Lean Management, Six Sigma and Lean Six Sigma: Possible Connections

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Abstract: *Six Sigma has been the best set of tools, for quality improvement, in the past 20 years, for optimization processes and minimizing risks in our systems. Six Sigma is a window of future opportunities for each company, once the ultimate goal is set to improve quality and customer satisfaction. Six Sigma tools are simple and easy to master, with full knowledge of the status, weaknesses and strengths of our systems and processes. With the review of the current and relevant literature, this research, has explored combining Six Sigma, with other quality improvement tools, such as, Lean Management tools. If the two methods are combined, Six Sigma offers much better results, since the defects of both systems can be simply eliminated by the mutual integration of tools into the other system. Lean Six Sigma improvement offers a new standard which serves as the basis, for further opportunities to improve processes, if they are safely sustainable. It is crucial for the implementation of developments in our subsequent work. Acquiring knowledge of Lean Six Sigma tools is extremely important, for employees, in the future, since awareness of its significance enables them to use this set of tools, without obstacles in their work. The work herein provides the basic guidelines for preparing camera-ready papers, for conference proceedings*.

Keywords: *process, quality improvement tools, Lean Six Sigma, quality, value*

Introduction

Six Sigma represents a value and an objective for enterprises to strive for, the implementation of which may yield better performance. Six Sigma creates value for enterprises, by identifying defects to be corrected. This method is usually referred to as the tool of Total Quality Management and Lean Management; whereas it is a totally independent quality improvement tool which works perfectly well in parallel to other systems and it can be used efficiently by both production- and service-based enterprises. The Six Sigma methodology does not only refer to production processes, but it can be applied in all areas of an organization ranging from administration to finances in order for output optimization and performance improvement steps to be significant. In our research, we present the positive impacts of a Lean and Six Sigma approach, on business management, as factually shown by various Authors [1, 2, 3, 4, 5, 6, 7, 8, 9].

The objectives are to introduce the devolvement and paradigm of the Six Sigma method, to determine the tools which may be utilized efficiently in quality improvement, as well as, to detail the differences and overlaps between the popular Lean Management and Six Sigma approaches.

1 Results

1.1 Introduction of the Six Sigma quality approach

Six Sigma may be referred to as a quality tool, since it can contribute to reaching a higher quality level. At the same time, this method is also a benchmark, as its usually guarantees better quality. Six Sigma is a philosophy, a way of thinking and a symbol at the same time, as it shows that the given enterprise considers its customers' opinions and quality expectations to be important. In addition, Six Sigma is a procedure to improve quality and it serves as a basis for comparison in terms of various processes.

If one takes a look at the enterprises using Six Sigma, it becomes apparent, that it helps reshape the whole enterprise culture. Six Sigma results in cultural changes which positively affect the market position of the enterprise. It leads to a higher level of customer satisfaction and better income production capabilities, while creating a better competitive status [10]. The managers of Motorola arrived at the same conclusion based on their own experience: in reality, Six Sigma is a cultural issue and a form of behavior, as changing the enterprise culture calls for producing higher quality products and providing higher quality service [11].

The Six Sigma method is a structured problem-solving and process improvement procedure, which unifies the efforts of several pioneering quality improvement professionals.

Sigma (σ) is a character of the Greek alphabet, used by statisticians for expressing the fluctuation of processes. Sigma is a statistical indicator which measures the squared deviation from the mean; however, in the field of Quality Assurance (QA), it is used for measuring the variability of a process. Six Sigma uses Defects per Opportunities (DPO) as a measure "defectiveness", which is an outstanding measurement unit of the quality of a certain procedure or product, as it compares defectiveness, costs and time to each other. Sigma values represent the probability level at which defectiveness occurs in the process. The higher the value of sigma is, the lower the probability of defectiveness is. Reaching back to functions with normal distribution, the basic concept of Six Sigma was established by Walter Shewhart in 1920. According to Shewhart, intervention into a process is necessary only if the typical value of process attribute is three standard deviations above the mean [12].

The sigma level represents the enterprise performance in each key business process. Enterprises operating in traditional environment are capable of reaching 3 and 4 sigma levels which calculates as 6,200 and 67,000 defects per million opportunities. The Six Sigma standard, which represents 3-4 defects per million opportunities, is a response to constantly increasing customer expectations, as well as, the sudden change of the complexity of modern production and service processes [13]. A defect could be anything which causes dissatisfaction for clients. Increasing sigma values results in decreasing costs, a shortening of process times and an improving customer satisfaction level. The majority of companies use sigma levels of 3 and 4, which represents a performance of 99.73%, while in reality, they could lose up to 25% of their total income [14].

Table 1 shows the change of the number of defective parts per million products in the case of one and six sigma processes. Consequently, Six Sigma translates as higher product quality with a very low number of defects and therefore, low defect costs [15].

Table 1

Six Sigma level of processes against the number of defects

Sigma level	Long-term defect level (ppm*)
1	691,462
2	308,538
3	66,807
4	6,210
5	233
6	3.4

Source: own construction [15]

*ppm=parts per million, i.e., number of defects per one million products

The basis of Six Sigma is provided by the following equation: $Y = f(X)$.

Y (dependent variable) is the function of X (independent variable). In reality, it means that the output result of the project is the function of input processes where

Y= the results (the aim of the project)

f= the function (connection between the variable to be controlled and the controlled variable)

X= controllable and non-controllable variables which have an impact on the value of Y [15].

The Six Sigma process designates three areas as main priorities:

- Cycle time reduction
- Defect rate reduction
- Increasing customer satisfaction

The source of losses may be different; therefore, it is very important to get to know the processes and analytically filter out the elements which result in defects, leading to longer lead time and increased costs. Consequently, achieving good results calls for finding the defects of the system first.

Loss types:

Lead time loss: The period between the beginning and the end of the process, which, if it is not continuous or if there are defects in it, leads to reduced customer satisfaction.

Stockpiling loss: If customer needs are not properly recognized, there might be defects in the applied stockpiling method. Surplus material between work processes and surplus material provided by the suppliers are considered as loss.

Movement loss: The improper loss and location of staff or machinery may cause defects in the system.

Waiting loss: It can be concluded that 99% of time during processes, is consumed by waiting. This is also a loss in the system.

Overproduction: Producing more than needed to meet customer demand. Producing the given product or service quicker than needed is also a form of overproduction.

Over processing: Providing more products and higher quality to the customers than needed and what they can afford. Movements which do not create value and do not increase product quality should be avoided.

Quality defect: Customers pay for products and services they expect and invest money into [16].

In general, it can be stated that manufacturing companies tend to achieve 4 sigma performance, at an increasing rate, while the performance of service provider enterprises, is 1-2 sigma [17].

Six Sigma is not only a quality initiative, but also business-focused, as a result of measurement and analysis. This method can be built into an already operating ISO/QS 9000, TQM, Lean Management or Malcolm Baldrige management system. These management systems alone represent the indispensable basis of quality, but if they are incorporated into the processes of Six Sigma, they become parts of the Six Sigma program. However, it is false to think that the principles of Six Sigma override the value of existing quality management systems, as Six Sigma is only a development step towards full-fledged quality management [18].

According to [19], Six Sigma is defined as follows:

- A quality-focused approach with the aim to make the given product or service the best in its category
- Methods to mitigate defects in order to satisfy customers
- An index number based on static measurements which shows how proper the given process is
- A management system, since it has an impact on all segments of the enterprise

In order for Six Sigma to achieve its objective, it is important to involve the management and the whole organizational structure. Opportunities to step up between each step are not the same and the extent of investment is also different. The number of defects for each level decreases exponentially; therefore, in the statistical sense of the word, the Six Sigma process converges to zero [14]. Several advantages can be achieved with the introduction of this method while the number of defects decreases: increasing customer satisfaction, decreasing costs and

losses, maintaining business, improving popularity, increasing competitive advantages and increasing work discipline [20].

1.2 Development stages of Six Sigma

The methodology of Six Sigma underwent significant development in recent years, influenced by several quality management philosophies and methodologies, including Total Quality Management (TQM) and Lean Management. The process of development can be divided into four periods:

The **first period** was between 1984-1994. In this period, the methodology was introduced by Texas Instruments, IBM, Xerox and Ericsson. At the time, there were only four phases: M (Measure), A (Analyse), I (Improve) and C (Control), abbreviated as MAIC. The method was only used for industrial production processes in technical areas. The so-called Black Belt Concept was developed in this period.

The **second period** was between 1993-2001. At ABB, the focus was not only on product quality, but also manufacturing-related costs. Separation from TQM was started in this period. It was revealed that the success of processes greatly depended on adequate preparation. The methodology which consisted of four phases was supplemented with an extra step. The abbreviation "MAIC" was supplemented with the D (Define) phase, changing it to DMAIC.

The **third period** started in 2001 at DuPont Corporation. The main objective was not only to reduce losses and costs, but also to create value. As a result, the owner of the process, the customer and the supplier move closer to each other. The appearance of value-centred Six Sigma, indicates the impact of Lean Management. The elements of Six Sigma are used to improve non-value creating processes, but the principles of Lean and Six Sigma still did not merge.

According to experts, the **fourth stage** is the incorporation of Six Sigma into people's own lives [19].

1.2.1 Nine rules of Six Sigma

- Performance has to be evaluated from the customer's aspect
- The process has to be known in every detail
- Decisions are made on the basis of data and analyses
- Concentration on the main problems
- Statistical tools need to be used
- Changes need to be tracked continuously
- Standard methods have to be used
- Projects need to be selected based on their financial impact
- The support of top managers has to be earned [21].

1.2.2 The paradigm of Six Sigma

Six Sigma is a customer-focused methodology in which all processes are subordinate to the maximum satisfaction of customers' expectations. The first step is always to identify the needs and expectations of customers. This approach is called VOC (Voice of Customer). There are four aspects of customer needs: proper quality, quality expectations associated with reliability and quality and reliability at an affordable price. The product or service is accessible whenever the customer requests it. Various feedback mechanisms can be used to determine customer preferences and how to meet their demands [22].

1.3 The process development model of Six Sigma

In addition to statistics, the main essence of Six Sigma lies in its 5-step DMAIC process. The method has a cyclical structure; therefore, it is possible to return from each phase to the previous one if new information is obtained and if it is intended to improve something. The different steps of the DMAIC process are described below [23].

Define – (D): In this phase the business environment is assessed, shortcomings are identified and it is revealed why the given project is necessary. Targets need to be set; project leads and stakeholders have to be designated. The main purpose of this stage is to launch the project.

The first step is to identify the CTQ (Critical to Quality) parameter which the project refers to. These parameters come from the customers. The participants of the process will help in describing the process and comparisons will be drawn with the quality criteria, which customers consider to be important. If there are differences between the two sides of the comparison, it clearly refers to a defect in the process.

During the second step, the project charter is prepared, in which, the current situation, the project objectives and the area of the project's operation are laid out. Many make the mistake of creating too wide an area of operation, which cannot be realised in the Six Sigma project of a 2 to 6 month long duration. The project team members have to be identified and their sphere of responsibility must be accurately defined too. Also, it is important to determine the dates of supervising project implementation.

The SIPOC map is also prepared in the Define phase. This map documents the different process steps, including Suppliers, Inputs, the internal Process itself, Outputs and Customers. The SIPOC map can be used to describe how the process looks like in its actual status and what the ideal process would look like. Stakeholder groups and their approach to the project also need to be identified in this phase.

Measure (M): measure means that the quality parameters determined in the previous phase are quantified. As a first step, CTQ (Critical to Quality) parameters are associated with a certain measurable characteristic. This characteristic is the final result of the process which created it; therefore, the quantified target value is identified at this point. Following the definition of the CTQ parameters, the acceptable parameter value also needs to be determined, as well as its minimum and maximum values which are still acceptable for customers. As a next step, performance prescriptions need to be determined in relation to KPOV (Key Process Output Variable). This means that a target value and a tolerance range needs to be set. Previous quality management systems did not emphasise the importance of measurement, which Six Sigma incorporated into its processes.

Analyse - (A): In this phase, the current process capability needs to be examined and the yield results, followed by a comparison with the project objective and the determination of various indexes. The analytical phase begins with brainstorming, during which, the potential shortcomings of the given processes are revealed. As a next step, a cause and effect diagram is generated. In addition, a process analysis is prepared and the correlation between outputs, the process and inputs is identified before the main root causes are outlined.

Improve - (I): During the analytical phase, there were several outputs which had an impact on subsequent results, but their size is not properly known. In the next step, the most important results are selected, the results measured in the analytical phase are evaluated and specific solutions are worked out. In addition, the ideal process is outlined.

Control - (C): In the previous phases, the process was improved, but the achieved results have to be guaranteed, in subsequent periods. In order to do so, the continuous controlling phase acts as a quality system which constantly controls the process. Within this phase, work instructions, training plan, maintenance plan and a long-term measurement system are developed [23].

1.4 Introduction of the Six Sigma system

As in the case of every other system, the main aspect is to earn the commitment of the management to development, since these initiatives are usually top-down. If the manager is not committed to a new system, it is not possible to incorporate it into all units of the system and the organisational culture. For this reason, manager training is the first step, during which the management learns why this system is good for them and what they will gain from it. It is important to set realistic targets and the available time frame, human and financial resources and waiting times need to be determined accordingly. If the top management is committed to introducing the system, it is important to identify the projects to be initiated and to designate the person responsible for managing the processes. The next step is to select group leaders within the framework of the "Black Belt" training which has to be implemented during a 16-week-cycle. After one week of training, Masters return to their job to work on a selected project for three weeks, followed by another week of training. This cycle is repeated four times during the 16 weeks. The Six Sigma Master candidate is expected to implement 4-6 projects with the aim of significant cost savings. Mentoring is an important part of the process. The task of the mentor is guidance and setting up the implementation structure in addition to establishing the appropriate environment. There are levels both above and below the Six Sigma Master. It is generally accepted in an organisation to have 10 Six Sigma Masters and 1 Six Sigma Grand Master per 1000 people [20].

Six Sigma Champion: Business management members whose main task is to coordinate the enterprise's business strategy with the Six Sigma activities. They take part in selecting projects, define the topic of the project, designate the responsible staff, coordinate the necessary resources and try to overcome any possible obstacles. Champions are highly educated professionals who are committed to success. They use the methodology of Six Sigma during their daily work and communicate it to the stakeholder groups whenever they have the opportunity.

Master Black Belt: Highly qualified key actors of the Six Sigma project who participate in constant development trainings. They communicate daily with Green Belts and mentor the given project. The ultimate goal of Black Belts' projects is to increase customer satisfaction and reduce costs and losses. There are enterprises where these professionals are expected to have at least two finished projects. It is enough for a small or medium enterprise to employ 1-5 Black Belts at the same time. These professionals usually spend 2 years in the black belt position before they step up to management position.

Master Green Belt: Functional workers who participate in special trainings, coordinating Green Belt projects in which they also take part as members. Green Belts are able to use the basic tools of quality and to develop quality in teamwork. In general, it can be stated that an enterprise which employs 100 people may consider employing 1 Black Belt and 60 Green Belts. During their trainings, Green Belts learn project management, quality management, communication development and they get to know how to use descriptive statistics [24, 25, 19].

Not only do Black Belt and Green Belt professionals have to be well trained, but they also need to have some basic skills which contribute to project success. These skills include the following:

- Positive thinking, as one always must remain optimistic about the success of the project which also must be accompanied by a certain type of self-confidence.
- It is indispensable for these professionals to dare to take a risk and change if the success of the project makes it necessary.
- Good communication skills are a must, since the elements of Six Sigma have to be conveyed to stakeholder groups. In addition, the success of the group is greatly increased if communication between group members is efficient.
- They should respect each other's opinion.
- They must have managerial skills, since the project has to be managed and the available resources have to be used effectively in order to reach the project objectives [26].

Being classified as a Six Sigma organisation takes more than an enterprise which is able to satisfy its customers' demand at a six sigma level, as Six Sigma's set of tools needs to be applied, in order to increase performance and achieve significant improvements. It is the advantage of Six Sigma that it is flexible and adaptive and its theory develops in parallel with practice. However, it is a disadvantage of the system that the advantages of this method can only be really utilised by multinational companies and not by small and medium enterprises.

1.5 The connection between Lean Management and Six Sigma

Connecting Lean Management and Six Sigma became more significant in recent years [27]. Lean Six Sigma (LSS) emerges from the integration of the consecrated lean manufacturing production system with the efficient

Six Sigma improvement methodology. [28] defines LSS as a business strategy and at the same time a methodology that increases process performance, resulting in greater client satisfaction and results. In a theoretical conceptual study, [29] found that LSS leads to an incremental increase in the level of quality of the products and reliability of processes. LSS, therefore, supports the implementation of lean practices like kanban, Total Production Management and others.

LSS does not have an accurate and accepted definition. There are numerous overlaps between the two quality improvement methods and LSS usually refers to the combination of the two methods in order to reduce losses, increase the value stream, correct defects, increase customer focus and reduce the fluctuation in process performance. In general, it is better if the two methods are used in parallel and in combination, instead of implementing them separately in the processes of the enterprise [30]. While the definitions of Lean Managemnet and Six Sigma differ, the aim of the different concepts seems to be similar: reducing waste and resources while improving customer satisfaction and financial results [31].

In the context of systems design, the application of Six Sigma and Lean concepts results in a flexible and adaptable framework. A combined framework is presented here that allows better visualization of the system-level components and their interactions at parametric level and it also illuminates gaps that make way for continuous improvement [32]. When various consultancy companies implemented the methodology of Six Sigma at General Electric (GE), it was foreseen that the developed basic principles could be brought further towards the value stream process, as well [33]. This way, enterprises started to customize the methodology of Six Sigma and mix it with other quality control tools, resulting in LSS [34].

[35] Conducted research with professionals and academic researchers from the area to identify the differences between Lean and Six Sigma. The main differences identified were as follows:

- Six Sigma requires longer training time than lean.
- Six Sigma requires a larger investment than lean.
- Lean seeks to reduce the inefficiency of the process and Six Sigma aims to improve the effectiveness of the process.
- Six Sigma seeks to eliminate defects in the process and increase the capability and stability of the process.

The primary aim of Lean Management is to optimize outputs by minimizing losses. The defect and inappropriate quality of the product or service causes loss for the enterprise. A general rule is that the smaller the loss, the better the quality of the product or service.

[36] Demonstrates the importance of the following factors.

Identifying the loss: Lean does not consider losing a customer to be a loss which leads to losing income. One of the advantages of Six Sigma is that that it listens to the Voice of Customer (VOC) and incorporates it into its target system.

Reducing lead time: In practice, it was shown that using both methods resulted in a significant reduction of lead time, resulting in higher quality.

Quick projects: Lean could contribute to shorter-term projects. The objectives of Six Sigma can be implemented more quickly if the method of Lean is used to eliminate steps which do not result in any value.

Integration is possible through management, expertise and training, specific roles and the organisation itself, tools and methodology. The main difference between the two methods lies in the fact that Six Sigma is used for activity development and Lean Management is used for securing the process of the value stream [12]. Six Sigma aims to correct the defects and problems of the activity, thereby achieving better quality, while the aim of Lean Management is to provide the flow of processes.

Lean reduces cycle time and balances the process, while the primary aim of Six Sigma is to increase efficiency and reduce process variability. Both methods aim to eliminate defects from the processes and both of them put the customers into focus [37]. LSS is a very good approach in managing waste and variability, and it is also relevant for application to current manufacturing management system. By implementing LSS, the overall company goal of maximizing profit can be materialized [38].

The methods of Six Sigma and Lean Management differ from each other from the aspect that Lean Management aims to eliminate losses, while Six Sigma mitigates defects. The other difference between the two systems is that Lean Management is process-centered, while Six Sigma is problem-centered. As regards the primary outcome of the two quality systems, Lean Management reduces the duration of processes, while the primary objective of Six Sigma is the unification of outputs.

Furthermore, organizational costs can be grouped as process cost, cost of quality, and cost of poor quality, therefore managers should be trained in the theory and application of LSS, including the seven categories of waste and how to remove them. In healthcare, financial executives should work with managers in eliminating waste to improve service and reduce costs [39].

Therefore, Lean Management and Six Sigma initiatives should lower the workload and the need for recovery after a workday, for employees. In addition, some argue that employees who directly participate in Lean Management Six Sigma initiatives show improved levels of commitment and satisfaction [40, 41]. Lean and Six Sigma each have their own strengths in different applications and the two methodologies can be combined or applied in different situations to achieve the best results.

However, LSS might be the latest operations management fad [42] that could lead to questionable performance improvement benefits [43]. Whether a combined LSS approach is the latest management fad, or leads to significant performance benefits that exceed isolated implementation is not yet apparent.

LSS refers to the combination of the two methods in order to reduce losses, increase value stream, eliminate defects, increase customer focus and reduce fluctuation in process performance [2, 44, 45, 46, 47]. The combination of the two methods makes it possible for employees to be much more independent and creative in their daily production processes [47].

LSS, is applied in an airline company [49] and the findings suggest that the factors that influence the implementation of LSS are leadership and strategic orientation, quality-driven organizational culture, continuous training, teamwork, customer satisfaction, and technical system. Research suggests that a climate of continuous improvement becomes tangible by encouraging employees to respond and behave in ways that support the strategic objectives of Lean Management and Six Sigma [50].

Work [51] **was c**arried out in a case study on a help-desk service company in the area of information technology. As the main results, the authors found that with the implementation of LSS the company reduced the service time by nearly 52%, in addition to reducing the cost of operations.

[52] Conducted a survey in companies from the electronics segment to analyze the critical factors for successful LSS deployment. For this, through a survey of the literature, the authors identified the 25 factors that lead to success in the implementation of LSS, the main factors are linked to the involvement of senior management, a reward system for employees and frequent dissemination of results to all employees.

If both methods are used, lower stocks need to be maintained. Table 2 shows what the two methods have in common and the differences.

Table 2

Differences between Six Sigma and Lean Management

	Six Sigma	**Lean Management**
Aim	Improving process performance, reducing dispersion	Planning continuous flow, eliminating losses
Use	All business processes	Mainly production processes
Process of use	Define Measure Analyze Improve Control	Identify value Identify value stream Flow Pull Perfection
Focal point	Problem-centered	Process-centered
Approach	Education of general problem-solving approach based on statistics	Education of principles, introduction of best practices with stable methods
Project duration	2 - 6 months	1 week - 3 months
Infrastructure	Dedicated resources, wide range education	In small, but changing teams

Source: was constructed by the Author, based on literature [48]

Conclusions

Six Sigma is the best quality improvement method of the past 20 years, aiming to optimize processes and reduce defects in a business system. In our research, we examined the relevant technical literature to demonstrate that Six Sigma can be easily built into other quality improvement methods, one of which being Lean Management. By mixing the two methods, the resulting Lean Six Sigma may yield a much better outcome. The result of the LSS development is a new standard which establishes further process improvement opportunities assuming its sustainability is guaranteed. The Six Sigma method envisions a potential future for all enterprises, if the goal is to increase customer satisfaction. The tools of Six Sigma are very simple and easy to learn, if the situation, weaknesses and strengths of the given system and processes are properly identified. This is an indispensable requirement of implementing development in one's future work. In the future, complete education of employees of the Six Sigma tools, is very important. If an employee understands the significance of Six Sigma, they will be able to overcome obstacles and implement this system in their work.

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