI in Germany.

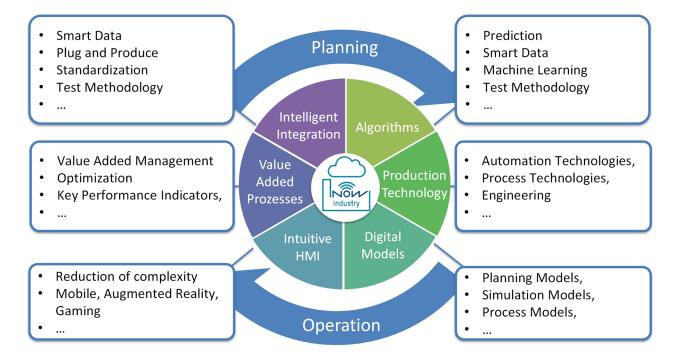


Figure 1. Interdisciplinary research focus of "industryNOW" Source: Daniel Großmann (research application industryNOW)

Furthermore, the realization of the present survey has been supported by the Bavarian Center for Applied Research and Technology with Latin America (AWARE for short) and the Bavarian University Center for Latin America (BAYLAT for short). The AWARE Center is permanent service facility at THI that provides services and structures for a community of industrial and academic partners in Bavaria and Latin America

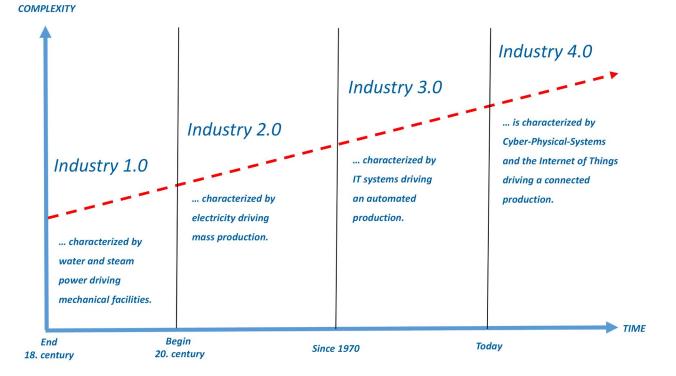
and promotes applied research, thematic networks, international exchange and technology transfer between science and industry. BAYLAT is a service facility of the Bavarian State Ministry of Science and Arts operating throughout Bavaria which promotes the networking of Bavarian and Latin American universities and research institutions.

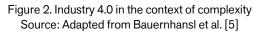
2 Theoretical background

2.1 Definition of Industry 4.0

Digitalization of production is known under the term Industry 4.0. The term "Industry 4.0" became publicly known in 2011, when a German government initiative named "*Industrie 4.0*" promoted the idea as an approach to strengthening the competitiveness of the German manufacturing industry and has been used to represent the fourth industrial revolution [1]. Despite of the importance of Industry 4.0, there is no common definition of Industry 4.0 to date. But there is a vision for Industry 4.0., which represents a new step for organizing and steering of the whole value creation over a cycle of products and services [2].

This new technological revolution has been preceded by three other industrial revolutions in the history of mankind, being the first one related to the steam engine, the second one related to the development of mass production systems and the third one associated with automation technologies [1, 3, 4] (see Figure 2).





5

Over the time periods from Industry 1.0 to 4.0, the complexity of production increased continuously (see Figure 2). Nevertheless, Baumhansl et al. [5] forecast the biggest cost saving by Industry 4.0 in complexity. What looks like a contradiction, is actually a benefit of implementing Industry 4.0. The use of Industry 4.0 technologies leads to an increase of transparency, which will reduce 60% to 70% of existing complexity costs. In addition, Industry 4.0 promises cost savings in inventory, manufacturing, logistics, quality and maintenance (see Figure 3). In recent years, along with the increased research attention on this topic, governments and industries worldwide have noticed this trend and acted to benefit from what this new industrial revolution could provide [6].

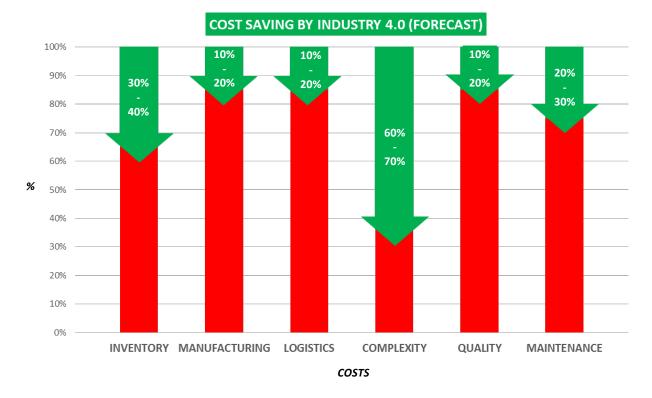


Figure 3. Forecast of cost savings by Industry 4.0 Source: Adapted from Bauernhansl et al. [5]

The approach of this new industrial revolution is based on new and radically changed technology that aims at a fusion of the physical and the virtual world into cyber-physical systems (CPS) that will have a disruptive impact on every business domain of manufacturing companies [7, 8]. Currently, there are several technologies associated with this approach and, for this reason, no overall agreement exists regarding the technologies associated with Industry 4.0 [7–11]. Therefore, an assessment of an own set of Industry 4.0 technologies was made based on their appearances on consulting reports, as will be explained in the following topic.



KEY FACTS TO GO:

Digitalization of production is known under the term Industry 4.0, which represents the 4th industrial (digital) revolution. It is a new step for organizing and steering of the whole value creation over a cycle of products and services.

2.2 Assessment of Industry 4.0 Technologies

For the assessment of technologies associated with Industry 4.0, the 27 technologies proposed by Brunheroto *et al.* [12] were taken as basis for the selection. Then, based on the number of uses of each technology on Brunheroto *et al.*'s [12] research and the number of appearances of them on consulting reports, the technologies were filtered as shown in Figure 4, resulting in 6 technologies to be used for the present analysis [7–10, 12, 13].

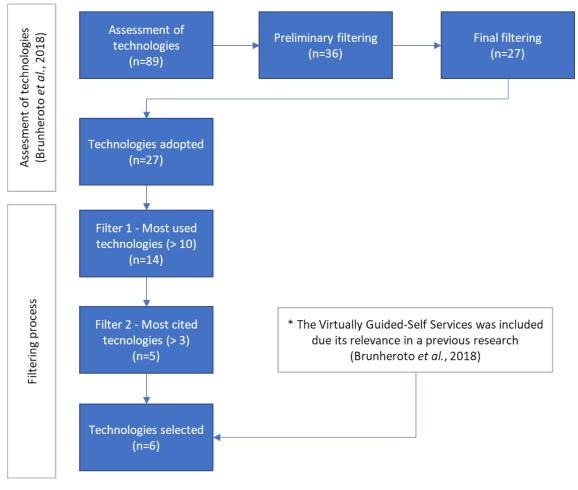


Figure 4. Filtering process (Overview) Source: The authors

As seen in Figure 4, the six technologies were chosen based on their number of uses (>10) and the number of appearances (>3) on the five consulting reports used to assess the 27 previous technologies of Brunheroto *et al.*'s [12] research. However, due to the relevance of the Virtually Guided Self-Services on

this research, it was also included on the final set, even not being as cited as the others on the consulting reports.

Therefore, six technologies were selected to be used to analyze de implications of their adoption to the performance objectives: "Internet of Things", "Cloud", "Cybersecurity", "Big Data Analytics", "Virtually Guided Self-Services" and "3D Printing". The definition of each one of the six mentioned technologies can be observed in the following topics.

2.2.1 Internet of Things (IoT)

IoT refers to the networked interconnection of everyday objects, which are often equipped with ubiquitous intelligence, integrating every object for interaction via embedded systems, which leads to a highly distributed network of devices communicating with human beings as well as other devices [13, 14].

2.2.2 Cloud

Cloud Computing describes the applications, platform and infrastructure solution delivered as services over public or private networks on a pay-per-use basis, accessible anywhere around the globe, at any time [8, 15].

2.2.3 Cybersecurity

Cybersecurity is the body of technologies, processes, and practices designed to protect networks, computers, programs, and data from attack, damage, or unauthorized access [13, 16].

2.2.4 Big Data Analytics

Software and systems that can interpret and analyze data received in large volume (Big Data). Analytics refers to analyzing this large body of data in order to find relationships between data that can provide better insights for improving processes and products and exploring new markets [13, 17].

2.2.5 Virtually Guided Self-Services

They are technologies that support the assisted execution of services that aim to improve the most common areas of an organization, such as performance and configuration of information systems, management of large volumes of data, change management, optimization and security and business processes [18–20].

2.2.6 3D Printing

Also called additive manufacturing, it refers to the production of three-dimensional objects directly from virtual models. This allows for rapid prototyping and highly decentralized production processes: the product model could simply be sent off to the 'printing' site nearest to the customer, eliminating intermediate manufacturing steps, transportation and warehousing [8, 17].



KEY FACTS TO GO:

"Internet of Things", "Cloud", "Cybersecurity", "Big Data Analytics", "Virtually Guided Self-Services" and "3D Printing" has been identified as the key technologies of Industry 4.0.

2.3 Performance Objectives

Performance objectives describes what the manufacturing function should achieve in order to satisfy market requirements [21–23]. About the definition of this set, many authors on operations strategy have their own set of performance objectives, and no overall agreement exists on terminology [23]. Therefore, for the present research the model proposed by Slack & Lewis [23] and Corrêa & Corrêa [24] was chosen, where five performance objectives are considered: "Dependability", "Cost", "Flexibility", "Quality" and "Speed". The definitions of each one of the five mentioned performance can be observed in the following topics.

2.3.1 Dependability

Carrying out the work in a timely manner, abiding by the delivery commitments promised to the customers [25].

2.3.2 Cost

Carrying out the work in an inexpensive manner [25].

2.3.3 Flexibility

The ability to change or match the activities of operations in order to overcome unexpected circumstances or introducing new products or services [25].

2.3.4 Quality

Performing tasks properly, procuring goods and services without error and in accordance with the previously-determined goals [25].

2.3.5 Speed

Performing tasks rapidly, minimizing the time between the customers' request for goods or services and the delivery [25].



KEY FACTS TO GO:

"Dependability", "Cost", "Flexibility", "Quality" and "Speed" are performance objectives which describes what the manufacturing function should achieve in order to satisfy market requirements.

3 Quantitative study: Implications of the Industry 4.0 Technologies to the performance objectives

3.1 Study design

Aiming to analyze the main implications to the production systems, more specifically the performance objectives, a survey was conducted with companies of the metal-mechanic and automotive sectors in the larger area of Upper Bavaria. For this, the production system management model proposed by Slack & Lewis [23] and Corrêa & Corrêa [24] was taken as basis, which emphasize the strategic aspects of the production systems management, since some companies' initiatives are being conducted in a strategic domain [26]. For the assessment of the Industry 4.0 technologies, as presented early, results from the Brunheroto *et al.* [12] and five consulting reports were taken as basis [7–10, 12, 13]. Regarding the specific method for the present research, including the questionnaire construction and survey conduction, they will be further explained in the next topics.

3.1.1 Hypothesis

As stated early, along with the increased research on this topic (Industry 4.0), several studies were made approaching this theme, mainly related to the technologies being used, such as Internet of Things (IoT) and computational techniques associated with large volumes of data (Big Data Analytics) [6]. However, the main implications of these adoptions for the production management are still unclear, since great part of the researches focus excessively on the technologies without approaching their impact on management systems.

Based on that context, the present research intents to support the understanding of how these technologies are impacting the production management systems, aiming to answer the following question: What are the main implications of the Industry 4.0 technologies for the performance objectives? For this, a questionnaire was developed and sent to companies of the metal-mechanic and automotive sector in the larger area of Upper Bavaria, aiming to determine the overall implementation level of these technologies and their respective impacts to the performance objectives

3.1.2 Target group

The target group for the present research is the larger area of Upper Bavaria (German: Oberbayern). The Technische Hochschule Ingolstadt (THI) is sited in this region and, therefore, a great number of respondents can be achieved due to the knowledge of the university and the proximity to the companies. In relation to the sector, metal-mechanic and automotive, it was chosen due its economic relevance, because several headquarters of important automotive companies and suppliers are also located in this region. Besides that,

it also should be noted that, the present research was made after a successful approach in Brazil with companies of the same sector in the region of Curitiba. The region and sector chosen for the German research also aimed to be comparable to the first research in terms of number of cities, companies and sector.

For the identification of the metal-mechanic and automotive companies in the larger area of Upper Bavaria, a database, made available by Bayern International, was used [27]. In this database, filters were made, and 690 companies were found as the groundwork of companies for the present research. Focusing at the administrative division of Upper Bavaria, 23 districts were considered as being part of Upper Bavaria, as can be observed in Figure 5 [28].

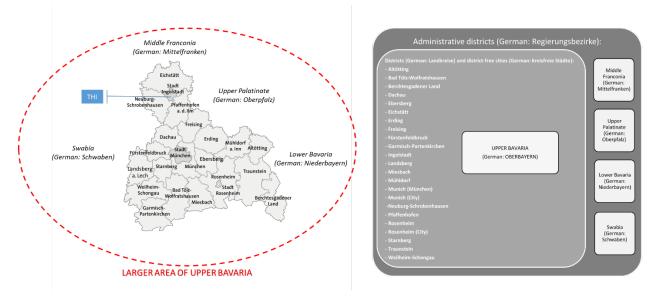


Figure 5. Scope of Interest: Larger Area of Upper Bavaria Source: Adapted from Bezirk Oberbayern [28]



KEY FACTS TO GO:

Target group of the study are metal-mechanic and automotive companies in the larger area of Upper Bavaria due to the economic relevance of the sector for this region. Focus on Upper Bavaria was chosen due the location of the Technische Hochschule Ingolstadt, sited in this region, and comparability with the previously carried out Brazilian research in state Parana.

3.2 Questionnaire construction

Once the basis of companies was defined, the next step was the questionnaire construction. For this, a questionnaire, hosted on *Online Pesquisa*, was developed based on the information gathered in the theoretical background. Regarding the structure of the questionnaire, it was divided in a presentation section, four main sections and a last section referring to feedback. In the first section, information about the questionnaire was presented, such as research objective, estimated response time, confidentiality of

information, contact information, among others. After this presentation, the questionnaire was further divided into four main sections, which will be described below.

The first two main sections consisted of a step regarding the respondent information and the implementation level of the six technologies described previously by their company, in which the respondent was asked to inform, in a level from 1 (We don't have) to 5 (We have advanced implementation), the level of the implementation, similar to the model proposed by Frank *et al.* [29]. In relation to these questions, an example can be observed in Figure 6.

Internet Of Things *

IoT refers to the networked interconnection of everyday objects, which are often equipped with ubiquitous intelligence, integrating every object for interaction via embedded systems, which leads to a highly distributed network of devices communicating with human beings as well as other devices.



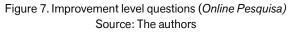
Source: The authors

Based on that information, in the last two main sections was presented some concepts regarding the performance objectives and the respondent was asked to inform, in a level from 1 (None) to 5 (Excellent), the improvement level in each one of performance objectives due to the implementation of the technologies selected in the previous sections, as shown in Figure 7. Finally, the last section consisted in a feedback section, in which the respondent could give some feedback regarding the questionnaire. In relation to the full questionnaire, it can be found in the appendix of the present working paper.

Internet Of Things *

IoT refers to the networked interconnection of everyday objects, which are often equipped with ubiquitous intelligence, integrating every object for interaction via embedded systems, which leads to a highly distributed network of devices communicating with human beings as well as other devices.





3.3 Collection of responses

After the questionnaire construction, they were sent by e-mail to the whole companies mentioned previously, with some other relevant information. After the first round of e-mails, adjustments were made to the e-mail list, because some of the companies had closed or had the wrong contact information, being later sent to the correct contacts.

After the questionnaire was sent to the companies, some measures were still necessary to collect these responses, which will be briefly described below. The first one was the preparation of a questionnaire in document format, due some possible problems with access to the link from companies that have restrictions on Internet access. For this, the questionnaire was rewritten and resent in *Microsoft Word* and *Portable Document Format* formats, aiming to solve this problem.

The second measure carried out was in relation to the risk of the e-mail sent having been redirected to the spam box or the recycle bin. For this, after the preliminary submissions (link and attached document), a warning was sent to the whole companies, without any link or attachment, regarding the last e-mails and informing the deadline for the responses, asking to request the resending of the e-mails in case of non-receipt.

After these two main measures, related to questionnaire access, a last round of e-mails, with the link and the attachments, were sent on the last week of the collection period, aiming to remind the companies of the deadline. After the data collection period, the data processing was started.

3.4 Data processing

For the data processing, the responses were exported, briefly organized via *Microsoft Excel* and then sent to the *Microsoft Power BI* platform for the final organization and the report generation. Regarding this report, it is divided in 3 main sections: Sample Data, Implementation and Improvement and are explained below.

3.4.1 Sample Data

For the sample data section, pizza graphs regarding the companies' size and sector were elaborated, as well a map indicating the cities of the participant companies and graphs presenting the participation status, including the incomplete and complete responses, number of respondents and number of respondent companies.

3.4.2 Implementation

The implementation section aims to analyze the implementation level of each technology. For this, pizza and bar graphs were elaborated to present, respectively, the implementation level responses and the number of uses of each technology. Besides that, a table and a dispersion graph were also elaborated aiming to analyze

the average implementation level and standard deviation for each technology through different sizes of companies.

3.4.3 Improvement

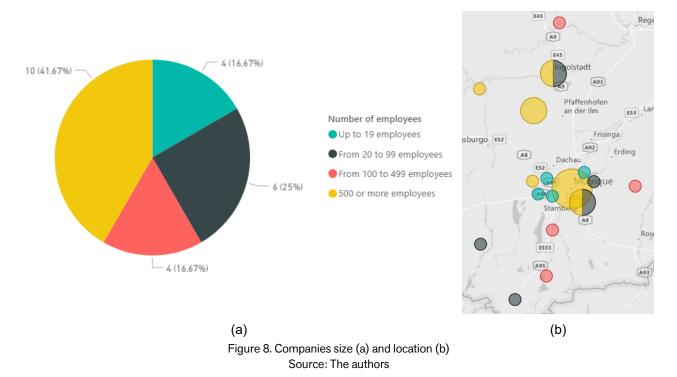
For the improvement section, spider and boxplot graphs were elaborated, as well as a table with the average improvement level and the standard deviation for each technology in each performance objective. In relation to the spider graph, it was elaborated aiming to facilitate the visualization of which performance objective were more impacted by the adoption of each technology. Finally, regarding the boxplots, as well as the table, it was developed to analyze the responses distribution and identify if the improvements are usually the same of if it has some discrepancies through different contexts of applications (companies' size, sector, etc.).

4 Study result

For a better understanding of the present research, the results are divided according to the questionnaire sequence, being presented first the sample data, followed by the implementation level and the improvement level results. After that, the individual results for each technology are shown.

4.1 Results overview

Using the method described previously, 25 responses from 24 companies were obtained, including 7 incomplete responses that could be used for the analysis. Regarding the size of the respondent companies according to SEBRAE [30] classification and their location, it can be seen, respectively, on Figure 8(a) and Figure 8(b).



As seen in Figure 8(a), great part of the responses were from large companies, even being harder to approach due to the lack of internal contacts. Regarding the reason for these considerable number of large companies participating on the study, it can be related to the interest regarding the subject (Industry 4.0), that attracts more interest from companies that are trying implementing those technologies, which are usually the larger companies, but mainly due to the amount of large companies existent in the larger area of Upper Bavaria, where the headquarters of several automotive companies are located.

In relation to the Figure 8(b), the diameter of the bubbles represents the number of companies that participated in each city, being the color associate with the size of those companies according to the legend of the Figure 8(a). As can be seen in the map, great part of the respondent companies are located in Munich and its surroundings. This result was expected because great part of the economy is located in this region.

Regarding the average implementation levels, they can be seen in Figure 9. In relation to the graph shown in Figure 9(b), the center of the bubbles represents the average implementation levels and the diameter their respective standard deviation, being the larger diameters associated with greater standard deviations and vice-versa.



Source: The authors

As shown in Figure 9, the overall implementation levels of companies in the larger area of Upper Bavaria are, in general, higher than 3, representing that, if the company does not have a technology, they have at least an implementation project being developed. Regarding these high overall implementation levels, it can be explained by two main reasons. The first one is related to the region itself, because the concept of Industry

4.0 started in Germany and it has more consolidated culture of adopting technologies than other countries and, as stated early, great part of the headquarters are located in this region, in which usually these technologies are developed before spreading to other sites around the world. Regarding the second reason, it can be related to the sample, more accurate 41,67% of the sample were large companies (Figure 8(a)), which can reflect directly on the average results, more accurate the higher adoption levels are usually associated with the larger companies. Therefore, for this reason, the results were split by the companies' size and will be presented in the next topic.



KEY FACTS TO GO:

"Cybersecurity" and "Big Data Analytics" have the highest implementation levels within Industry 4.0 technologies in the larger area of Upper Bavaria. Conversely, "3D Printing" has the lowest implementation level among the key technologies. Furthermore, the implementation level varies according to the company size (see chapter 4.2).

4.2 Results by company size

For the reasons mentioned above, the implementation level results were divided by the companies' size, resulting in the Table 1. Regarding this division, it was based on SEBRAE and the EU Commission classification for industries [30].

	Table 1.7 Werage implementation levels by company size						
Technology	Micro	Small	Medium	Large			
Internet of Things	1,00	3,67	3,00	3,75			
Cloud	1,33	4,00	2,00	3,63			
Cybersecurity	2,33	3,83	3,75	3,88			
Big Data Analytics	1,67	3,40	3,75	3,63			
Virtually Guided Self-Services	1,00	4,00	3,00	3,43			
3D Printing	1,00	2,67	4,25	3,13			

Table 1. Average implementation levels by company size

Source: The authors

As seen in Table 1, the average adoption level increase according to the companies' size is not observed, being the small companies with the higher average implementation levels of "Cloud" and "Virtually Guided Self-Services", the medium with the "3D Printing" and "Big Data Analytics" and the large with "Cybersecurity" and "Internet Of Things", showing that the high overall implementation levels seen in Figure 9 are not exclusive for some sizes of company. Therefore, the association between company size and implementation level is not a completely true, being the technologies more well distributed throughout different sizes of companies, showing their accessibility regardless of size. Regarding the results for each size of company, they will be individually discussed in the following topics.

4.2.1 Evaluation: Large enterprises

41,67 % of the of study participants are represented by large companies with 500 or more employees. The results regarding the average implementation level of each technology in large companies can be seen Figure 10.

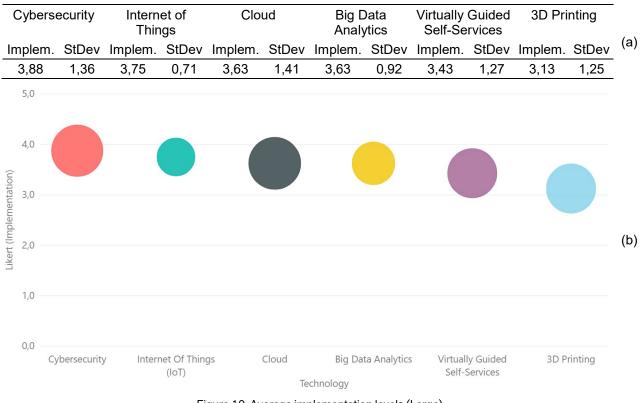


Figure 10. Average implementation levels (Large) Source: The authors

As observed in Figure 10, the overall implementation level of the key technologies is high, being all levels higher than 3, representing that, if the company does not have a technology, they have at least an implementation project being developed. Regarding these high overall implementation levels, it can be explained by the fact that these technologies usually attract more interest from larger companies, more accurate some of the solutions can be too complex, or expensive, to be implemented in smaller companies.

In relation to the highest implementation levels for the large companies (Figure 10), it is associated with the "Cybersecurity" (3,88) and "Internet of Things" (3,75) and the lowest with the "3D Printing" (3,13). Even having a small difference between the highest and the lowest average implementation level, it is possible to observe that the highest implemented technologies are associated with communication and digitalization technologies, like the "Internet of Things" and "Cloud", which, consequently, need a support from a technology such as the "Cybersecurity" to ensure their security and correct operation. In the other hand, the lowest implemented technologies can be associated with manufacturing, because the "3D Printing" is a manufacture technology and the "Virtually Guided Self-Services" and the "Big Data Analytics" are technologies that usually aim to optimize the production process, increasing their reliability.

However, as described early, even having a high overall implementation levels, some of the technologies are lower implemented comparing to smaller companies, as the "3D Printing", which is lower implemented than the medium sized companies, and the "Virtually Guided Self-Services" and "Cloud", which are lower implemented than the small sized companies. Regarding the reason, it can be related to the different goals that each size of company has, which, consequently, reflects in the option for a specific technology. In addition, it also should be noted that these 3 technologies have high standard deviations, representing that not all large companies have an implementation level lower than the smaller ones, but that it is depends of the context of each company.



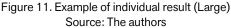
KEY FACTS TO GO:

For large companies, communication and digitalization technologies, such as "Internet of Things", combined with security technologies ("Cybersecurity") have the highest implementation levels within Industry 4.0 technologies in the larger area of Upper Bavaria. Conversely, manufacturing technologies, such as "3D Printing", has the lowest implementation level among the key technologies.

4.2.2 Case study: Large enterprises

An example of an individual result from a large company of the machinery and equipment sector located in the district of Donau-Ries (administrative division of Swabia in in southwest Bavaria) can be observed in Figure 11. The spider graph in black, as well as the numbers below the graphs, represents the average results obtained with the survey. The indicator graphs, as well as the spider graph in green, indicates the individual responses in comparison with these average results. In relation to the recommendations sent to the company regarding their results, they can be observed below.





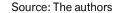
As shown in Figure 11, the overall improvement level of some technologies is below the average for the studied company. In relation to these differences, it is more evidenced in Cloud and Big Data Analytics, but is also observed in other specific objectives, as the "Dependability" for the Virtually Guided Self-Services and "Quality" for the IoT.

Based on that context, the main recommendation for the company was to review the adoptions of the Internet of Things and Cloud, because the improvements of key objectives, such as the "Dependability" and "Quality" are below the average and, therefore, can also reflects on the performance of other technologies. Regarding these performance impacts, it can be mainly observed in the Virtually Guided Self-Services and Big Data Analytics, because the data processed for these technologies are usually provided by the IoT and Cloud and, therefore, a low quality/reliable input can result in a low quality/reliable output.

4.2.3 Evaluation: Micro-sized enterprises

16,67 % of the of study participants are represented by micro companies with less than 19 employees. The results regarding the average implementation level of each technology in micro companies can be seen Figure 12.





As observed in Figure 12, the overall implementation level of the key technologies is low, being all levels lower than 3, representing that, in general, the companies do not have even an implementation project under development. Regarding these low overall implementation levels, as stated before, it can be explained

by the fact that these technologies usually attract more interest from larger companies, being too expensive, or complex, for the micro companies.

In relation to the highest implementation level for the micro companies (Figure 12), it is associated with the "Cybersecurity" (2,33) and the lowest with the "Internet of Things" (1,00), "Virtually Guided Self-Services" (1,00) and "3D Printing" (1,00). Analyzing the obtained standard deviations, it is possible to identify that all technologies with the lowest implementation level (1,00) had a null standard deviation, representing that none of the participating micro companies have interest in implementing any of these technologies in the future. In addition, even analyzing the highest implementation levels, it is possible to observe that the standard deviation increases with the implementation level, representing that, even some companies having the interest, or adopting, some of these technologies, great part do not have interest in any of the analyzed technologies.

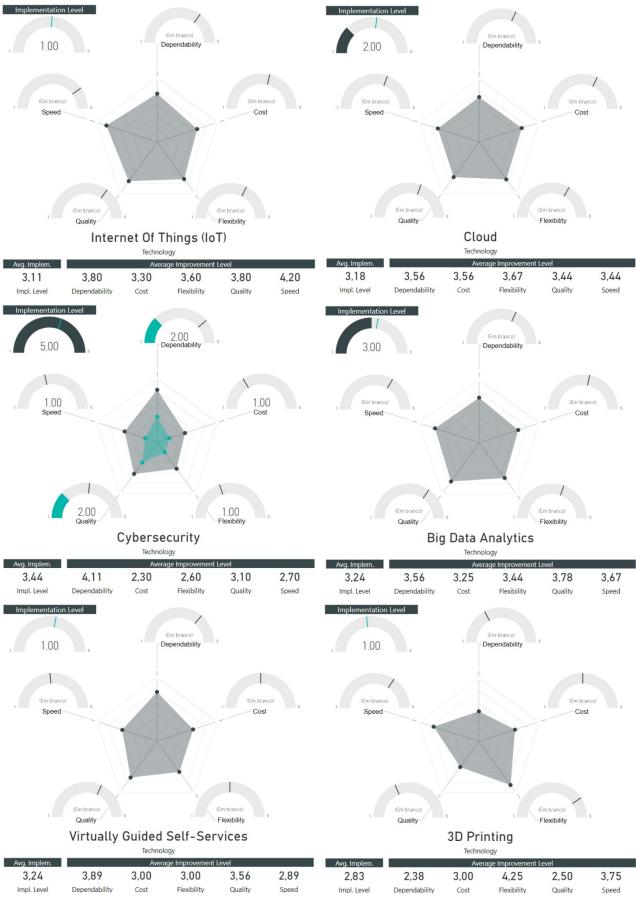


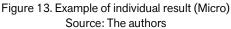
KEY FACTS TO GO:

Great part of the micro companies does not have interest of adopting any of the analyzed technologies, being the "Internet of Things", "Virtually Guided Self-Services" and the "3D Printing" the main ones with the lowest implementation level.

4.2.4 Case study: Micro-sized enterprises

An example of an individual result from a micro company of the aerospace sector located in the district Starnberg can be observed in Figure 13. In relation to the recommendations sent to the company regarding their results, they can be observed below.



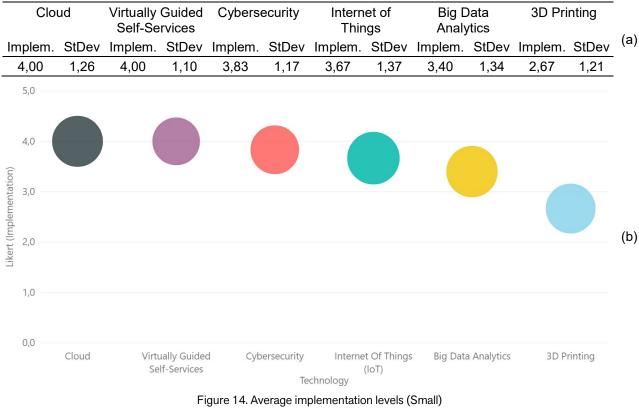


As shown in Figure 13, the overall implementation level of the studied company is below the average comparing to all companies but is the highest comparing only with the micro companies. Based on that context, the recommendations were only based on the average results and the context of the company, more accurate it is already the highest adopter comparing with companies of the same size.

Regarding the recommendations, the first one was to begin the implementation process of the Internet of Things, as will be further discussed, it presented the highest overall improvement level comparing with other technologies and, therefore, can bring a great performance improvement for the studied company. In addition, the Internet of Things is also a key technology to enable the potential of other technologies, such as the Big Data Analytics, which the company already has an implementation project under development. Finally, the second recommendation was to proceed with the implementation process of the Big Data Analytics, as stated early, already has an implementation project under development and also presented a high overall improvement level.

4.2.5 Evaluation: Small-sized enterprises

25 % of the of study participants are represented by small sized companies, which have from 20 to 99 more employees. The results regarding the average implementation level of each technology in small sized companies can be seen Figure 14.



Source: The authors

As observed in Figure 14, the overall implementation level of the key technologies is high, being all average levels, except for the "3D Printing", higher than 3 representing that, if the company does not have a technology, they have at least an implementation project being developed. Regarding these high overall implementation levels, even usually attracting more interest from larger companies, it shows, as stated early, how these technologies are not exclusively present in larger companies, showing their accessibility for different sizes of companies, including the small sized ones, as observed with the present research.

The highest average implementation levels for the small sized companies was observed for "Cloud" (4,00) and "Virtually Guided Self-Services" (4,00) and the lowest for "3D Printing" (2,67), which, as stated early, was the only technology with a average implementation level below 3. Regarding the reason for this difference in the ranking from other sizes of companies, it can be associated, as stated before, with the goals that each size of company has.

Analyzing the small sized ranking (Figure 14), it is possible to observe that the most used technologies is associated with communication, but mainly with the reliability of the process, while manufacturing and more sophisticated technologies have a lower implementation level. Regarding the reason for these level of adoptions, besides the difficulties to implement more advanced technologies, such as Big Data Analytics, it can be related to the fact that the small sized companies are usually suppliers of large companies and, therefore, the delivered product usually has to have, besides a great quality, traceability, aiming to avoid unexpected events. Therefore, for this reason, technologies that help to locate the product in the production process are very important, such as the "Virtually Guided Self-Services", being this reliable information usually made available to the large companies through a cloud-based service.



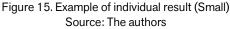
KEY FACTS TO GO:

For the small sized companies, technologies related to traceability have the highest implementation levels, such as the "Virtually Guided Self-Services", combined with technologies responsible for making those data available (Cloud). Conversely, manufacturing technologies, such as "3D Printing", has the lowest implementation level among the key technologies.

4.2.6 Case study: Small-sized enterprises

An example of an individual result from a small sized company of the machinery and equipment sector located in the district of Munich can be observed in Figure 15. In relation to the recommendations sent to the company regarding their results, they can be observed below.

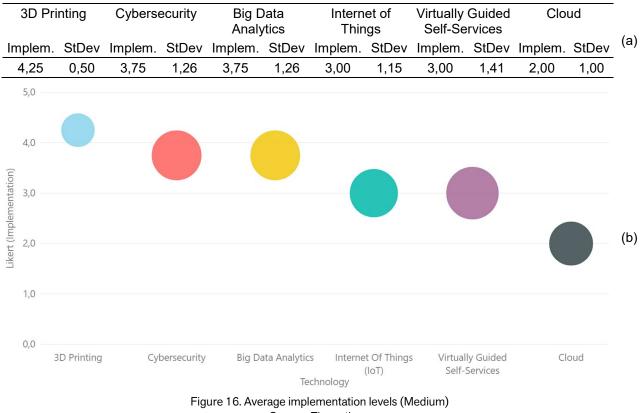




As shown in Figure 15, the overall improvement level of some technologies is below the average for the studied company. In relation to these differences, it is more evidenced in Internet of Things and 3D Printing. Based on that context, as in the large company case study, the main recommendation for this company was also to review the adoption of the Internet of Things, because the improvements of key objectives, such as the "Dependability" and "Quality" are below the average and, therefore, can also reflects on the performance of other technologies. Regarding these performance impacts, it can be mainly observed in the Big Data Analytics, because the data processed in this technology is usually provided by the IoT and, therefore, a low quality/reliable input can result in a low quality/reliable output.

4.2.7 Evaluation: Medium-sized enterprises

16,67 % of the of study participants are represented by medium sized companies, which have from 100 to 499 employees. The results regarding the average implementation level of each technology in medium sized companies can be seen Figure 16.



Source: The authors

As observed in Figure 16, even do not having a high overall implementation as the small sized and the large companies, the overall implementation level of the medium sized companies is also high, being most average levels higher than 3. Regarding these overall implementation levels, as stated early and will be

further discussed, it can be related to the goals of each size of companies, differently from the other sizes of companies, the manufacturing technologies have the highest implementation levels.

The highest average implementation level for the medium sized companies was observed for "3D Printing" (4,25) and the lowest for "Cloud" (2,00). Regarding these results, the average implementation level of "3D Printing" for the medium sized companies was the highest comparing with all technologies of all sizes of companies, even the technology having the lowest implementation level for all other sizes of companies between the technologies. In relation to the "Cloud", even having the highest implementation level for the small sized companies and a high overall implementation level, the results for the medium sized companies was the lowest companies of the small, medium and large companies.

Regarding this ranking, it can also be associated with the goals of each size of company, more accurate the highest implementation levels are associated with manufacture technologies and the lowest with communication. In relation to these difference from the other companies, it can be related to the fact that these companies are manufacturing companies which have their own final product and, therefore, do not have a demand regarding traceability from large companies as the small sized companies and a need to improve the communication as the large companies, more accurate most part of the process is done internally without the necessity of a great number of suppliers. Therefore, technologies that can help in the manufacturing and prototyping, such as "3D Printing", and that can improve the current processes, such as "Big Data Analytics", are preferred compared with the others.



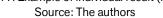
KEY FACTS TO GO:

For the medium sized companies, technologies related to manufacture, such as "3D Printing", have the highest implementation levels. Conversely, communication technologies, such as "Cloud" and "Internet of Things", has the lowest implementation level among the key technologies.

4.2.8 Case study: Medium-sized enterprises

An example of an individual result from a medium sized company of the machinery and equipment sector located in the district Bad Tölz-Wolfratshausen can be observed in Figure 17. In relation to the recommendations sent to the company regarding their results, they can be observed below.





As shown in Figure 17, the overall improvement level of the adopted technologies from the company is higher than the average. Based on that context, the recommendations were mainly based on the adoption of new technologies, because the company had great results regarding the implemented technologies.

Regarding the recommendations, they main recommendations were to begin the implementation process of the Cloud and Cybersecurity, more accurate the company has interest in these technologies and, as will be explained next, are key technologies for the integration and security. In relation to Cloud, as well as the IoT, it is a key technology that, as stated early, enables the full potential of other technologies, such as the Virtually Guided Self-Services, which the company already has a pilot implementation, and Big Data Analytics, which the company also have interest in implementing. Regarding the Cybersecurity, it is a very important technology to ensure the security of the data transmitted throughout the company.

4.3 Results by technologies

As observed in Table 2, the overall improvement levels were, in general, higher than 3, representing they had at least a good improvement with the adoption of the technologies considering all performance objectives.

	Table 2. Average improvement levels						
Technology	Depend.	Cost	Flexibility	Quality	Speed	Total	
Internet of Things	3,89	3,44	3,78	3,89	4,33	3,87	
Big Data Analytics	3,56	3,25	3,44	3,78	3,67	3,55	
Cloud	3,56	3,56	3,67	3,44	3,44	3,53	
Virtually Guided Self-Services	3,89	3,00	3,00	3,56	2,89	3,27	
3D Printing	2,43	3,14	4,14	2,57	4,00	3,26	
Cybersecurity	4,11	2,30	2,60	3,10	2,70	2,94	

Table 2. Average improvement levels

Source: The authors

In relation to the technologies, as shown in Table 2, the Internet of Things presented the highest overall improvement level (3,87), being the average improvement for "Speed" even higher than 4, representing that the adoption, in general, provides a very good to excellent improvement on this objective. Regarding the lowest overall improvement level, it was associated to Cybersecurity (2,94). However, it should be noted that, differently from other technologies, the Cybersecurity usually aims to improve the dependability of the processes, which had an average improvement of 4,11, and, therefore, it does not represent that the technology had a bad result, only that it aims to improve specifics objectives, different from other technologies. Finally, regarding the individual results for each technology, they are discussed in the following topics.

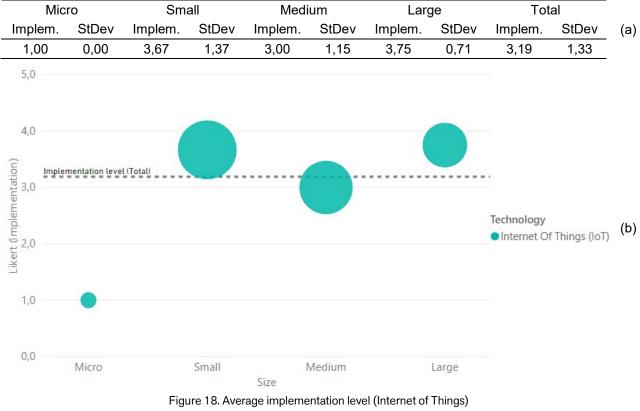


KEY FACTS TO GO:

"Internet of Things" and "Big Data Analytics" have the highest overall improvement levels within Industry 4.0 technologies in the larger area of Upper Bavaria. Conversely, "Cybersecurity" has the lowest overall improvement level among the key technologies. Furthermore, a lower overall improvement level does not necessarily represent a bad result, because some technologies aims to improve specific objectives.

4.3.1 Evaluation: Internet of Things

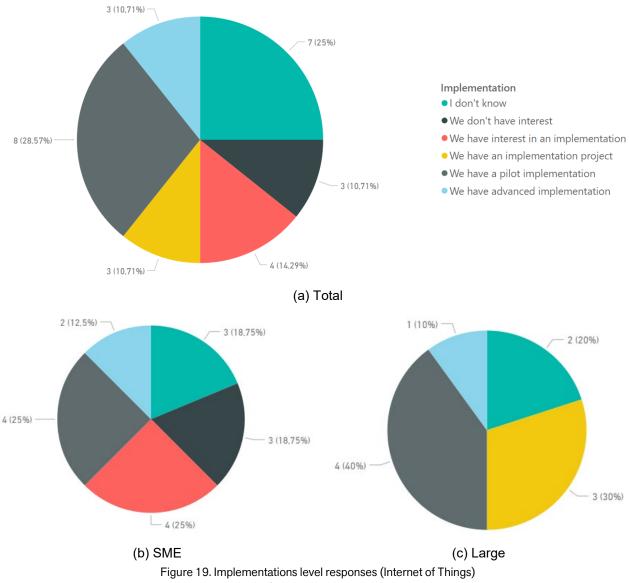
The average implementation level of the Internet of Things can be observed in Figure 18, being the results now filtered for a better visualization. In relation to the implementation level responses, they can be observed in Figure 19.



Source: The authors

As stated early, the Internet of Things presented a high overall implementation level, being the highest implementation levels in the large and small companies, as can be observed in Figure 18. In addition, it also should be noted that, even the small companies presenting a high overall implementation level for this technology, the standard deviation of the sample is the highest comparing with the other sizes companies, and, therefore, it does not mean that all small companies have a high implementation level, representing that the technology probably has a higher adoption level in some companies than others. Besides that, it also should be noted that, even having an average implementation level of 3, the medium companies are

still behind the small companies in terms of IoT (3,67), which, as will be explained further, can be related to goals of each size of company.

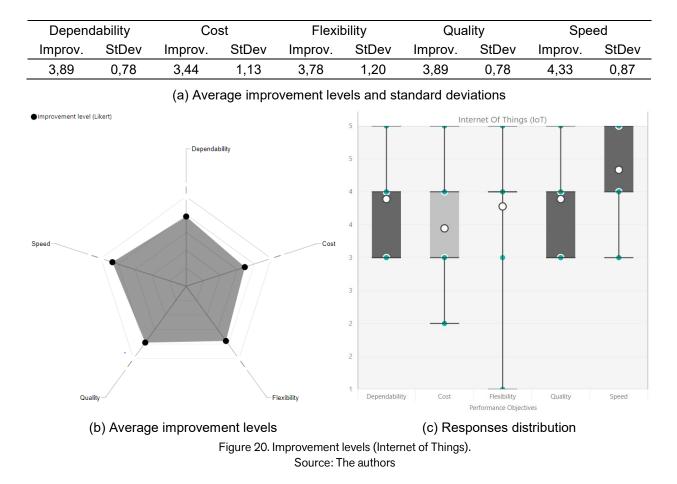


Source: The authors

As shown in Figure 19(a), a considerable number of respondents (25%) do not know the implementation level of IoT in their companies, representing that, even this technology having a high average implementation level, not all interviewed know about the technology or their use. However, as will be seen in the other topics, this situation is not exclusively for the IoT, being the percentual even higher for other technologies. In addition, it also should be noted that, great part of the respondents already has a pilot implementation (28,57%), and 50% of them has at least an implementation project being developed, being even higher for the large companies (80%) as shown in Figure 19(c), showing the interest by the companies to adopt this technology.

In relation to the average improvement levels, it can be observed in Figure 20(a). In addition, a spider graph with the average improvement levels and a boxplot with the responses distribution can also be seen,

respectively, in Figure 20(b) and Figure 20(c). Regarding the boxplot, the minimum and maximum are related, respectively, to the lowest and highest improvement level that the companies have obtained and the white circles are related to mean, that can also be seen in Figure 20(a).



As stated early, the Internet Of Things presented the highest overall improvement level comparing with other technologies, showing their potential to improve more than just one performance objective. As shown in Figure 20, the most improved aspect by adopting IoT was the "Speed" (4,33), being followed by the "Dependability" (3,89) and "Quality" (3,89) in second.

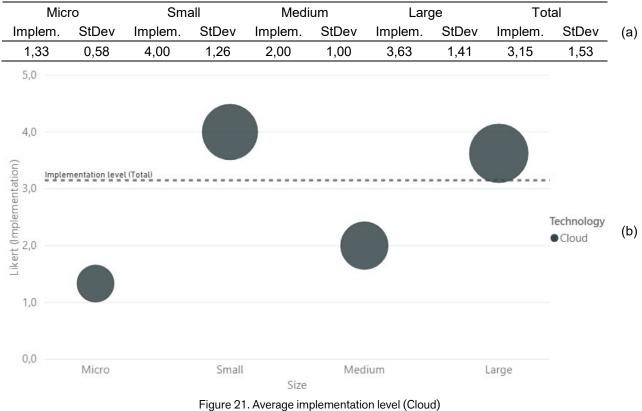
Comparing these average results (Figure 20(a)) with the distribution of the responses (Figure 20(c)), is possible to identify that these high improvement levels were not exclusive for some companies, however the distribution and standard deviations for these 3 objectives were the lowest ones, showing the great performance of this technology throughout different context and sizes. Because, regarding the other objectives, they had higher distributions and standard deviations, showing that the improvements can vary according the applications. As example, the "Flexibility", even showing an average improvement 3,78 (Figure 20(a)), in some cases it do not presented any improvement by adopting the loT, while in others the improvement was excellent (Figure 20(c)), confirming that the results can have high variations depending on the context of the application.



KEY FACTS TO GO: 50% of the total companies have at least an implementation project being developed regarding the Internet of Things. The IoT also presents the highest overall improvement level, being the "Speed" (4,33) the most improved performance objective. Conversely, "Costs" (3,44) have the lowest improvement level comparing with the other objectives.

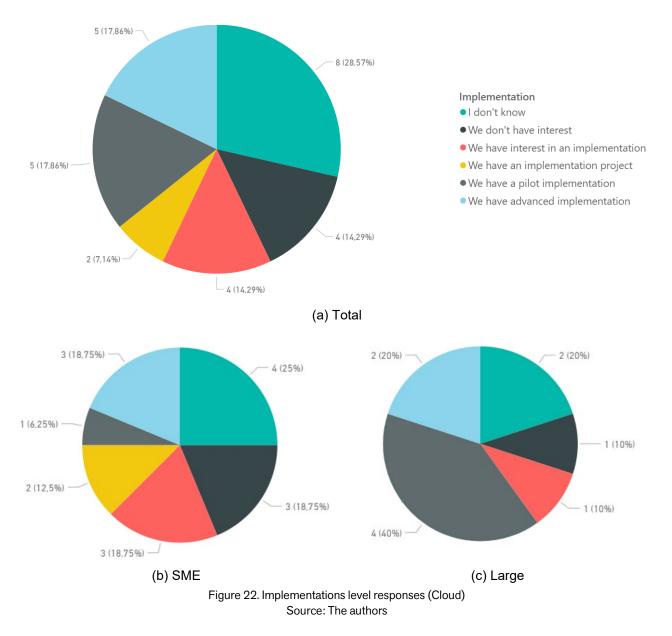
4.3.2 Evaluation: Cloud

The average implementation level of the Cloud can be observed in Figure 21, being the results now filtered for a better visualization. In relation to the implementation level responses, they can be observed in Figure 22.



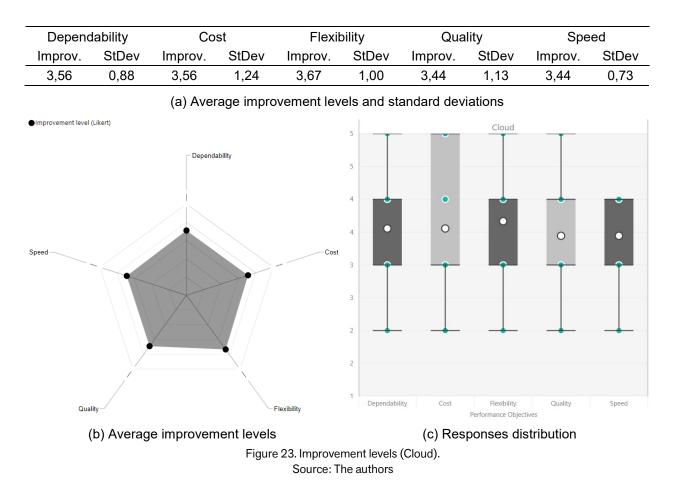
Source: The authors

As shown in Figure 21, Cloud presented a high overall implementation level mainly in the large and small companies. However, it should be noted that, even these companies having a considerably higher implementation levels than the micro and medium companies, it does not represent that all companies have a high implementation level, because the standard deviations are considerably high. As example, the large companies have one of the highest standard deviations for Cloud adoption comparing with all technologies and sizes of companies, representing that not all large companies have a high implementation level of Cloud.



As shown in Figure 22, a considerable number of respondents (28,57%) do not know the implementation level of Cloud in their companies, as observed in other technologies. Besides that, comparing these results with other technologies, some controversy around this technology can be observed, because it has the second highest percentual of respondents that do not have interest on the technology (14,29%), but it also is the second technology with the highest percentual of advanced implementation (17,86%). Regarding the reason for this uncertain around this technology, it can possible be related to the security of the data, because not all companies are willing to take a risk for implementing it, even with the constant improvements regarding this aspect in the last few years.

In relation to the average improvement levels, it can be observed in Figure 23(a). In addition, a spider graph with the average improvement levels and a boxplot with the responses distribution can also be seen, respectively, in Figure 23(b) and Figure 23(c).



As shown in Figure 23, Cloud, besides its controversy, presented one of the highest overall improvements comparing with other technologies. In relation to the most improved aspects, they were "Flexibility" (3,67), "Dependability" (3,56) and "Cost" (3,56).

Comparing these average results (Figure 23(a)) with the distribution of the responses (Figure 23(c)), is possible to identify that, besides the "Cost" having one of the highest improvement levels, it also had the highest distribution and standard deviation comparing with the other objectives, showing that the improvements in this aspect can vary according to the context of the Cloud application. In the other hand, the "Speed", even not being one of the most improved objectives, had the lowest distribution and standard deviation, representing that, even not being so high as other aspects, the improvement in this objective is more constant between different scenarios.

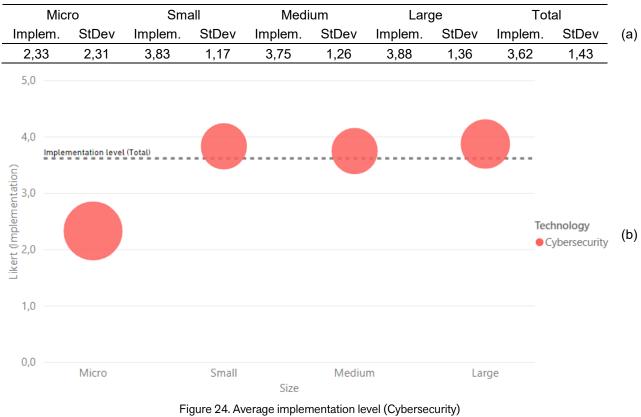


KEY FACTS TO GO:

Cloud presents the second highest percentual of advanced adopters (17,86%) and of respondents that do not have interest on the technology (14,29%). The most improved aspect for Cloud is "Flexibility" (3,67). "Quality" and "Speed" (both 3,44) are the least improved objectives.

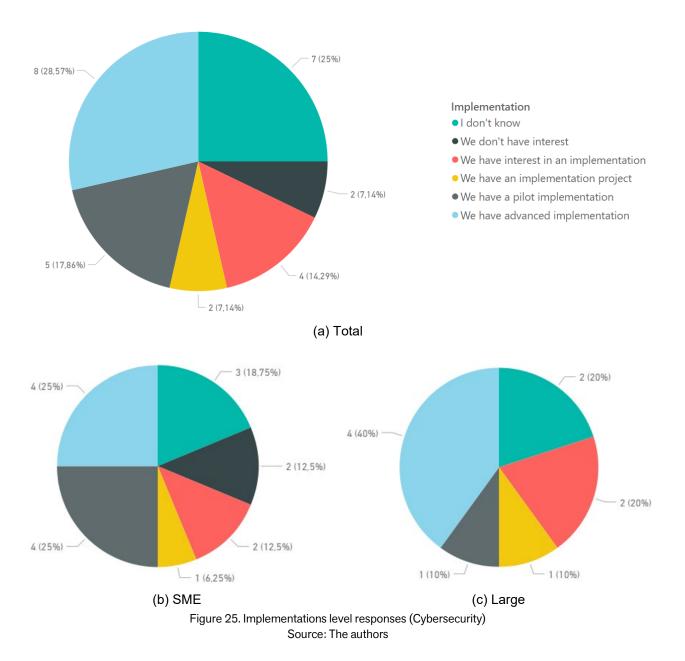
4.3.3 Evaluation: Cybersecurity

The average implementation level of the Cybersecurity can be observed in Figure 24, being the results now filtered for a better visualization. In relation to the implementation level responses, they can be observed in Figure 25.



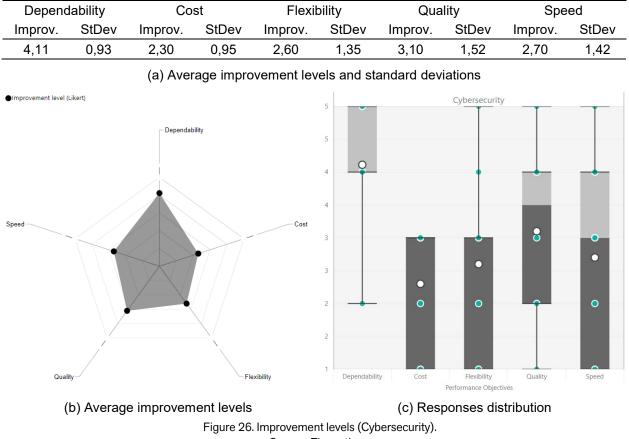
Source: The authors

As shown in Figure 24, the Cybersecurity presented the highest overall implementation level comparing with the other technologies, being this reflected for all sizes of companies. However, it should be noted that, even having a considerably high implementation level for the smaller companies, it does not represent that the majority of the companies has a high implementation level, because the overall standard deviation are considerably high, even comparing to the other technologies. As example, for the micro companies, the standard deviation is the highest comparing will all technologies and sizes, being even considerably higher than the second highest standard deviation, representing that the technology can have different levels of adoptions even when comparing with companies of the same size.



As shown in Figure 25, a considerable number of companies has an advanced implementation of Cybersecurity (28,57%), being the highest percentual of advanced implementation comparing with other technologies. However, at the same time, the technology has the lowest percentual of pilot implementations (17,86%) and implementation projects (7,14%), which can explain the high standard deviations observed in Figure 24. Regarding the reasons of this difference, it can be related to the speed of the development process, since, differently from the other technologies, the Cybersecurity is usually a more accessible technology which has usually an easier implementation process and, therefore, some steps such as the project and pilot implementing are faster than observed with other technologies that demand a more in depth study for their application.

In relation to the average improvement levels, it can be observed in Figure 26(a). In addition, a spider graph with the average improvement levels and a boxplot with the responses distribution can also be seen, respectively, in Figure 26(b) and Figure 26(c).

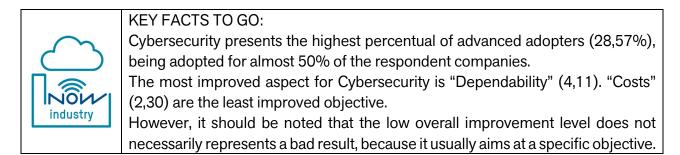


Source: The authors

As stated early, the Cybersecurity has the lowest overall improvement level when comparing with other technologies. However, it should be noted that, differently from other technologies, the Cybersecurity usually aims to improve the dependability of the processes, which had an average improvement of 4,11, and, therefore, it does not represent that the technology had a bad result, only that it aims to improve specifics objectives, different from other technologies.

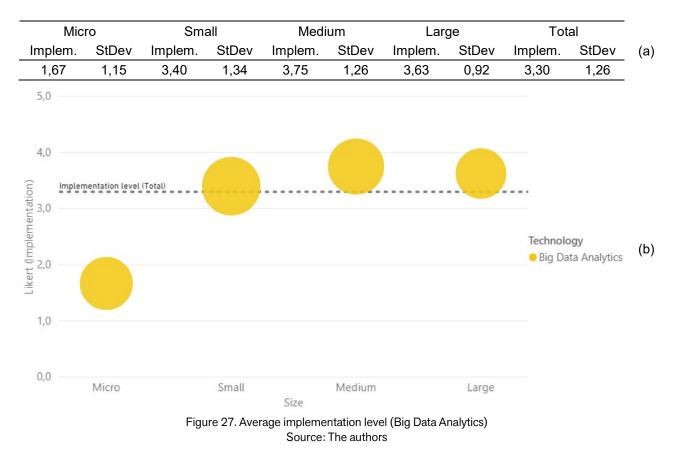
Comparing these average results (Figure 26(a)) with the distribution of the responses (Figure 26(c)), is possible to identify that these high improvement levels were not exclusive for some companies, because the distribution and standard deviation for the "Dependability" were the lowest one, showing the great performance of this technology throughout different context and sizes. However, regarding the other objectives, besides the "Cost", they had higher distributions and standard deviations, showing that the improvements can vary according the applications, presenting from any improvement to excellent improvement on these three scenarios. Regarding the "Cost", it presented the lowest average improvement level comparing with all technologies and objectives associated with a low standard deviation and

distribution, representing that the technology, in general, do not promote great improvements in this objective.

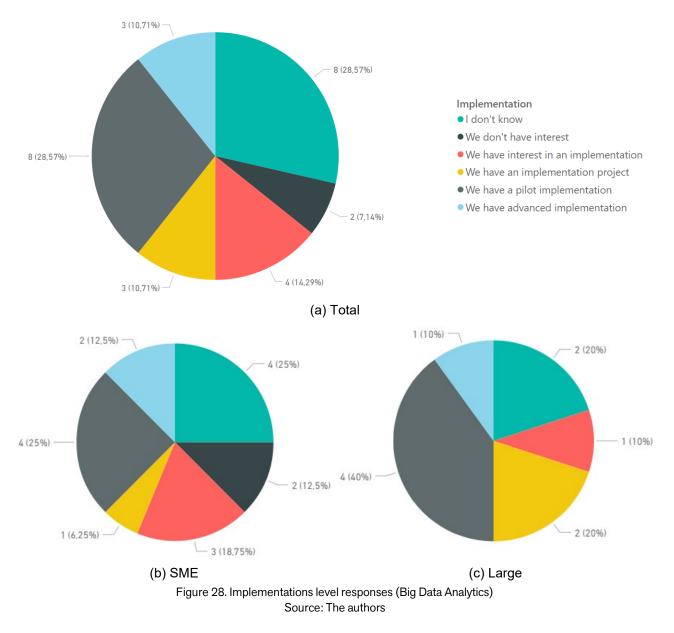


4.3.4 Evaluation: Big Data Analytics

The average implementation level of the Big Data Analytics can be observed in Figure 27, being the results now filtered for a better visualization. In relation to the implementation level responses, they can be observed in Figure 28.

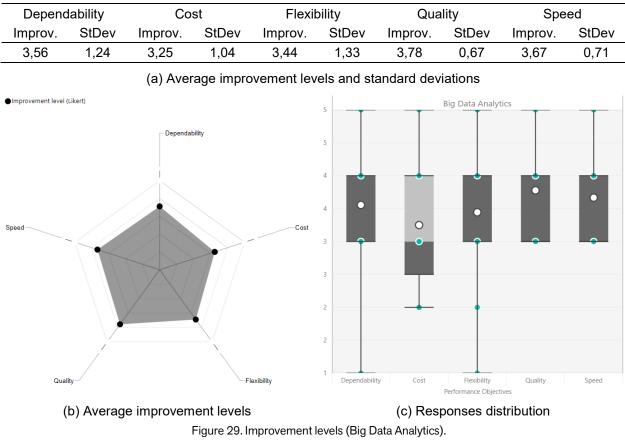


As seen in Figure 27, the Big Data Analytics presented a high overall implementation level, being the highest implementation levels in the medium and large companies. However, even the medium companies presenting the highest average implementation level, it also has one of the highest standard deviations comparing with other companies sizes, and, therefore, it does not necessarily mean that all these companies have a higher implementation level than the large companies, for example.



As shown in Figure 28, a considerable number of respondents (28,57%) do not know the implementation level of Big Data Analytics in their companies, representing that even the technologies that have a high average implementation level are not well known by all interviewed. However, as stated early, even with the highest percentual of interviewed that do not know about the Big Data Analytics application, this situation is not exclusively for this technology. In addition, it also should be noted that, great part of the respondents already has a pilot implementation (28,57%), and 50% of them has at least an implementation project being developed, showing the interest by the companies for adopting this technology.

In relation to the average improvement levels, it can be observed in Figure 29(a). In addition, a spider graph with the average improvement levels and a boxplot with the responses distribution can also be seen, respectively, in Figure 29(b) and Figure 29(c).



Source: The authors

As shown in Figure 29, the Big Data Analytics presented one of the highest overall improvements comparing with other technologies. In relation to the most improved aspects, they were "Quality" (3,78) and "Speed" (3,67).

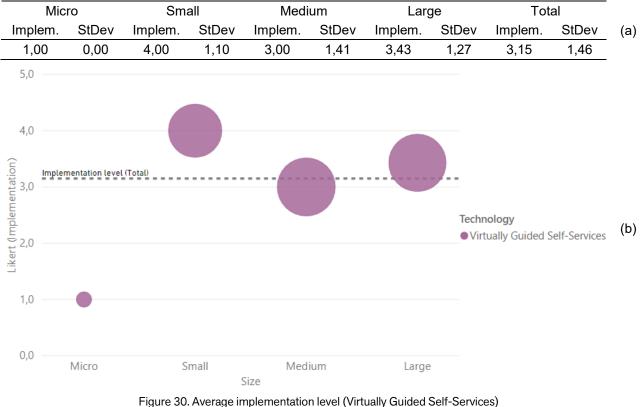
Comparing these average results (Figure 29(a)) with the distribution of the responses (Figure 29(c)), is possible to identify that these high improvement levels were not exclusive for some companies, because the distribution and standard deviations for these 2 objectives were the lowest ones, showing the great performance of this technology throughout different context and sizes. However, regarding the other objectives, mainly the "Dependability" and "Flexibility", they had higher distributions and standard deviations, showing that the improvements can vary according the applications, presenting from any improvement to excellent improvement on these two scenarios. However, as the Big Data Analytics is usually associated to predictive analysis, aiming to improve the quality and speed of the process, it can be said that, in general, the technology is achieving its objective, more accurate these were the most improved objectives with the lowest deviations.



KEY FACTS TO GO: 50% of the total companies have at least an implementation project being developed regarding Big Data Analytics. In relation to the improvements, "Quality" (4,11) has the highest improvement level. Conversely, "Costs" (3,25) presents the lowest improvement level comparing with the other objectives.

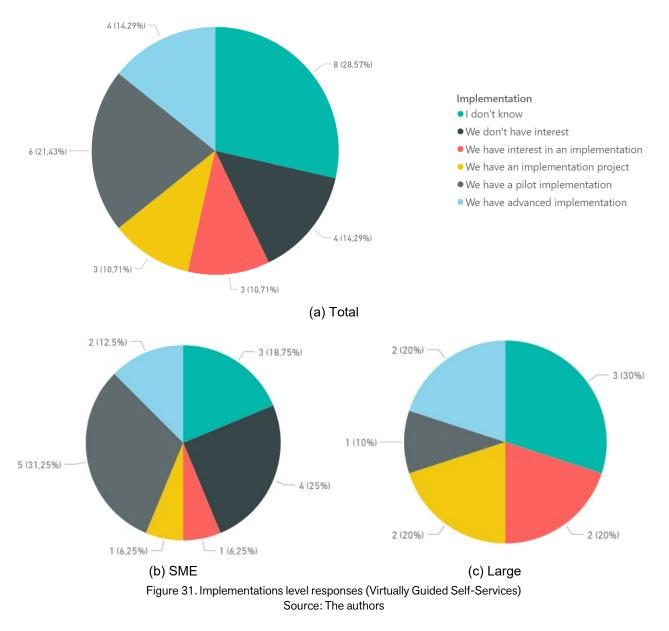
4.3.5 Evaluation: Virtually Guided Self-Services

The average implementation level of the Virtually Guided Self-Services can be observed in Figure 30, being the results now filtered for a better visualization. In relation to the implementation level responses, they can be observed in Figure 31.



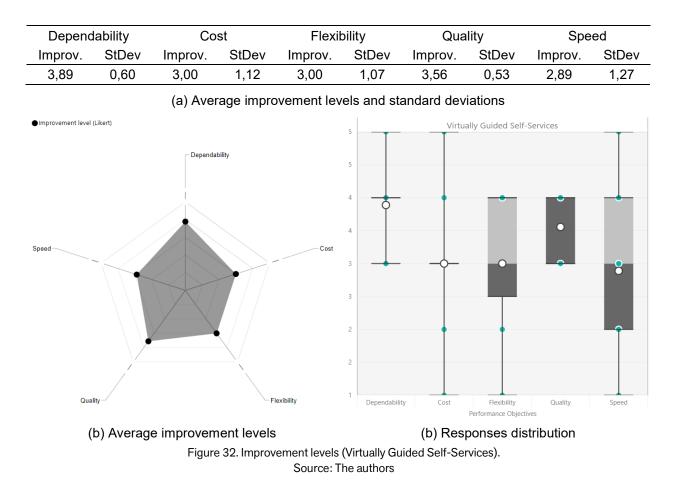
Source: The authors

As seen in Figure 30, the Virtually Guided Self-Services also presented a high overall implementation level, being the highest implementation levels in the small companies. However, different from the other technologies, the small companies also have one of the lowest standard deviations comparing with other companies' sizes, showing that, in general, they have even a higher implementation level than the large companies, for example, which has a lower average implementation level and higher standard deviation.



As shown in Figure 31, the Virtually Guided Self-Services presented the highest percentual of interviewed that do not know their implementation level (28,57%) and the second that do not have interest in this technology (14,29%), similar to the Cloud results, but with more projects and pilot implementations.

In relation to the average improvement levels, it can be observed in Figure 32(a). In addition, a spider graph with the average improvement levels and a boxplot with the responses distribution can also be seen, respectively, in Figure 32(b) and Figure 32(c).



As shown in Figure 32, the Virtually Guided Self-Services have not presented high overall improvements as other technologies. However, the most improved aspects, which were "Dependability" (3,89) and "Quality" (3,56), presented some interesting results regarding their distribution and deviation, as will be explained next.

Comparing these average results (Figure 32(a)) with the distribution of the responses (Figure 32(c)), is possible to identify that these high improvement levels were not exclusive for some companies, more accurate the distribution and standard deviations for these 2 objectives were the lowest ones, even comparing with other technologies and objectives, showing the consistency of this technology throughout different context and sizes, with all companies having at least a good improvement in these aspects. However, regarding the other objectives, they had higher distributions and standard deviations, showing that the improvements can vary according the applications, presenting from any improvement to excellent improvement for "Cost" and "Speed", for example.



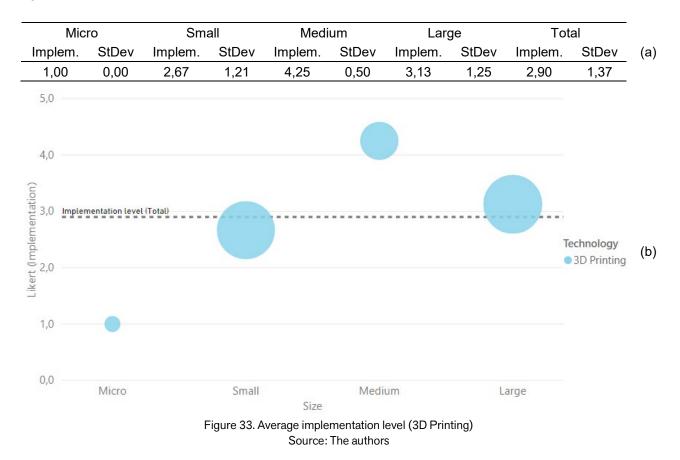
KEY FACTS TO GO:

The Virtually Guided Self-Service presents the highest percentual of interviewed that do not know their implementation level (28,57%).

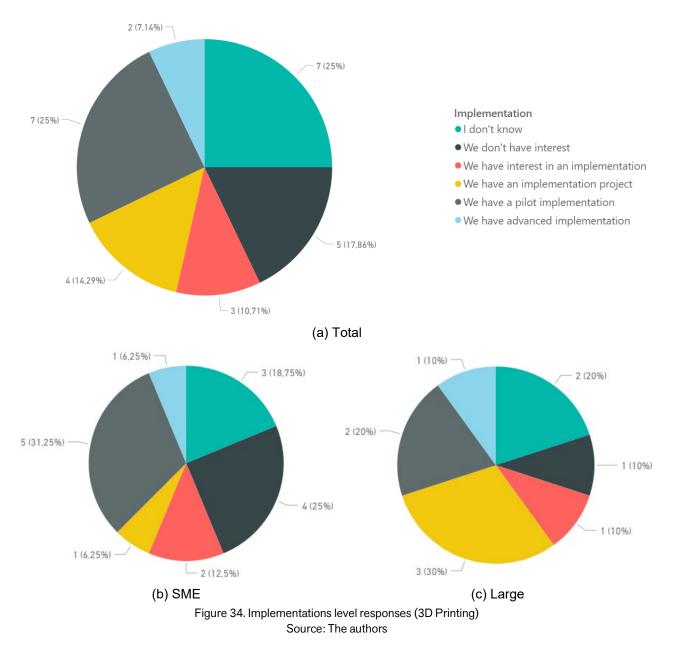
In relation to the improvements, "Dependability" (3,89) has the highest improvement level and "Speed" (2,89) presents the lowest improvement level comparing with the other objectives.

4.3.6 Evaluation: 3D Printing

The average implementation level of the 3D Printing can be observed in Figure 33, being the results now filtered for a better visualization. In relation to the implementation level responses, they can be observed in Figure 34.

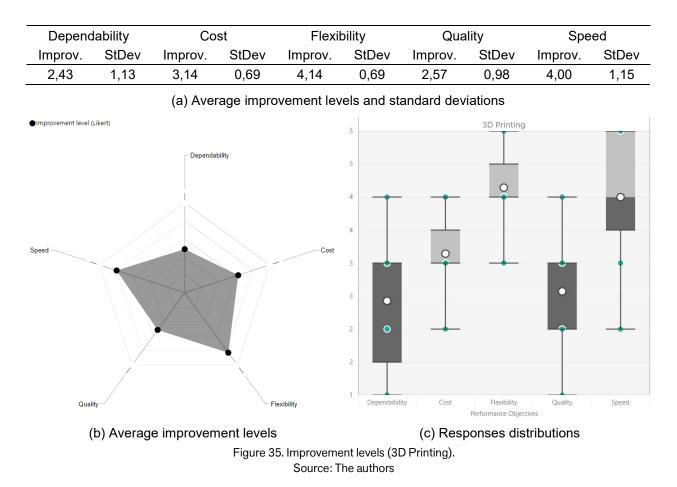


As seen in Figure 33, the 3D Printing presented the lowest overall implementation level comparing with other technologies, having a considerably high implementation only in the medium companies. However, even having a low overall implementation level, the implementation level for medium companies is the highest one comparing with all technologies and sizes of companies. In addition, besides the null standard deviations of the micro companies, it also has the lowest standard deviation comparing with all technologies, presenting that the most part of the participant companies have a high implementation level of this technology.



As shown in Figure 34, the 3D Printing presented the highest percentual of interviewed that do not have interest in this technology (17,86%) and the lowest percentual of advanced implementations (7,14%). Regarding the reasons for these results, it can be related to the fact that, differently of the other technologies presented, it is a manufacture technology and, therefore, it has a more restricted application, not being applicable for companies that do not have a production process, for example. In addition, regarding the low advanced implementation, it also can be related to the fact that this technology is usually used for prototyping and development process, not necessarily demanding an advanced implementation.

In relation to the average improvement levels, it can be observed in Figure 35(a). In addition, a spider graph with the average improvement levels and a boxplot with the responses distribution can also be seen, respectively, in Figure 35(b) and Figure 35(c).



As the Virtually Guided Self-Services, the 3D Printing have not presented high overall improvements as other technologies, as can be seen in Figure 35. However, the most improved aspects, which were "Flexibility" (4,14) and "Speed" (4,00), presented as one of the most improved aspects comparing with all technologies and objectives.

Comparing these average results (Figure 35(a)) with the distribution of the responses (Figure 35(c)), is possible to identify that these high improvement levels in the "Flexibility" was not exclusive for some companies, more accurate the distribution and standard deviations for this objectives was one of the lowest ones, even comparing with other technologies and objectives, showing the consistency of this technology throughout different context and sizes, with all companies having at least a good improvement in this aspects. However, regarding the other objectives, besides the "Cost", they had higher distributions and standard deviations, showing that the improvements can vary according to the applications.



KEY FACTS TO GO:

3D Printing presented the highest percentual of interviewed that do not have interest in their implementation (17,86%) and the lowest of advanced adopters (7,14%). The most improved objectives are "Flexibility" (4,11) and "Speed" (4,00). Conversely, "Dependability" (2,43) and "Quality" (2,57) have the lowest improvement level comparing with the other objectives

5 Conclusion

Through the presented method, it can be said that the objective of identify the main implications of the Industry 4.0 technologies for the production management has been achieved, because a survey of companies in the larger area of Upper Bavaria regarding the overall implementation level and their implication to the performance objectives could be performed. However, it should be noted that the results presented refer only to the scenario of the larger area of Upper Bavaria, more specifically of the companies of the metal-mechanic and automotive sector and may differ from other sectors or regions studied.

As presented in the topic of results and discussion, the overall implementation level of the Industry 4.0 technologies of companies in the larger area of Upper Bavaria is high. In addition, it also should be noted that the technologies adoptions have been well distributed throughout different sizes of companies. An example of this scenario is the "Cloud" adoption, which has the highest average implementation level in the small sized companies, showing its accessibility regardless the companies' size. In relation to the improvement levels, the Internet of Things shows the highest overall improvement level (3,87) with an average improvement for "Speed" even higher than 4, and, therefore, presenting the great diversity of possible benefits that the companies can get by adopting this technology. In relation the lowest overall improvement level, it is associated to Cybersecurity (2,94). However, it should be noted that, differently from other technologies, the Cybersecurity usually aims to improve the dependability of the processes, which had an average improvement of 4,11, and, therefore, it does not represent that the technology had a bad result, only that it aims to improve specifics objectives, different from other technologies.

Furthermore, it can be concluded that even with the constant adoption of Industry 4.0 technologies and the high overall implementation levels obtained, these concepts are not yet well widespread throughout the companies, more accurate over 25% of the responses regarding the implementation levels were "I don't know", showing the difficulties to understand some of these technologies. Regarding the improvement levels, it could be observed that not all technologies has the potential to improve all the performance objectives like the Internet of Things. Examples of this scenario are the Cybersecurity, which aims to highly improve a specific objective ("Dependability"), and the Virtually Guided Self-Services, that presents a lower but more consistent improvement throughout different contexts.

Finally, for future works, it is suggested to apply the proposed methodology to other regions and sectors to analyze the differences between the applications in different scenarios. In addition, case studies are also suggested related to these adoptions, aiming to understand how that adoptions occurred and the reasons for these differences between regions.

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KEY FACTS TO GO:



Key technologies of Industry 4.0 are highly implemented in the larger area of Upper Bavaria. Despite of high overall implementation level, the concept of Industry 4.0 is not widespread within companies in the larger area of Upper Bavaria, e.g. 25% of the interviewed do not know their implementation level.

Internet of Things shows the highest overall improvement level with a high improvement for all performance objectives. Conversely, the lowest overall improvement level is associated to Cybersecurity with a high improvement only for a specific objective ("Dependability").

6 References

- Hermann, M., Pentek, T., Otto, B.: Design principles for industrie 4.0 scenarios. In: Proceedings of the Annual Hawaii International Conference on System Sciences. pp. 3928–3937 (2016)
- Arbeitskreis Industrie 4.0: Umsetzungsempfehlungen für das Zukunftsprojekt. (2013) http://www.plattform-i40.de/was-industrie-40-f%C3%BCr-uns-ist
- Kagemann, H., Wahlster, W., Helbig, J.: Recommendations for implementing the strategic initiative INDUSTRIE 4.0. acatech. 1–80 (2013). https://doi.org/10.13140
- Schwab, K.: The Fourth Industrial Revolution. World Economic Forum, Geneva (2016)
- Bauernhansl, T., ten Hompel, M., Vogel-Heuser, B.: Industrie 4.0 in Produktion, Automatisierung und Logistik. Springer Fachmedien Wiesbaden, Wiesbaden (2014)
- Liao, Y., Deschamps, F., de Freitas Rocha Loures, E., Pierin Ramos, L.F.: Past, present and future of Industry 4.0 - a systematic literature review and research agenda proposal. Int. J. Prod. Res. 55, 3609–3629 (2017). https://doi.org/10.1080/00207543.2017.1308576
- Dujin, A., Geissler, C., Horstkötter, D.: Industry 4.0 The new industrial revolution How Europe will succeed. Rol. Berger Strateg. Consult. 1–24 (2014). https://doi.org/10.1007/s00287-014-0809-1
- Bechtold, J., Kern, A., Lauenstein, C., Bernhofer, L.: Industry 4.0 The Capgemini Consulting View. Capgemini Consult. 1–31 (2014)
- Reinhard, G., Jesper, V., Stefan, S.: Industry 4.0: Building the digital enterprise. Price Waterhouse Coopers. 1–39 (2016). https://doi.org/10.1080/01969722.2015.1007734
- Wee, D., Kelly, R., Cattel, J., Breunig, M.: Industry 4.0 how to navigate digitization of the manufacturing sector. McKinsey Co. 1–62 (2015). https://doi.org/10.1007/s13398-014-0173-7.2
- Bischoff, J., Taphorn, C., Wolter, D., Braun, N., Fellbaum, M., Goloverov, A., Ludwig, S., Hegmanns, T.,
 Prasse, C., Henke, M., tan Hompel, M., Döbbeler, F., Fuss, E., Kirsch, C., Mättig, B., Braun, S., Guth,
 M., Karspers, M., Scheffler, D.: Erschließen der Potenziale der Anwendung von Industrie 4.0 im
 Mittelstand. (2015)
- BRUNHEROTO, P.H., LING, B.P., DESCHAMPS, F., VALLE, P.D.: Como as tecnologias da Indústria 4.0 estão sendo aplicadas? Um survey das indústrias do setor metal-mecânico e automobilístico de Curitiba e Região Metropolitana. XXXVIII Encontro Nac. Eng. Produção. 1–13 (2018). https://doi.org/10.14488/ENEGEP2018_TN_STO_264_515_36525
- Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., Harnisch, M.: Industry 4.0 The Future of Productivity and Growth in Manufacturing Industries. Bost. Consult. Gr. 1–20 (2015)
- Xia, F., Yang, L.T., Wang, L., Vinel, A.: Internet of Things. Int. J. Commun. Syst. 25, 1101–1102 (2012). https://doi.org/10.1002/dac
- Yue, X., Cai, H., Yan, H., Zou, C., Zhou, K.: Cloud-assisted industrial cyber-physical systems: An insight, http://dx.doi.org/10.1016/j.micpro.2015.08.013, (2015)
- Kobara, K.: Cyber physical security for Industrial Control Systems and IoT. IEICE Trans. Inf. Syst. E99D, 787– 795 (2016). https://doi.org/10.1587/transinf.2015ICI0001

- Kang, H.S., Lee, J.Y., Choi, S., Kim, H., Park, J.H., Son, J.Y., Kim, B.H., Noh, S. Do: Smart manufacturing: Past research, present findings, and future directions, (2016)
- Costa, C.J., Ferreira, E., Bento, F., Aparicio, M.: Enterprise resource planning adoption and satisfaction determinants. Comput. Human Behav. 63, 659–671 (2016). https://doi.org/10.1016/j.chb.2016.05.090
- Klaus, H., Rosemann, M., Gable, G.: What is ERP? Inf. Syst. Front. 2, 141–162 (2000). https://doi.org/10.1023/A:1026543906354
- Shkurskii, S.A., Sabel'nikova, E.A.: Resource-control system based on the SAP ERP system. Coke Chem. 54, 426–427 (2011). https://doi.org/10.3103/S1068364X1111010X
- Andersson, C., Bellgran, M.: On the complexity of using performance measures: Enhancing sustained production improvement capability by combining OEE and productivity. J. Manuf. Syst. 35, 144–154 (2015). https://doi.org/10.1016/j.jmsy.2014.12.003
- Kim, J.S., Arnold, P.: Operationalizing manufacturing strategy. Int. J. Oper. Prod. Manag. 16, 45–73 (1996). https://doi.org/10.1108/01443579610151751
- Slack, N., Lewis, M.: Operations Strategy. Pearson, Harlow (2015)
- Corrêa, H.L., Corrêa, C.A.: Administração de Produção e Operações Manufatura e Serviços: Uma Abordagem Estratégica. Editora Atlas SA (2012)
- Kaviani, M.A., Abbasi, M.: Analysing the operations strategies of manufacturing firms using a hybrid Grey DEA approach - A case of Fars Cement Companies in Iran. Int. J. Supply Oper. Manag. 1, 371–391 (2014)
- Pinheiro de Lima, E., Eduardo Gouvêa da Costa, S., Reis de Faria, A.: Taking operations strategy into practice: Developing a process for defining priorities and performance measures. Int. J. Prod. Econ. 122, 403–418 (2009). https://doi.org/10.1016/j.ijpe.2009.06.022
- Bayern International: Key to Bavaria the foreign trade database, https://www.bayerninternational.de/en/company-database/
- Bezirk Oberbayern: Bezirk Oberbayern 2019: Zahlen und Daten. Bezirk Oberbayern, München (2019)
- Frank, A.G., Dalenogare, L.S., Ayala, N.F.: Industry 4.0 technologies: Implementation patterns in manufacturing companies. Int. J. Prod. Econ. 210, 15–26 (2019). https://doi.org/10.1016/j.ijpe.2019.01.004
- SEBRAE: Anuário do Trabalho na Micro e Pequena Empresa: 2014. (2015)

Appendix – Questionnaire

Fragebogen zu den Auswirkungen von Industrie 4.0-Technologien auf die Leistungsziele im Unternehmen

Sehr geehrte Damen und Herren,

zunächst vielen Dank, dass Sie sich die Zeit nehmen, diesen Fragebogen zu beantworten!

Dieser Fragebogen untersucht, wie Unternehmen Technologien im Zusammenhang mit Industrie 4.0 anwenden. Die Untersuchung zielt auf die Identifizierung von Verbesserungspotenzialen, Ideen für Produktinnovationen, Prozesse und Geschäftsmodelle ab.

Dieser Fragebogen gliedert sich in:

- Fragen zur ihrer Person,
- Fragen zum Unternehmen,
- Fragen zum Umsetzungsniveau von Industrie 4.0 und
- Fragen zum Verbesserungsniveau von Industrie 4.0.

Die geschätzte Zeit zum Ausfüllen dieses Fragebogens beträgt 7 Minuten. Es werden keine ihrer einzelnen Antworten veröffentlicht, die es erlauben Sie als Befragten oder ihr Unternehmen zu identifizieren. Die Antwortergebnisse werden ausschließlich konsolidiert veröffentlicht und so bald wie möglich allen Befragten zur Verfügung gestellt.

Dieser Fragebogen ist Bestandteil der kooperativen Forschung zwischen der Universidade Federal do Parana in Brasilien und der oberbayrischen Technischen Hochschule Ingolstadt. Die Ergebnisse des Fragebogens der beiden staatlichen Hochschulen streben ausschließlich einen wissenschaftlichen Erkenntnisgewinn an. Es besteht ausdrücklich keine kommerzielle Absicht in der Vermarktung der Ergebnisse.

Für weitere Fragen zögern Sie bitte nicht uns zu kontaktieren:

Paulo Henrique Brunheroto, Forschungsstudent an der Technischen Hochschule Ingolstadt / Bachelorstudent an der Universidade Federal do Parana (UFPR) / Brasilien paulobrunheroto@hotmail.com

(Herr) Dr. Dagmar Piotr Tomanek, Forschungsreferent und Wissenschaftlicher Mitarbeiter für den Ausbau des Schwerpunkts Industrie 4.0 und Digitalisierung in der Produktion an der Technischen Hochschule Ingolstadt (THI) dagmar.tomanek@thi.de

Prof. Dr. Fernando Deschamps, Professor am Institut für Maschinenbau an der UFPR / Brasilien fernando.deschamps@ufpr.br

Nochmals vielen Dank! Ihr Beitrag ist wertvoll und unverzichtbar für den Erfolg unserer Forschung!

Fragen zur Person:

Bitte geben Sie ihre persönlichen Daten an. Wir weisen Sie darauf hin, dass Ihre Daten nicht offengelegt oder weitergegeben werden.

	Herr			
Anrede:	Frau			
	Divers			
Vor- und Nachname:				
Name des Unternehmens				
Standort:				
Position:				
	15 bis 29 Jahre			
	30 bis 39 Jahre			
Alter (optional):	40 bis 49 Jahre			
	50 bis 59 Jahre			
	60 Jahre oder älter			
E-Mail-Adresse:				
Telefon (optional)				
	ch bin damit einverstanden, dass ich ggf. bei Rückfragen zum Fragebogen contaktiert werde.			

Fragen zum Unternehmen:

Sektor:

Metallverarbeitung
Maschinen und Anlagenbau
Automobilbau (inkl. Herstellung von Anhängern und Karosseriebau)
Herstellung anderer Transportmittel, ausgenommen Kraftfahrzeuge (z.B. Boote, etc.)
Anderer Unternehmenssektor (bitte angeben):

X

Anzahl der Angestellten:

Bis zu 19 Mitarbeiter
Von 20 bis 99 Mitarbeitern
Von 100 bis 499 Mitarbeitern
500 oder mehr Mitarbeiter

Fragen zum Umsetzungsniveau von Industrie 4.0

Bitte geben Sie für jede der unten beschriebenen Technologien die Implementierungsebene an, auf der sie sich ihr Unternehmen befinden.

Internet Of Things (IoT) / Internet der Dinge

Wesentliches Element des Internets of Things (dt. Internet der Dinge) ist die digitale Vernetzung aller physischen, smarten Objekte. Durch das Internet of Things soll die Qualität der Interaktion von Menschen und Maschinen (inklusive der Kommunikation von Maschine) verbessert werden (Quelle: Schlatt, V. et al., S. 31).

		Implementierungsebene						
	Wir sind an keiner Implementierung interessiert.	Wir sind an einer Implementierung interessiert, aber haben noch kein Umsetzungsprojekt.	Wir haben ein Umsetzungsprojekt angestoßen, das sich in der Entwicklungsphase befindet.	durch Pilotprojekte	Wir haben die Umsetzung flächendeckend im Unternehmen vorangebracht.	lch weiß es nicht. / Keine Angabe möglich.		
Internet Of Things								
Achtung: Mehrfachnen	nungen <u>nicht</u> möglic	h						

Cloud

Cloud Computing beschreibt Infrastrukturanwendungen und -lösungen, die als öffentliche oder private Netzwerkdienste auf Pay-per-Use-Basis bereitgestellt werden und jederzeit und überall zugänglich sind (Quelle: Bechtold, J. et al., 2014; Yue, X. et al., 2015).

			Implementierungsebene				
	Wir sind an keiner Implementierung interessiert.	Wir sind an einer Implementierung interessiert, aber haben noch kein Umsetzungsprojekt.	Wir haben ein Umsetzungsprojekt angestoßen, das sich in der Entwicklungsphase befindet.	durch Pilotprojekte	Wir haben die Umsetzung flächendeckend im Unternehmen vorangebracht.	Ich weiß es nicht. / Keine Angabe möglich.	
Cloud							
Achtung: Mehrfachne	nnungen nicht möglig	:h			D		

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Cybersecurity

Es ist der Aufbau von Technologien, Prozessen und Praktiken, die zum Schutz von Netzwerken, Computern, Programmen und Daten vor Angriffen, Beschädigungen oder unbefugtem Zugriff entwickelt wurden. In einem rechnerischen Kontext umfasst Sicherheit sowohl Cybersicherheit als auch physische Sicherheit. Zum Beispiel die Tiefenverteidigung, die je nach Klassifizierung ein gewisses Maß an Schutz für jede Unternehmensinformation zuweist, unter anderem mit Technologien wie Firewalls, Intrusion Prevention System (IPS / IDS), Zutrittskontrolle und Verschlüsselung (Quelle: Kobara, H. et al., 2016; Russmann, M. et al., 2015).

		Implementierungsebene							
	Wir sind an keiner Implementierung interessiert.	Wir sind an einer Implementierung interessiert, aber haben noch kein Umsetzungsprojekt.	Wir haben ein Umsetzungsprojekt angestoßen, das sich in der Entwicklungsphase befindet.	durch Pilotprojekte	Wir haben die Umsetzung flächendeckend im Unternehmen vorangebracht.	lch weiß es nicht. / Keine Angabe möglich.			
Cybersecurity									
Achtung: Mehrfachner	Achtung: Mehrfachnennungen nicht möglich								

Big Data Analytics

Software und Systeme generieren große Mengen von Daten (Big Data). Big Data Analytics bezieht sich auf die Analyse dieser großen Masse von Daten, um Beziehungen zwischen Daten zu finden, die bessere Einblicke in Prozess- und Produktverbesserungen und die Erforschung neuer Märkte liefern können (Quelle: Kang, H. et al., 2016; Russmann, M. et al., 2015).

			Implementierung	sebene		
	Wir sind an keiner Implementierung interessiert.		Wir haben ein Umsetzungsprojekt angestoßen, das sich in der Entwicklungsphase befindet.	Wir haben eine Implementierung durch Pilotprojekte (nicht flächendeckend).		lch weiß es nicht. / Keine Angabe möglich.
Big Data Analytics			\boxtimes			

Achtung: Mehrfachnennungen nicht möglich

Virtually Guided Self-Services / ERP

Diese Technologien unterstützen die Ausführung von Diensten, die darauf abzielen, die gängigsten Bereiche einer Organisation zu verbessern, wie z. B. die Leistung und Konfiguration von Informationssystemen, Big Data-Management, Change Management sowie Optimierung und Optimierung. Sicherheits- und Geschäftsprozesse. Beispiele: Oracle- und SAP-Systeme, die Assistenten für einige Aufgaben einbetten, z. B. einen Einkaufsprozess und seine Formulare (Quelle: Costa, C. et al., 2016; Klaus, H. et al., 2000; Shkurskii, S. et al., 2011).

		Implementierungsebene					
	Wir sind an keiner Implementierung interessiert.	Wir sind an einer Implementierung interessiert, aber haben noch kein Umsetzungsprojekt.	Wir haben ein Umsetzungsprojekt angestoßen, das sich in der Entwicklungsphase befindet.	Wir haben eine Implementierung durch Pilotprojekte (nicht flächendeckend).	Wir haben die Umsetzung flächendeckend im Unternehmen vorangebracht.	lch weiß es nicht. / Keine Angabe möglich.	
Virtually Guided Self- Services							
Achtung: Mehrfachnen	Achtung: Mehrfachnennungen nicht möglich						

3D Printing

Es wird auch als additive Fertigung bezeichnet und bezieht sich auf die Produktion dreidimensionaler Objekte direkt aus virtuellen Modellen. Dies ermöglicht schnelles Prototyping und stark dezentrale Produktionsprozesse: Das Produktmodell kann einfach an den "Druckstandort" des Kunden geliefert werden, wodurch Zwischenschritte in Fertigung, Transport und Lagerhaltung entfallen (Quelle: Bechtold, J. et al., 2014; Kang, H. et al, 2016).

		Implementierungsebene				
	Wir sind an keiner Implementierung interessiert.	Wir sind an einer Implementierung interessiert, aber haben noch kein Umsetzungsprojekt.	Wir haben ein Umsetzungsprojekt angestoßen, das sich in der Entwicklungsphase befindet.	Wir haben eine Implementierung durch Pilotprojekte (nicht flächendeckend).	Wir haben die Umsetzung flächendeckend im Unternehmen vorangebracht.	lch weiß es nicht. / Keine Angabe möglich.
3D Printing						
Achtung: Mehrfachner	nnungen nicht möglic	h	L			

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Leistungsziele

Im Folgenden finden Sie die Definitionen, die mit den einzelnen Leistungszielen in dieser Forschung verknüpft sind, sowie einige anschauliche Beispiele für Prozesssituationen, Produkte, Dienstleistungen, Produktionssysteme und andere Elemente, die sie erfüllen. Im Folgenden werden Sie gebeten, die Auswirkungen der Technologien von Industrie 4.0 hinsichtlich der Leistungsziele zu bewerten.

Zuverlässigkeit

Die Arbeit zeitnah durchführen, die Lieferverpflichtungen, die den Kunden versprochen wurden, einhalten. Beispiele:

- Betrieb, der ohne Unterbrechungen erfolgt.
- Weniger Eventualitäten, die sich auf den Vorgangauswirken.
- Mehr innere Stabilität.
- Lieferung / Ankunft von Produkten und Dienstleistungen pünktlich, ohne Variabilität.
- Kenntnis der Lieferzeiten.

Kosten

Die Arbeit kostengünstig durchführen. Beispiele::

- Höhere Gewinnmargen.
- Geringe Prozessbetriebskosten.
- Niedrige Rohstoffkosten.

Flexibilität

Anpassungen an ihre Arbeit oder die Art und Weise, wie die Arbeit ausgeführt wird. Die Möglichkeit, die Aktivitäten von Vorgängen zu ändern oder anzupassen, um unerwartete Umstände zu überwinden oder das einzigartige Verhalten der Kunden zu gewinnen oder neue Produkte oder Dienstleistungen einzuführen. Beispiele:

- Bessere Reaktion auf unvorhergesehene Ereignisse.
- Fähigkeit, sich schnell an neue Produkte und Dienstleistungen anzupassen.
- Breite Palette von Produkten und Dienstleistungen, die schnell in die Herstellung gebracht werdenkönnen.
- Fähigkeit, Produktionsvolumina anpassen zu können.

Qualität

Ordnungsgemäße Produkte, fehlerfreie Beschaffung von Waren und Dienstleistungen und in Übereinstimmung mit den zuvor festgelegten Zielen. Beispiele:

- Prozesse ohne Fehler.
- Vorgabeneinhaltungen von Produkten und Dienstleistungen.
- Produkte und Dienstleistungen, die die Erwartungen von Kunden erfüllen.

Geschwindigkeit

Schnelles Ausführen von Aufgaben, Minimierung der Zeit zwischen der Anforderung des Kunden nach Waren oder Dienstleistungen und der Lieferung. Beispiele:

- Schnelle Bearbeitungszeiten, die eine schnelle Lieferung an den Kunden ermöglichen.
- Niedrige Wartezeiten oder Lagerbestände.
- Kurze Lieferzeiten und Warteschlangen.
- Schnelle Antwort auf costumer-Anforderungen.

Fragen zum Verbesserungsniveau von Industrie 4.0

Geben Sie für jede der beschriebenen Technologien an, welchen Verbesserungsgrad sie für jedes der Leistungskriterien bereitgestellt hat.

	\$			
Zuverlässigkeit	Kosten	Flexibilität	Qualität	Geschwindigkeit
 Robustheit Sicherheit Pünktlichkeit 	 Gewinn Herstellungskosten Versandkosten 	 Anpassung Anpassungsfähigkeit Vielseitigkeit 	 Übereinstimmung Haltbarkeit Leistung 	 Produktivität Effizienz Vorlaufzeit

Internet Of Things (IoT) / Internet der Dinge

Wesentliches Element des Internets of Things (dt. Internet der Dinge) ist die digitale Vernetzung aller physischen, smarten Objekte. Durch das Internet of Things soll die Qualität der Interaktion von Menschen und Maschinen (inklusive der Kommunikation von Maschine zu Maschine) verbessert werden (Quelle: Schlatt, V. et al., S. 31).

			Verbesserungsgrad						
		nichts	Regelmäßige	gut	Sehr gut	Ausgezeichnet	lch benutze es nicht		
	Zuverlässigkeit								
ziele	Kosten								
Leistungsziele	Flexibilität	Ч							
Leist	Qualität								
	Geschwindigkeit								

Cloud

Cloud Computing beschreibt Infrastrukturanwendungen und -lösungen, die als öffentliche oder private Netzwerkdienste auf Pay-per-Use-Basis bereitgestellt werden und jederzeit und überall zugänglich sind (Quelle: Bechtold, J. et al., 2014; Yue, X. et al., 2015).

			Verbesserungsgrad						
		nichts	Regelmäßige	gut	Sehr gut	Ausgezeichnet	lch benutze es nicht		
	Zuverlässigkeit								
ziele	Kosten								
Leistungsziele	Flexibilität								
Leist	Qualität								
	Geschwindigkeit								

Zuverlässigkeit	Kosten	Flexibilität	Qualität	Geschwindigkeit	
 Robustheit Sicherheit Pünktlichkeit 	 Gewinn Herstellungskosten Versandkosten 	 Anpassung Anpassungsfähigkeit Vielseitigkeit 	 Übereinstimmung Haltbarkeit Leistung 	 Produktivität Effizienz Vorlaufzeit 	

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Es ist der Aufbau von Technologien, Prozessen und Praktiken, die zum Schutz von Netzwerken, Computern, Programmen und Daten vor Angriffen, Beschädigungen oder unbefugtem Zugriff entwickelt wurden. In einem rechnerischen Kontext umfasst Sicherheit sowohl Cybersicherheit als auch physische Sicherheit. Zum Beispiel die Tiefenverteidigung, die je nach Klassifizierung ein gewisses Maß an Schutz für jede Unternehmensinformation zuweist, unter anderem mit Technologien wie Firewalls, Intrusion Prevention System (IPS / IDS), Zutrittskontrolle und Verschlüsselung (Quelle: Kobara, H. et al., 2016; Russmann, M. et al., 2015).

		Verbesserungsgrad					
		nichts	Regelmäßige	gut	Sehr gut	Ausgezeichnet	lch benutze es nicht
	Zuverlässigkeit		П				
riele	Kosten		D				
Leistungsziele	Flexibilität			٥			
Leist	Qualität						
	Geschwindigkeit						

Big Data Analytics

Software und Systeme generieren große Mengen von Daten (Big Data). Big Data Analytics bezieht sich auf die Analyse dieser großen Masse von Daten, um Beziehungen zwischen Daten zu finden, die bessere Einblicke in Prozess- und Produktverbesserungen und die Erforschung neuer Märkte liefern können (Quelle: Kang, H. et al., 2016; Russmann, M. et al., 2015).

		Verbesserungsgrad					
_		nichts	Regelmäßige	gut	Sehr gut	Ausgezeichnet	Ich benutze es nicht
	Zuverlässigkeit						
riele	Kosten						
Leistungsziele	Flexibilität						
	Qualität						
	Geschwindigkeit						

Zuverlässigkeit	Kosten	Flexibilität	Qualität	Geschwindigkeit	
 Robustheit Sicherheit Pünktlichkeit 	 Gewinn Herstellungskosten Versandkosten 	 Anpassung Anpassungsfähigkeit Vielseitigkeit 	 Übereinstimmung Haltbarkeit Leistung 	 Produktivität Effizienz Vorlaufzeit 	

Virtually Guided Self-Services / ERP

Diese Technologien unterstützen die Ausführung von Diensten, die darauf abzielen, die gängigsten Bereiche einer Organisation zu verbessern, wie z. B. die Leistung und Konfiguration von Informationssystemen, Big Data-Management, Change Management sowie Optimierung und Optimierung. Sicherheits- und Geschäftsprozesse. Beispiele: Oracle- und SAP-Systeme, die Assistenten für einige Aufgaben einbetten, z. B. einen Einkaufsprozess und seine Formulare (Quelle: Costa, C. et al., 2016; Klaus, H. et al., 2000; Shkurskii, S. et al., 2011).

		Verbesserungsgrad					
		nichts	Regelmäßige	gut	Sehr gut	Ausgezeichnet	lch benutze es nicht
	Zuverlässigkeit						
ziele	Kosten						
Leistungsziele	Flexibilität						
Leist	Qualität						
	Geschwindigkeit						

3D Printing

Es wird auch als additive Fertigung bezeichnet und bezieht sich auf die Produktion dreidimensionaler Objekte direkt aus virtuellen Modellen. Dies ermöglicht schnelles Prototyping und stark dezentrale Produktionsprozesse: Das Produktmodell kann einfach an den "Druckstandort" des Kunden geliefert werden, wodurch Zwischenschritte in Fertigung, Transport und Lagerhaltung entfallen (Quelle: Bechtold, J. et al., 2014; Kang, H. et al, 2016).

		Verbesserungsgrad					
		nichts	Regelmäßige	gut	Sehr gut	Ausgezeichnet	lch benutze es nicht
	Zuverlässigkeit						
riele	Kosten						
Leistungsziele	Flexibilität						
Leist	Qualität						
	Geschwindigkeit						

Feedback (optional)

Haben Sie Kommentare oder Tipps, um unseren Fragebogen zu verbessern?

Verwenden Sie das Feld unten, um uns Ihre Vorschläge zu senden. Vielen Dank!

Vielen Dank für Ihren Beitrag!



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