The Impact of Digitalization on the Define Phase of the Six Sigma Methodology

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Abstract

The progressing digitalization not only has an impact on the technical infrastructure of companies but also on the implementation of improvement projects. Six Sigma is a well-tried and widely spread method for structured conduction of improvement projects. The structured approach is due to the division into the phases Define, Measure, Analyze, Improve and Control. It is assumed that digitalization will have differently pronounced impacts on these phases. For this, the purpose of this paper is to determine possible changes that may affect the Define phase of the Six Sigma methodology as a result of digitalization. For the realization of the research objective, expert interviews as a method of qualitative investigation have been selected. Therefore, interviews with seven experts in the field of Six Sigma with different training and experience levels were conducted. Results indicate, that according to the experts' assessment, the Define phase is only affected by minor changes caused by digitalization. They emphasize that the Define phase is characterized by human-supported working methods. Digitalization offers the chance of a more precise problem and target descriptions due to better data availability.

Keywords
Six Sigma, Digitalization, Process Optimization

1. Introduction

The importance of digitalization in the business environment is growing steadily. Due to the increasing progress of digitalization, nearly every industry sector is affected by its effects (Lipsmeier et al., 2020). Digitalization will have a large influence on future business strategies. One of the affected areas is the implementation of optimization projects. Digital networking of workplaces and automated collection and evaluation of data also create new possibilities for optimization projects (Da Silva et al., 2020). A proven optimization approach is Six Sigma, which consists of a total of five phases and is used as a globally recognized method for improving processes and reducing errors (Melzer, 2019).

GoThe results show that 72 % of the participating German companies are concerned with the topic of digitalization. The survey reveals Big Data and Data Mining as the most influential digitalization trends on optimization projects in companies. Due to this digitalization trends, the participants consider a change in the Six Sigma methodology concerning digitalization. First results of the survey confirm the assumption that in the course of digitalization the optimization method Six Sigma will change its components and implementation. Every process improvement project that applies Six Sigma is following the five phases of the DMAIC methodology. These phases are Define, Measure, Analyze, Improve and Control. It is a fixed framework of how to run the project and every phase provides the needed tools to achieve the project goal (Melzer, 2019). The steps of the DMAIC cycle ensure that within the Define and Measure phases, there is transparency about the process and the needed data, the root cause of the problem is identified in the Analyze phase, the right actions are taken in the Improve phase and Control phase results in sustainable improvement of the process (George et al., 2016). As shown, Six Sigma is a comprehensive methodology, which is why this investigation is limited to the first phase of the DMAIC cycle, the Define phase. The influence of digitalization on the Define phase of the Six Sigma methodology has not yet been investigated in detail. Regarding the quantitative survey from 2018, the participants consider the influence of digitalization in the Define phase to be rather low. This investigation aims at focusing the research gap more in detail by analyzing the impacts of digitalization and answering the following research question:

"Which changes in the Define phase of the Six Sigma methodology are conceivable in the course of digitalization?"

To answer this research question, interviews with seven experts in the field of Six Sigma from industry and research were conducted. To obtain meaningful statements, experts with different training levels and practical experiences were selected for investigation. An extensive literature research in the field of digitalization and Six Sigma was used to develop a semi-structured guideline for the conduction of the interviews. This allows a standardized execution of the expert interviews and offers a consistent data basis to conclude the influence of digitalization on the Define phase.

2. Theoretical Foundation

The following section comprises a brief overview of the theoretical concepts underlying (1) digitalization, (2) Six Sigma and (3) the link between digitalization and Six Sigma.

2.1. Digitalization

Progressive digitalization is changing the entire economy and creating unprecedented opportunities. Enormous technological change is creating new markets and changing industry structures (Lipsmeier et al., 2020). Digitalization refers to the time- and location-independent data acquisition and processing in real-time as well as systematic data analysis as decision-making aid (Obermaier, 2019). Digitalization is becoming increasingly important, especially for industry. With the help of information and communication technologies, digitalization enables a transformation of existing business models to ensure cross-border networking, reduce interfaces and increase the effectiveness and efficiency of processes (Dombrowski et al., 2017). The most widespread information and communication technologies are for example Internet of Things (IoT), Big Data, Cloud Computing, Data Mining, Artificial Intelligence (AI) and Machine Learning (ML) (iwd, 2019).

Big Data describes a large amount of information in the form of data that can be systematically evaluated and insights for the design of processes and products can be gained (Bruckner et al., 2018). Crucial for a systematic analysis of data is the availability of information in real-time (Klees/Moehlmann, 2018). With newly acquired information, production can be optimized and made more flexible (Bendel, 2019). As the degree of digitalization increases, the amount of data collected also increases continuously. In terms of scope, manual processing of data is not possible for human beings. For this purpose, procedures such as AI or algorithms are used to recognize logical patterns (Wrona/Reinecke, 2019).

Cloud Computing is a digital infrastructure that provides the necessary data and services. It includes all possibilities for monitoring, maintenance, and control of digital connections. Users can access the provided resources and programs, although they are not installed on their computer (Bruckner et al., 2018). All IT services are only provided by one provider and distributed over an existing network structure (Hentschel/Leyh, 2018). Cloud technologies standardize communication and create greater transparency for all participants since all necessary information is available at one exact location (Bousonville, 2017). Due to the central collection of data, a more efficient analysis and error detection can be realized (Fallenbeck/Eckert, 2014).

Data Mining is the application of systematic and statistical methods to examine existing data for trends, patterns, and connections. Registered data patterns can be used to identify possible actions for existing problems and to simplify decision-making. Classification of data objects, segmentation of these according to common characteristics, and preparation of forecasts based on acquired knowledge are among the characteristic functions of data mining. Big data and data mining are closely connected. While Big Data provides the necessary platform for processing large amounts of data, Data Mining controls the actual analytical process of generating knowledge from data (Luber/Litzel, 2016).
AI deals with the human way of thinking, deciding and solving problems to reproduce these using computer-aided procedures (Bendel, 2019). AI systems can evaluate existing data and uncover patterns.

ML represents the opposite and can learn new ways of acting through discovered knowledge (Goepfert, 2019). Machines can independently improve and develop their activities based on experience gained from existing data (Klumpp et al., 2019).

2.2. Six Sigma

Six Sigma is regarded as a project-oriented, data-driven improvement approach, which enables process improvements using a structured and phase-oriented procedure (Bertagnolli, 2020; Melzer, 2019). This approach is based on the principle of a zero-defect quality and reduction of deviations from the mean value to offer a better quality of products and services (Dahm/Haindl, 2015; Sreeram/Thondiyath, 2015; George, 2002). To achieve increases in quality, the Six Sigma methodology is firstly used to identify fluctuations in processes (Campos, 2013).

The term "Six Sigma" has its origin in statistics and refers to the standard deviation of the Gaussian normal distribution (Bergbauer et al., 2008). The standard deviation symbolizes the variation of the mean value of a process (Koch, 2015). Any deviation from customer requirements has to be interpreted as an error (Toutenberg/Knoefel, 2009). Data is collected to measure the deviations and to determine them with the help of statistical tools. The subsequent process improvement is based on collected data and knowledge gained from statistical methods. This data-supported analysis represents the decisive difference to further optimization methods (Dahm/Haindl, 2015).

As already mentioned, Six Sigma projects follow a defined procedure, the DMAIC cycle. The abbreviation stands for the phases Define, Measure, Analyze, Improve and Control (Dahm/Haindl, 2015). Within these phases, defined tools are applied (Koch, 2015).

The *Define phase* can be considered the most critical phase within the DMAIC cycle. In addition to the regulation of organizational requirements, e.g. the composition of a project team, a clearly defined target formulation, in-scope and out-of-scope analysis have to be carried out to clearly define the scope of the project (McCarty et al., 2005; Gupta, 2005; George et al., 2004). Based on a project charter, a common understanding of the desired optimization is established (Koch, 2015). A further instrument of the Define phase is the SIPOC (Supplier-Input-Process-Output-Customer) analysis, which provides an overview of the process under consideration (Melzer, 2019). In addition to the input and output factors as well as the decisive value creation steps, SIPOC also graphically displays the suppliers and customers involved within the process (Koch, 2015). To increase customer satisfaction, their requirements must be determined. With the help of a CTQ tree (Critical-to-Quality), the customer needs are made measurable (Hofman, 2019).

The main objective of the *Measure phase* is to capture the status quo of a process (McCarty et al., 2005). For this purpose, the critical quality factors, which were transferred into measurable units using the CTQ tree, are measured (Koch, 2015). By collecting data to determine the current process performance, fact-based findings can be made (Gorecki, 2018). In this phase, the data are graphically presented in various diagrams to illustrate variations of critical quality characteristics within a process. With the help of a process capability analysis, it is clarified whether the dispersion in the process is within given specification limits (Melzer, 2019).

Within the *Analyze phase,* the collected data are analyzed for the cause of process problems by using statistical tools (Koch, 2015). A cause-effect diagram is suitable for determining the causes of deviations. All potential causes that influence the focused problem are included. This procedure ensures that no potential risks are left (Drews et al., 2020). The *Improve phase aims at* developing process improvements that reduce variations. Creativity techniques are used to develop solutions. The most popular creativity technique is brainstorming, where the ideas of the project team have no limits (Dahm/Haindl, 2015). In principle, a solution with the greatest possible influence on customer satisfaction and thus the competitiveness of the company should be chosen (Koch, 2015).

The challenge of the *Control phase* is to ensure the sustainability of implemented solutions (Gupta, 2005). A decisive factor is a revolution in the way of thinking of the employees. Employees must be trained to perform their tasks in a new way. A pre-documentation of the new or revised process may be helpful (George et al., 2016). Besides the desired effect of the implemented improvements is checked (Giebel/Jochem, 2015). The control phase is characterized by sustained monitoring of objectives.

2.3. Link between Digitalization and Six Sigma

Companies are confronted with the increasing complexity of their environment, which requires continuous improvement of their processes to remain competitive on the market (Nadarajah/Kadir, 2014; Gibbons/Burgess, 2010;

Allweyer, 2005). Adapting to the changed conditions should not be seen as a unique task, but much more as a continuous process (Schmelzer/Sesselmann, 2008). To meet these challenges, process optimization has become an established task in companies (Boeckmann, 2013). As mentioned above, Six Sigma is a proven method for process optimization (Koch, 2015). But also process optimization is increasingly affected by progressing digitalization (bitkom, 2015).

This led to the assumption that digitalization will influence the Six Sigma optimization method in the future. In particular, the framework of the methodology needs to be reconsidered. In the course of the digitalization process, it may be possible to skip individual phases due to automatic data acquisition. This would lead to a complete change of the proven DMAIC cycle. Furthermore, an automated evaluation of analyses by business intelligence systems is conceivable. Based on these assumptions and on less existing research, the following investigation was carried out to obtain findings.

3. Research Methodology

To answer the research question given in section 1, qualitative expert interviews based on a semi-structured guideline were conducted. This methodology and its application are briefly presented in the following.

3.1. Qualitative interviews

An expert interview is a qualitative form of data collection and one of the most frequently used methods in empirical research (Meuser/Nagel, 2009; Kaiser, 2014). It represents a systematic and theory-based method of data collection by conducting oral interviews with human beings, which allows exclusive knowledge about processes, strategies, and instruments (Kaiser, 2014). Expert interviews thus have the purpose of gathering information on specific circumstances (Glaeser/Laudel, 2010). Within expert interviews, a targeted selection of persons who are eligible for the survey is made (Helfferich, 2019). For this, experts are defined as persons who exhibit extensive knowledge of specific subjects (Pfadenhauer, 2009).

In their application, expert interviews are often conducted in a semi-structured form. This means that the interviewer is flexible in the sequence of questions to ensure a natural course of conversation (Haeder, 2019). For the execution of the interviews, a guideline is created, which creates the course of the conservation. The questions contained in the guideline are designed in an open form (Mayer, 2008; Helfferich, 2019). This means that the topics to be dealt with are given by the guideline, but due to the flexible execution of the interview, some questions may be answered in more detail than others (Misoch, 2014).

Within this investigation, the interview process suggested by Kaiser (2014) was adopted. Following him, the conduction of an expert interview can be divided into the phases “planning”, “execution” and “analysis”. In the planning phase, the experts for the interview are identified and the guideline is created. The execution phase is characterized by the conduction of the interviews. The analysis phase deals with the evaluation of data and contains a discussion part. The planning and execution phases are described in the following subsections. Section 4 presents the results of the analyze phase.

3.2. Interview Planning

As no empirical research examines the impact of digitalization on the Define phase of the Six Sigma methodology, new questions for a guideline has to be constructed. To create suitable questions for the guideline, the experts should be defined in advance (Helfferich, 2019). Therefore, we defined trained Six Sigma experts with years of practical experience as our target group.

The development of the guideline is based on an extensive, international literature review regarding the topics of digitalization and Six Sigma. On this basis, four higher-level interview topics emerged: (1) Demographic Data, (2) Digitalization, (3) Digitalization & Six Sigma, and (4) Digitalization & Define Phase. In the following step, subtopics were assigned to these. A general overview of the allocation of topics is given in table 1.

Table 1. Structure of the semi-structured guideline

Topics	Subtopics
Demographic Data	• Training level • Practical experience
Digitalization	• Practical importance • Digitalization trends
Digitalization & Six Sigma	• Influence on the Six Sigma methodology • Positive & negative impact of digitalization on the Six Sigma methodology
Digitalization & Define Phase	• Relevance of digitalization on the Define phase • Influence on tools • Automation potential of the tools

In this investigation, the first topic "Demographic Data" refers to the interviewee's level of training and practical experience. This question is used to determine which belts the experts own. This topic also aims at determining the practical experience of the experts. This includes the number of optimization projects carried out by using the Six Sigma methodology. The second topic deals with digitalization. The experts will first assess the relevance of digitalization in the corporate environment. Furthermore, expert interviews will be used to determine which are the most influential digitalization trends. The third topic "Digitalization & Six Sigma" focuses on the link between digitalization and Six Sigma. In particular, the positive and negative impacts of digitalization on the Six Sigma methodology are discussed. The last topic of the guideline "Digitalization & Define Phase" deals specifically with the influence of digitalization on the Define phase of the Six Sigma methodology. Here, the influence of digitalization on the individual tools of the Define phase and their potential for automation will be determined. The experts should also assess whether the Define phase is still necessary for the course of digitalization.

To ensure that the guideline is not too complex, a pre-test should be carried out before the interviews are conducted (Kaiser, 2014). Thus, the developed guideline was first tested among two researchers from the field of Six Sigma. As no changes in the wording or the sequence of the questions were necessary, the final guideline for the expert interviews was available.

3.3. Interview execution

A total of seven experts from the field of Six Sigma were interviewed. The experts have different levels of knowledge. Referring to the training levels of Six Sigma, one Green Belt, two Black Belts, and four Master Black Belts were selected as interview partners. Regarding their practical experience, two experts have been working with Six Sigma for 3 to 5 years, one expert for 5 to 10 years and five experts for more than 10 years. These selection criteria ensure that the experts have expertise in Six Sigma. The interviews were conducted within two weeks. The guideline was sent to the interviewed experts in advance. This proved to be useful as the interview partners were prepared for the interview. More thoughtful and meaningful contributions could be obtained. The interviews were conducted using telephone conservation and were recorded on a recording device. A verbal declaration of consent was obtained from the participants. The transcription of the interviews took place afterward.

4. Results

To analyze the answers, the interviews were documented in a summarized form. In this way, the analysis was directed towards the leading research question to identify the changes in the Define phase of the Six Sigma methodology in the course of digitalization.

4.1. Demographic Data

This topic deals with the experience of the selected experts, which is visualized within table 2.

Table 2. Experts of the interviews

Experts	Training level	Project Experience
Expert 1	Green Belt	5 projects
Expert 2	Black Belt	10 projects
Expert 3	Black Belt	20 projects
Expert 4	Master Black Belt	20 projects
Expert 5	Master Black Belt	25-30 projects
Expert 6	Master Black Belt	>100 projects
Expert 7	Black Belt	>100 projects

The selection of experts ensures that all have sufficient knowledge in the field of Six Sigma. Table 2 shows that most of the experts have already completed a Master Black Belt training. Black Belts are represented by two people who have worked on an average of 15 Six Sigma projects. In comparison, the Green Belt has only two years of Six Sigma experience.

4.2. Digitalization

Regarding the answers to the second topic, six out of seven experts state that they certainly deal with digitalization in their operating business. Exclusively one expert emphasizes that there is hardly any discussion about digitalization in its company. One of these six agreeing experts states that its company has so far implemented little in the area of digitalization, but due to the high potential of digitalization plans for implementation are currently being discussed. This agrees with the statement of two experts who are the opinion that there is much discussion about digitalization, but that very few companies have taken concrete measures to implement. For all of the experts, AI and Big Data are the digitalization trends with the greatest potential in the industry. Accordingly, it is quite conceivable that these tools will be increasingly used in the future for process optimization and increasing productivity.

4.3. Digitalization & Six Sigma

Concerning the subsequent focus on the potential impact on Six Sigma, the first step is to examine whether there is a connection between digitalization and Six Sigma. The expert interviews confirm that there is a causality between the fields of digitalization and Six Sigma. According to the opinions of the interviewed experts, a change within Six Sigma will take place. The possibility of digitalization concerning the collecting, securing and administration of large amounts of data is a central factor for process optimization. The experts emphasize that the greatest change is to be expected in the area of data availability. While currently many measurement systems still have to be set up with a great manual effort to generate corresponding data, it is conceivable that in the coming years' data will increasingly be provided automatically. This is partly connected with the enormous increase in technological performance in recent years. The majority of experts believe that it is more an evolution than a revolution of the Six Sigma methodology. According to this, the actual method in its approach is affected by the change only to a small extent. It is still a universal framework structure, even for projects in the digital age. Although digitalization will lead to an enormous increase in efficiency and benefits in terms of faster data availability, the urgent consideration of the problem within the framework will also remain in the age of digitalization. Accordingly, individual tools have to be changed or developed further due to a large amount of data. Furthermore, the majority of the experts mention that there is a strong need for an expansion of statistical tools to be able to process large amounts of data. All of the interviewees agree that Six Sigma and digitalization will complement each other. This means even in the existence of digitalization trends, such as Big Data or AI, a structured and proven approach according to the Six Sigma methodology is still necessary.

Besides the experts deal with benefits concerning digitalization within the Six Sigma methodology. According to the opinions of the experts, Six Sigma has promising opportunities in better and faster data availability. Especially with the help of digitalization, less manual effort is required to collect necessary data for improvement projects, which is a great benefit for the entire improvement process and facilitates it immensely as it relieves the participants of a large amount of work. As a result, more time can be gained in problem-solving. Digitalization contributes to a considerable extent to the increase in efficiency. Another point is the possibility of more precise measurement, which is reflected in better data quality.

However, experts also stress that digitalization will lead to new challenges. For example, the complexity of data is constantly increasing. Traditional tools (e.g. Excel) are not designed to process large amounts of data. For this reason, new types of tools are needed to process the increasing flood of data. There is a risk that databases will be burdened with vast amounts of unusable data. Furthermore, the credibility of the data is compromised. The experts speculate that digitalization could lead to completely credulity. Thus, digitalization can lead to a new way of thinking, which would make people believe that digital data is crucial to any problem. This assumption is not entirely correct and may even be misleading. As a result, digital data must continue to be questioned in the future and, in the event of negative conspicuous features, checked for correctness since false conclusions cannot be ruled out despite digital processes.

4.4. Digitalization & Define Phase

The last section of the interview deals in detail with the Define phase of the Six Sigma methodology. The most popular tools of the Define Phase are examined in detail concerning the influence of digitalization. In general, the majority of the experts are the opinion that the influence of digitalization on the Define phase is very small. Only two of the experts estimate a medium influence. Overall, the experts agree that the Define Phase is much less affected compared to subsequent phases of the DMAIC cycle. The experts are the opinion that the Define phase will retain its current form in the future and the content components will continue to be necessary for the age of digitalization. The Define phase focuses on the analytical and creative engagement with the problem which is indispensable in its basic activity. According to the experts, digital technologies such as ML or AI are less helpful in this phase of the DMAIC cycle. Furthermore, the experts affirm that problems are caused by humans and humans are primarily responsible for questioning the cause and remedying the problem. However, digitalization can provide support for problem identification. In this respect, digitalization can help by providing higher quality data is usually associated. The experts stress that the accuracy of the Define phase is already sufficient in its current form. The corresponding data availability can certainly also be useful in the Define phase, but this is primarily decisive for the Measure and Analyze phase. Within the Define phase, the function of human beings will remain meaningful and irreplaceable. Since in the end, it is the individual project member who deals with the problem in the necessary depth. The formulation of objectives and problem descriptions are based on natural judgment and experience. Although digitalization can help to confirm existing assumptions or generate new indications, it cannot replace the expertise of specialists. Nevertheless, following the fact of better data availability, a comparatively more detailed actual state of the process at the beginning of an improvement process can be expected in the future. But it remains the task of the process members to take a look at the presented current situation, to recognize conspicuities and to initiate subsequent steps. The greatest potential for Six Sigma projects through digital conversion lies in improved availability of data. However, since these data are comparatively little needed in the Define phase, the impact of digitalization can ultimately be classified in the lower range. One of the experts emphasizes that the digital change has created the risk that data-based phases (e.g. Measure phase and Analyze phase) will gain the upper hand and the Define phase will be missed. This would not be desirable since the Define phase is crucial for the success of a project and must take the necessary time to define problems. Carelessly rushing to data and neglecting the Define phase can lead to hasty conclusions and identification of wrong problems and thus may have negative consequences on the entire project.

Furthermore, the experts were asked to give their assessment of the influence of digitalization on the tools of the Define phase. These tools are project charter, stakeholder management, SIPOC analysis, VOC (Voice of the customer) and CTQ tree. The results are shown in Figure 1.

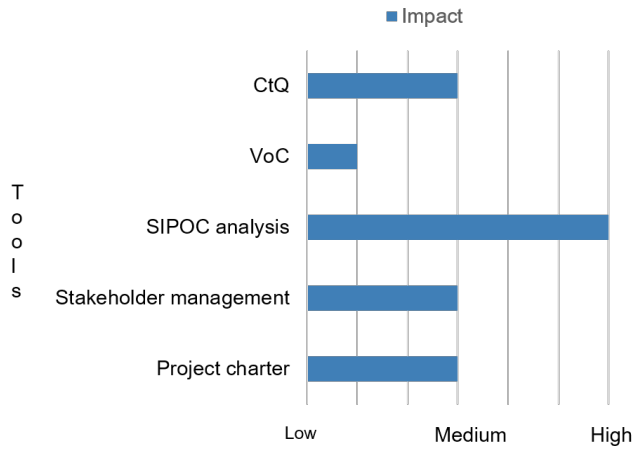

Figure 1. Impact of digitalization

Concerning the *project charter*, a clear opinion of the interviewed persons is available. Three out of seven experts state that they would rate the influence of the digitalization on the project charter as rather low. The remaining four experts are the opinion that digitalization will have a small or medium impact on the project charter. The experts consider the project charter as an important part of the Define phase, which will retain its value in the future. The human factor is a decisive influencing factor for a project charter. Project members gather information for the start of a project, deal with the problem and formulate the objectives. This tool is regarded as the core of the Define phase and an important document which contains all agreements and basic conditions between the parties involved. The development of the project charter is based, both according to the current status and future forecasts of the experts, on a human-driven approach. For this reason, the automation of the project charter within the Define phase is excluded by the experts. Only an improvement of the problem description and target formulation is conceivable based on better data availability due to the digital transformation. Several experts believe that digitalization could have a positive impact as project trigger. The digitally supported identification of weak points within a process could point out problem areas at an early stage, which could lead to an improvement project. Thus, digitalization can certainly lead to the necessity of improvement being emphasized and confirmed by supported facts and figures, thus promoting the entry into the Define phase.

Concerning the *stakeholder management*, it can be summarized that there is a little influence of digitalization on this tool of the Define phase. According to the results of the interviews, only an insignificant causal connection between digitalization and stakeholder management can be determined. Six of the seven experts asses the influence of digitalization on stakeholder management as low or rather low. The stakeholders are likely to continue to be among the most important success factors of improvement projects, who, according to an analysis as opponents or advocates of the project, are to be satisfied with appropriate measures. The experts emphasize that communication with stakeholders will continue to be an elementary part of efficient project work. Due to the existence of qualitative data, it can be assumed that factual and data-based discussions will increasingly be possible, which makes it easier to substantiate or explain the necessity of a project. Thus, digitalization can help to verify the assumptions made by the project with data and to convince the project's opponents. The increasing complexity of processes leads to the assumption of the experts that the amount of available data and the size of the project members will tend to increase. For stakeholder management, this would mean that an increased number of stakeholders would have to be proactively managed.

When estimating the influence of digitalization on the *SIPOC analysis*, the experts' assessments differ. Thus, five experts tend to a rather low influence and two experts to a medium influence of digitalization. Summarized, the influence level is on average rather low. This is since processes in the context of digitalization will be represented more graphically. Useful information such as automated input and output structured for individual process steps could be extracted from digital tools, which would simplify and accelerate the creation of a SIPOC. But some of the experts believe that partial automation of the SIPOC analysis is not conceivable within the next few years. Furthermore, the majority of the experts question whether this makes sense for the actual methodology. Finally, SIPOC is about a rough visualization of the current process, based on observations made by project members. The actual purpose of the SIPOC

analysis could be neglected. Because the SIPOC analysis serves as a communication medium for the entire project team to illuminate process steps that require explanation and to create a common understanding. Should digitalization influence the SIPOC analysis in future, it is important to ensure the actual value and purpose of the methodology are preserved.

Regarding *VOC*, there are different assessments of the experts. For two of the experts, it is conceivable that new technologies will make relevant information on customer requirements available in databases. For example, potential conclusions about costumer requirements could be drawn from stored usage behavior. However, two of the experts believe that VOC will continue to be human-made, as direct personal communication is necessary to determine actual customer requirements.

The same insight and argumentation also apply to the *CTQ tree* as the method also deals with customer requirements. According to expert opinions, digitalization can potentially be useful if the creation of the CTQ tree can be made easier and more valid based on better data. On average, the potential of digitalization in VOC is rated as rather low.
Furthermore, the experts were asked to what extent an automation of the Define phase is feasible. All experts consider an automation of the Define phase to be impossible. It can be assumed that the Define phase will retain its form and necessity in future. There may only be potential to automate some of these areas. For example, an automated warning system could be implemented that determine defined Key Performance Indicators (KPIs) and point out problems. This would allow reliable predictions of process quality and data-based assessments of the urgency of improvement projects based on early indicators. But the addition of digitalization has technical and supporting character and does not replace the methods. The still human-driven methods such as the project charter or stakeholder management will in future rely on automatically-collected data in the reactive approach of Six Sigma but as a supporting aid. Only the combination of humans and machines can Six Sigma develop its full potential. Six Sigma is a problem-solving technique that, despite automated support, ultimately still primarily requires human communication. Full automation would mean that interactive and interdisciplinary collaboration in improvement projects would be increasingly lost. This is neither desirable nor purposeful, which is why the Define phase is neither redundant nor dispensable in its form. Decisions in the Define phase often have to be made on the basis of complex circumstances that cannot be substituted by any automated procedure in future. These decisions are based on the joint development of results in a team as well as the human ability to think.

5. Conclusion and Limitations

The objective of this paper is to underestimate possible changes in the Define phase caused by the ongoing digitalization. In particular, the research objective is to examine the potential of the tools and existence of the Define phase within future. For this purpose, qualitative interviews with seven experts in the field of Six Sigma were conducted. The results are based on experience and subjective assessments of the selected experts.

According to the experts' assessment, a change in the Six Sigma methodology will occur as a result of progressive digitalization. The most significant change is expected in the area of data availability. The entire value chain is being networked. This makes data from individual process steps available, which allows a better description of the problem situation.

The experts agree that the original form of the Define phase will change little in the course of digitalization. The influence of digitalization and automation is rated as low. This is due to the fact that the Define phase is strongly influenced by human labor. Tools contained in the Define phase are human-driven, which is why high data availability plays a subordinate role. Much more, the Define phase is based on an interactive exchange of specialists, a coherent way of thinking and the ability to make rational decisions. Nevertheless, the Define phase can be improved by digitalization in terms of a better data basis and thus a more precise description of the current situation and design of the project charter. The results of the expert interviews show that the Define phase can be supported by higher data availability in future, but the Define phase will remain a well-tried planning phase within the Six Sigma methodology. Regarding the generalizability of the findings, it needs to be stressed out that only a limited sample in terms of respective experts was interviewed. Qualitative research was employed to explore possible changes in the Define phase. By pre-structuring the interviews with topics derived from previous research, certain aspects may not have been examined in depth (e.g., further tools of the Define phase). Hence, generalizability and completeness of the results are limited.

In further research, the phases Measure, Analyze, Improve and Control are to be examined regarding the influence of digitalization on Six Sigma. According to the experts, the greatest benefits of digitalization are in the phases Measure, Analyze and Control. Furthermore, first practical attempts to digitize tools of the DMAIC cycle can be made in practice.

References

Allweyer, T., *Geschaeftsprozessmanagement. Strategie, Entwurf, Implementierung, Controlling*, 5th edition, W3L-Verlag, Bochum, 2005.

Bendel, O., *350 Keywords Digitalisierung,* Springer Gabler, Wiesbaden, 2019.

Bergbauer, A. K., Kleemann, B., Raake, D., *Six Sigma in der Praxis. Das Programm fuer nachhaltige Prozessverbesserungen und Ertragssteigerungen*, 3rd edition, Expert Verlag, Renningen, 2008.

Bertagnolli, F., *Lean Management – Einführung und Vertiefung in die japanische Management-Philosophie*, 2nd edition, Springer Gabler, Wiesbaden, 2020.

Bitkom, Big Data und Geschaeftsmodell-Innovationen in der Praxis, Available: https://www.bitkom.org/sites/default/files/file/import/151229-Big-Data-und-GM-Innovationen.pdf, 2015.

Boeckmann, K. P., *Prozessoptimierung der Auftragsabwicklung in einem mittelstaendischen Unternehmen*, GRIN Verlag, 2013.

Bousonville, T., *Logistik 4.0: Die digitale Transformation der Wertschoepfungskette,* Springer Gabler, Wiesbaden, 2017.

Bruckner, L., Werther, S., Haemmerle, M., Pokorni, B., Berthold, M., Einleitung. In Werther,S., Bruckner, L., *Arbeit 4.0 aktiv gestalten: Die Zukunft der Arbeit zwischen Agilitaet, People Analytics und Digitalisierung*, Springer Verlag, Berlin, 2018.

Campos, L., Lean manufacturing and Six Sigma based on Brazilian model "PNQ", In *International Journal of Lean Six Sigma*, 4. vol., no.4, pp. 355–369, 2013.

Dahm, M., Haindl, C., *Lean Management und Six Sigma. Qualitaet und Wirtschaftlichkeit in der Wettbewerbsstrategie*, 3rd edition, Erich Schmidt Verlag, Berlin, 2015.

Da Silva, E. R., Shinohara, A. C., Nielsen, C. P., de Lima, E. P., Angelis, J., Operating Digital Manufacturing in Industry 4.0: the role of advanced manufacturing technologies, *53rd CIRP Conference on Manufacturing Systems*, vol. 93, pp. 174–179, 2020.

Dombrowski, U., Richter, T., Krenkel, P., Interdependencies of Industrie 4.0 & Lean Production Systems – a use case analysis, *27th International Conference on Flexible Automation and Intelligent Manufacturing*, vol. 11, pp. 1061–1068, 2017.

Drews, G., Hillebrand, N., Kärner, M., Peipe, S., Rohrschneider, U., *Praxishandbuch Projektmanagement*, 3rd edition, Haufe, Freiburg, 2020.

Fallenbeck, N., Eckert, C., IT-Sicherheit und Cloud Computing, In Bauernhansl, T., Michael, T.H., Vogel-Heuser, B., *Industrie 4.0 in Produktion, Automatisierung und Logistik: Anwendung · Technologien · Migration*, Springer Vieweg, Wiesbaden, 2014.

George, M. L., *Lean Six Sigma, Combining Six Sigma quality with lean speed*, McGraw-Hill Verlag, New York, 2002.

George, M. L., Rowlands, D., Kastle, B., *What is Lean Six Sigma?*, McGraw-Hill Verlag, New York, 2004.

George, M. L., Rowlands, D., Price, M., Maxey, J., *Das Lean Six Sigma Toolbook – Mehr als Werkzeuge zur Verbesserung der Prozessgeschwindigkeit und -qualität*, Verlag Franz Vahlen, München, 2016.

Gibbons, P. M., Burgess, S. C., Introducing OEE as a measure of lean Six Sigma capability, *International Journal of Lean Six Sigma*, 1. vol., no. 2, pp. 134–156, 2010.

Giebel, M., Jochem, R., Lean Sigma fuer KMU, In Gundlach, C., Jochem, R., *Praxishandbuch Six Sigma*, Symposion Publishing GmbH, Duesseldorf, 2015.

Glaeser, J., Laudel, G., *Experteninterviews und qualitative Inhaltsanalyse als Instrumente rekonstruierender Untersuchungen*, 4th edition, VS, Wiesbaden, 2010.

Goepfert, I., Ein Zukunftsmodell fuer die Handelslogistik im Jahr 2036, In Goepfert, I., *Logistik der Zukunft – Logistics for the Future, 8th edition,* Springer Gabler, Wiesbaden, 2019.

Gorecki, P., Pautsch, P., *Praxishandbuch Lean Management – Der Weg zur operativen Excellence*, 3rd edition, Hanser Verlag, München, 2018.

Gupta, P., The Six Sigma performance handbook, McGraw-Hill Verlag, New York, 2005.

Haeder, M., *Empirische Sozialforschung – Eine Einführung*, 4. Aufl., Springer, Wiesbaden, 2019.

Helfferich, C., Leitfaden- und Experteninterviews, In Baur, N., Blasius, J., *Handbuch Methoden der empirischen Sozialforschung*, 2. Aufl., Springer, Wiesbaden, 2019.

Hentschel, R., Leyh, C., Cloud Computing: Status quo, aktuelle Entwicklungen und Herausforderungen, In Reinheimer, S., *Cloud Computing: Die Infrastruktur der Digitalisierung*, Springer Vieweg, Wiesbaden, 2018.

Hofmann, M., *Prozessoptimierung als ganzheitlicher Ansatz – Mit konkreten Praxisbeispielen für effiziente Arbeitsabläufe*, Springer Gabler, Wiesbaden, 2020.

Iwd, Big Data: Neuland fuer viele Unternehmen, Available: https://www.iwd.de/artikel/big-data-neuland-fuer-viele-unternehmen-438143/, 2019.

Kaiser, R., *Qualitative Experteninterviews: Konzeptionelle Grundlagen und praktische Durchfuehrung*, Springer, Wiesbaden, 2014.

Klees, F., Moehlmann, T., Die Cloud in der digitalen Revolution und ihre Bedeutung fuer das SAP-Angebot. In S. Reinheimer, *Cloud Computing: Die Infrastruktur der Digitalisierung*, Springer Verlag, Wiesbaden, 2018.

Klumpp, M., Hagemann, V., Ruiner, C., Neukirchen, T. J., Hesenius, M., Arbeitswelten der Logistik im Wandel - Gestaltung digitalisierter Arbeit im Kontext des Internet der Dinge und von Industrie 4.0, In Burghard, H., Heupel, T., Fichtner-Rosada, S., *Arbeitswelten der Zukunft - Wie die Digitalisierung unsere Arbeitsplaetze und Arbeitsweisen veraendert,* Springer Gabler, Wiesbaden, 2019.

Koch, S., *Einfuehrung in das Management von Geschaeftsprozessen: Six Sigma, Kaizen und TQM*, 2nd Edition, Springer Vieweg, Berlin Heidelberg, 2015.

Lipsmeier, A., Kühn, A., Joppen, R., Dumitrescu, R., Process for the development of a digital strategy, *13th CIRP Conference on Intelligent Computation in Manufacturing Engineering*, vol. 88, pp. 173–178, 2020.

Luber, S., Litzel, N., BigData-Insider, Available: https://www.bigdata-insider.de/was-ist-machine-learning-a-592092/, 2016.

Mayer, H. O., *Interview und schriftliche Befragung – Entwicklung, Ausfuehrung, Auswertung*, 4th edition, Oldenburg, Munich, 2008.

McCarty, T., Bremer, M., Daniels, L., Gupta, P., *The six sigma black belt handbook*, McGraw-Hill Verlag, New York, 2005.

Meuser, M., Nagel, U., Das Experteninterview: Konzeptionelle Grundlagen und methodische Anlagen, In Pickel, S., Pickel. G., Lauth, H-J., Jahn, D., *Methoden der vergleichenden Politik- und Sozialwissenschaft: Neue Entwicklungen*, GWV, Wiesbaden, 2009.

Melzer, A., *Six Sigma – kompakt und praxisnah – Prozessverbesserung effizient und erfolgreich implementieren*, 2nd edition, Springer Gabler, Wiesbaden, 2019.

Misoch, S., *Qualitative Interviews*, De Gruyter, Berlin, 2014.

Nadarajah, D., Latifah Syed Abdul Kadir, S., A review of the importance of business process management in achieving sustainable competitive advantage, *The TQM Journal*, 26. vol., no. 5, pp. 522–531, 2014.

Obermaier, R., Industrie 4.0 und Digitale Transformation als unternehmerische Gestaltungsaufgabe, In Obermaier, R., *Handbuch Industrie 4.0 und Digitale Transformation – Betriebswirtschaftliche, technisch und rechtliche Herausforderungen*, Springer Gabler, Wiesbaden, 2019.

Pfadenhauer, M., Das Experteninterview. Ein Gespraech auf gleicher Augenhoehe, In Buber, R., Hartmut, H., *Qualitative Marktforschung*, Gabler, Wiesbaden, 2009.

Schmelzer, H. J., Sesselmann, W., *Geschaeftsprozessmanagement in der Praxis*, 6. Edition, Hanser Verlag, Munich, 2008.

Sreeram, T., Thondiyath, A., Combining Lean and Six Sigma in the context of systems Engineering design, In *International Journal of Lean Six Sigma*, 4. vol., no. 6, pp. 290–312, 2015.

Toutenberg, H., Knoefel, P., *Six Sigma. Methoden und Statistik fuer die Praxis*, 2nd edition, Springer Verlag, Berlin Heidelberg, 2009.

Wrona, T., Reinecke, P., Wie strategisch sind Algorithmen? Die Rolle von Big Data und Analytics im Rahmen strategischer Entscheidungsprozesse, In Schroeder, M., Wegner, K., *Logistik im Wandel der Zeit – Von der Produktionssteuerung zu vernetzten Supply Chains,* Springer Gabler, Wiesbaden, 2019.