APPLICATION OF LEAN SIX SIGMA METHODOLOGY IN INDUSTRIAL ENTERPRISES

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Abstract

The Lean Six Sigma methodology is a disciplined and logical approach that is used in industrial companies to improve various processes. The essence of improvement is to reduce variability, eliminate defects and eliminate waste, especially in manufacturing processes of which logistics activities are an integral part. This methodology is based primarily on statistical methods, simpler and more complex quality management methods as well as lean management methods. The main importance that adds to the value of the Lean Six Sigma methodology compared to other improvement methodologies is the application of advanced industrial engineering methods and more complex statistical methods and the use of measurable financial indicators to interpret results.

The paper focuses on the application of Lean Six Sigma or Six Sigma methodology in industrial practice. The main objective of the paper is to identify and analyze the critical factors of failure of implementation of Lean Six Sigma methodology in industrial enterprises in Slovakia in comparison with enterprises in the world.

Keywords: Lean Six Sigma, quality management, process improvement, industrial engineering methods

1. INTRODUCTION

All industries operating in the open global competition have the same market opportunities. In order to respond to the pressures created by global competition, businesses must adopt competitive and innovative methods that are an opportunity and tend to emphasize quality and customer orientation. The use of appropriate methods enhances the competitive ability of the enterprise, but also requires the knowledge of the people in the organization for the proper implementation and subsequent application of the improvement methods. Six Sigma methodology also uses such methods in its application.

The Six Sigma methodology as we know it today has been around for over three decades. Like any methodology, method, tool, or discipline, Six Sigma has undergone a certain evolution. Today, the main focus is on the link between Lean Management and Six Sigma, i.e. Lean Six Sigma, and it focuses on reducing variability and making production leaner. There is a debate among experts on whether these two philosophies should merge and merge into one philosophy or methodology. In this paper, we will use Lean Six Sigma terminology, but we will be primarily concerned with advanced industrial engineering methods and more complex statistical tools or methods. There is ample scope to consider the question of why manufacturing companies operating in Slovakia are not motivated to use the Lean Six Sigma methodology.

2. THEORETICAL BACKROUND

The goal of the Lean Six Sigma methodology is to reduce variability and waste in manufacturing processes. Motorola was one of the companies that were successful in adapting the Six Sigma methodology in the 1980s in an effort to increase quality levels by reducing variability in manufacturing operations in a continuous and consistent manner [1].

Albliwi (2014) in his research defined Lean Six Sigma as "*a business strategy and methodology that improves process performance and results in increased customer satisfaction and better bottom line*." [2].

Lean Six Sigma has become the leading methodology for improving processes and the entire business, it has gained this status due to its successful implementation in all types of businesses. The goal of Lean Six Sigma is to drive and kick-start business improvement with the core functions of industrial engineering methods, quality management, and statistics and also in conjunction with the idea of Lean. Then to incorporate these methods and solutions into integrated approaches to improving the performance and quality of processes, products, and services. Lean Six Sigma focuses on the elimination of key quality criteria (CTQ) issues [3].

The Lean Six Sigma methodology is used by large corporations and businesses to eliminate non-conformances, reduce variability, and streamline the production system. As such, the methodology has an excellent track record of improvement and ensures comprehensiveness in addressing improvement. Thus, Lean Six Sigma focuses on reducing variability, and reducing defects, and waste in the process or products. In doing so, it uses the DMAIC logical sequence, which is the most well-known and commonly used sequence in the application of Lean Six Sigma.

The most successful implementations of the Six Sigma methodology share common characteristics [4]:

- Six Sigma embeds quality into the functioning of the company and also the departments themselves, instead of being maintained as a separate entity. The idea of Six Sigma implementation being a private matter of the quality department is deeply distorted first: the vice president of quality management could not bear to answer the possibility of a company wide Six Sigma implementation.

- In most successful implementations, the Six Sigma program has been extended to all of the company's processes. It would be a big mistake to limit the implementation to only the most relevant areas.

- Six Sigma assumes management involvement and support. It is paramount that the company's board of directors put quality as a priority.

- Six Sigma focuses on well-defined, measurable goals. Often the finance department is involved and is in charge of verifying the economic savings resulting from various improvement actions.

Although many of the tools, and methods of the Lean Six Sigma methodology are known, there is a lack of understanding of the sequence of these methods or a model for effectively guiding the implementation of the methodology. Since there is no specific implementation model, practitioners have encountered tremendous difficulties in implementing the Lean Six Sigma methodology and there are reports of widespread Lean Six Sigma failures [5].

According to Paslawski, one of the reasons for the failure of Lean Six Sigma programs is that these programs are not implemented properly [6].

Many articles present case studies of Lean Six Sigma implementation. A useful exercise was to sort out the various aspects that the authors believe are the basis and successful implementation of Lean Six Sigma. We will refer to these items as the Critical Failure Factors (CFFs) of Lean Six Sigma. Many publications such as [4,7] have defined the critical failure factors involved in the implementation of the methodology. Of course, the specific items pointed out by each author vary according to the type of industry, size of the company, etc.

According to research by Fonseca and colleagues [8] it appears that there is a significant difference in the level of knowledge of Six Sigma issues among employee groups. In the publication, the groups were divided into TOP MANAGEMENT (board member CEO, and General Manager), MANAGEMENT (quality, environment, safety, and health), and the last group was OTHER FUNCTIONS. They found that there was a significant difference in knowledge between these groups and specifically the Top Managers had a weaker knowledge of Lean Six Sigma issues. Although this research was conducted on a sample of Portuguese companies, it can be assumed that this trend and the given unfavorable conditions are also present in Slovak

companies. Research also says that only about 10% of companies that implement Lean practices are successful in understanding and implementing the philosophy into their business processes. Also, lean manufacturing systems and practices are challenging to implement [9].

In exploring the issue, we set the following the research questions:

RQ1: Which process improvement methodologies need to be developed, deepened, and applied in your company in the context of Industry 4.0?

RQ2: What factors hinder the implementation of Lean Six Sigma in medium and large industrial enterprises in Slovakia?

3. METHODOLOGY

To obtain data and analyze the application of industrial engineering methods in company practice, we used a questionnaire from the VEGA project. The questionnaire contained 37 closed questions. The first part of the questionnaire was focused on the identification questions of the respondents and from the second part of the questionnaire we focused on the evaluation and analysis of the questions "Which process improvement methodologies need to be developed, deepened, and applied in your company in the context of Industry 4.0?" and "Which industrial engineering methods do you currently use most often in process improvement in the context of Industry 4.0 elements?". With these questions, we analyze the real application of the Lean Six Sigma methodology in Slovakia and the use of industrial engineering methods that are applicable to the Lean Six Sigma methodology. It was 556 respondents from different organizations in Slovakia participated in the survey, and 322 respondents were from industrial enterprises of different sizes. The distribution of enterprises by a number of employees is shown in **Figure 1**.

Data processing was carried out using Microsoft Excel. The ANOVA method was used to test the relationships between the dependent and independent variables to evaluate the statistical hypotheses.

A further breakdown of respondents, which we created based on the industry sector, is shown in **Figure 2**. We focused on six industries where there is the greatest potential for Lean Six Sigma to be used in industrial practice.

In exploring the issue, we also focused on analyzing the factors of Lean Six Sigma´s failure. By reviewing the published literature in the area focusing on implementation, advantages/disadvantages, application benefits, and other issues related to Lean Six Sigma methodology, we obtained information on the real state of Lean Six Sigma implementation as well as the benefits of this improvement methodology are for businesses. We studied papers in scientific journals focusing on the subject that was published in the WOS and Scopus databases between 2014 and 2022 and that originated from many countries around the world, e.g., Italy, Sweden, Brazil, USA, United Kingdom, Slovakia and others. The criteria for searching information in the given scientific databases and digital libraries were identified as Lean Six Sigma implementation, Lean Six Sigma failure/failures, and Lean Six Sigma success/benefits. Information was also obtained through personal interviews with employees of manufacturing companies in Slovakia who have experience with Lean Six Sigma implementation. We gained personal experience with the implementation of Lean Six Sigma in a particular medium-sized manufacturing company operating in Slovakia in the chemical/textile industry.

As Sony [10] states in their research many companies have successfully implemented Lean Six Sigma, on the contrary, some companies that have proceeded with the implementation have not gained any of the benefits that this methodology provides. Thus, these companies have not managed to implement Lean Six Sigma. Like any new implementation in a company, Lean Six Sigma is prone to failure and in our research, we present the key failure factors that we have defined for our three research areas (Enterprises of the World, Specific Enterprise, and Slovak Enterprises).

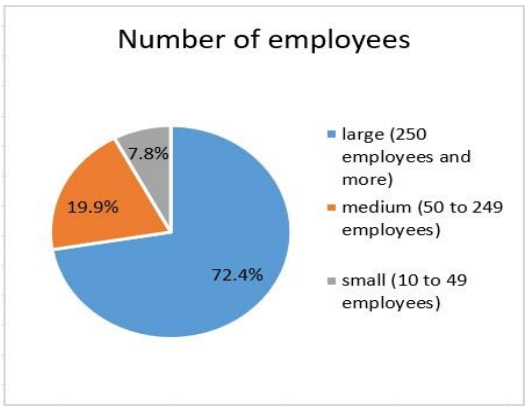

Figure 1 Percentage of enterprises by size [own processing, 2022]

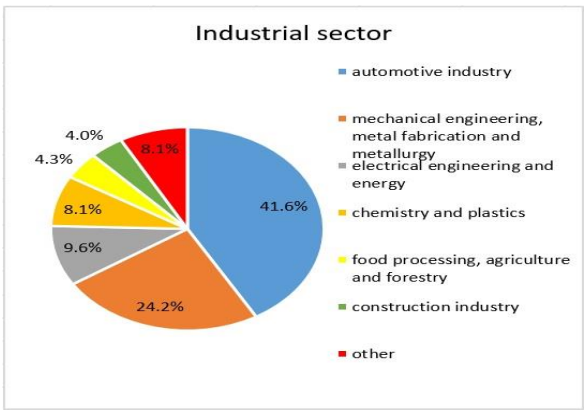

Figure 2 Distribution of respondents based on industry sector [own processing, 2022]

RESULTS

By studying research materials in Web of Science (WOS), Google Scholar, IEEE Xplore Digital Library, Taylor and Francis, Scopus, and survey data, we evaluated the answers to the research questions and research hypotheses.

RQ1: Which process improvement methodologies need to be developed, deepened, and applied in your company in the context of Industry 4.0?

We investigated and compared industry areas and process improvement methodologies that need to be developed in the context of Industry 4.0 with each other. We compared the industries, as based on our experience we expected that there would be a significant difference between the companies with regard to the application of the methodologies. Following the research question, we also defined a scientific hypothesis.

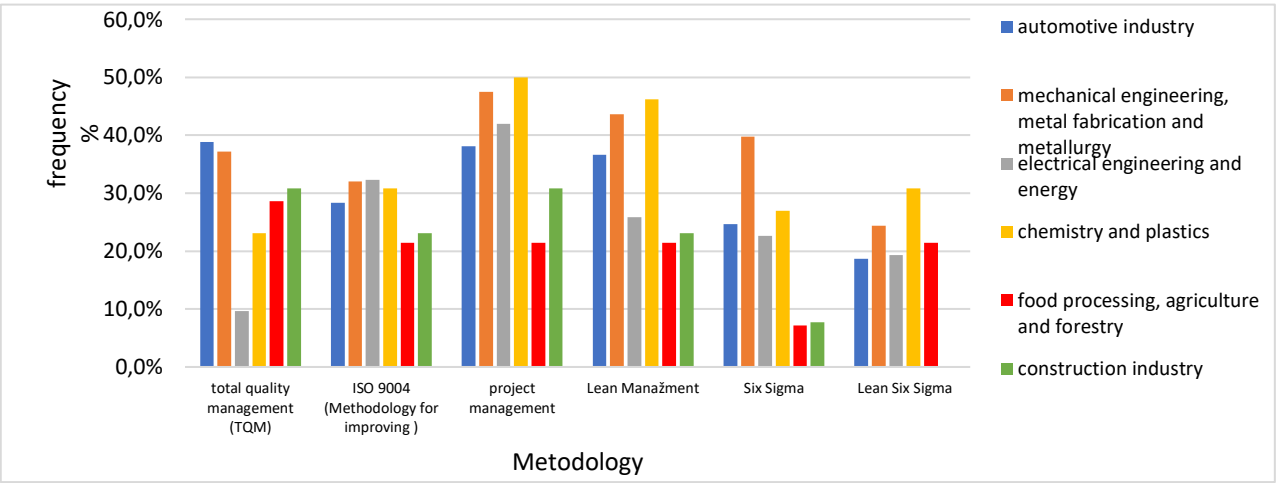

Figure 3 Improvement methodologies applied in industries [own processing, 2022]

The processed results are shown in **Figure 3**. Relative abundances were calculated relative to the industrial area, not to the total number of respondents. Based on the above results, it can be concluded that project management is the most commonly reported methodology. The results vary quite a bit in comparison, as the use of improvement methodologies is a company-specific issue, but also a sector-specific issue in the industry. Each industrial sector is characterized by distinctive processes that need the application of a different improvement methodology to improve. Also, these enterprises implement technologies in different ways in the

context of Industry 4.0, so they assume that it will be necessary to develop a specific improvement methodology. There are significant differences between industries in the application of Lean Six Sigma and Six Sigma methodologies, respectively. These methodologies are mostly applied in the engineering and chemical sectors.

In our opinion, it is the Lean Six Sigma or Six Sigma methodology that can work better with data in solving complex projects in real-time thanks to Industry 4.0 technologies, e.g. Big Data technology. By integrating these tools, it will be possible to make rapid interventions in processes and implement improvements at a lower cost.

Based on the findings from research question 2, we defined the following hypothesis:

H1: **There is a significant difference between industries regarding the need to develop improvement methodologies in the context of Industry 4.0.**

In testing Hypothesis 1, we based the frequencies on **Figure 3**, looking to see if there was a significant difference between the work sector and the need to develop improvement methodologies in the context of Industry 4.0.

Table 1 Results of testing hypothesis H1

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	382.22	5	76.44	3.430	0.017	2.603
Columns	7707.56	5	1541.51	69.174	7.95E-14	2.603
Error	557.11	25	22.28			
Total	8646.89	35				

Based on the results from the analysis of variance (**Table 1**), we can conclude that there is a significant difference between companies in different industries in terms of the need to develop improvement methodologies in the context of Industry 4.0.

We have also addressed the issue of the application of the Lean Six Sigma methodology or the factors that hinder its successful application.

RQ2: What factors hinder the implementation of Lean Six Sigma in medium and large industrial enterprises in Slovakia?

A comparison of the areas with respect to the factors of failure in the implementation of the Lean Six Sigma methodology is shown in **Figure 4**. After studying the research [2, 8, 12] and the findings obtained from industrial enterprises operating in Slovakia, we have defined the most critical factor for the failure of Lean Six Sigma implementation as the lack of documentation. This fact was also confirmed to us in a specific enterprise in Slovakia. Due to the lack of documentation and sequencing of the use of improvement methods, the project team did not know how to define the project and the logical sequence of the individual improvement phases. The managers stated that the training company identified to them that Lean Six Sigma projects are handled using the DMAIC sequence, but the identification of the use of key improvement methods within DMAIC was left to the newly trained managers, who, however, did not know what methods and tools to use in each step and required further study of the literature on the subject. It is the appropriate use of improvement methods and tools within the DMAIC phases that is essential for the successful application of Lean Six Sigma. Based on the above, we conclude that there is a great need for application documentation focusing on the use of industrial engineering, quality management, and statistical methods tools and methods to guide Lean Six Sigma project teams in process improvement.

In most cases, companies prepare documentation on their own and often inexperienced project managers include mainly simple statistical methods and simple industrial engineering methods, which by themselves are of little value without mutual cooperation and without the use of other more complex or advanced methods.

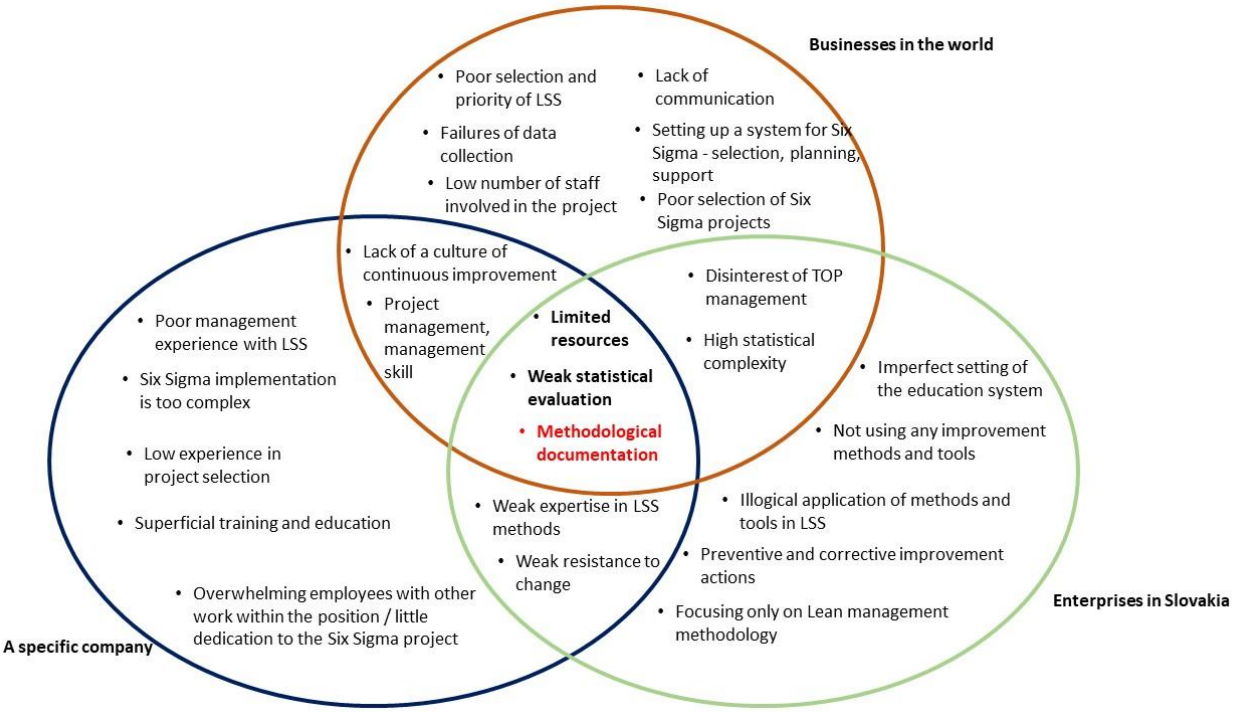

Figure 4 Critical factors of Lean Six Sigma implementation failure [own processing, 2022]

Due to the fact that project teams and project managers work with simple methods individually and define results based on the application of these simple methods, the application of the Lean Six Sigma methodology is unsuccessful. It is the Lean Six Sigma methodology that requires working with more complex or advanced improvement methods and tools.

Other failure factors for Lean Six Sigma methodology include the lack of ability of employees to perform statistical analyses, poor knowledge of statistical methods, poor application skills with advanced statistical tools and methods, as well as industrial engineering and quality management methods.

4. CONCLUSION

We see the primary scope for improving the application of the methodology in individual companies in the creation and implementation of general application documentation for Lean Six Sigma projects. It is necessary to create a proposal or framework for the sequence of the use of methods and tools in relation to the existing sequence of DMAIC phases. The aim is that these methods and tools should be logically linked to each other, that the data obtained should be linked, and that the results of the analyses should be correctly interpreted in relation to the defined project objective. With regard to the implementation of Lean Six Sigma, the concept of Industry 4.0 cannot be forgotten, where there will be synergies between this improvement methodology and the paradigm. This will ensure an increase in the ability to improve processes more quickly in real-time, so to speak, with a greater proportion of data and information in the implementation of a given measure, which will be of great benefit to businesses. Industry 4.0 technologies should also change the traditional application of Lean Six Sigma methodology in enterprises, as traditional data analysis techniques will not be sufficient, as it is a time-consuming activity. Also, in our paper and research, we have identified that businesses and employees are aware of the need to develop individual improvement methodologies in the context of Industry

4.0 in order to be competitive. However, our interest and focus are specifically on the Lean Six Sigma methodology and our findings show that approximately 25% of respondents employed in the four largest industries reported the need to develop Lean Six Sigma in context with Industry 4.0 specifically and 10% of respondents reported active use of the methodology in practice.

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