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Quality Tools and Their Applications in Industry

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ABSTRACT

Almost all quality improvement methods require data collection and analysis to solve quality problems. The combination of six sigma and agile creates a six sigma agile methodology that aims to reach quality levels according to the Six Sigma requirements of 3.4 defects per million measurements. In order to achieve these objectives, it is necessary to know the industry well and implicitly the product or the analysed process. Thus, the correctness of these analyses depends on the collection of the data that will be analysed. The use of data analysis methods at each stage, especially in the measurement and analysis stages, is critically important for making strong decisions. The purpose of this article is to present the added value of the integration of six sigma and agile methodologies for IT projects. Thus, the integration of the two methodologies will lead to faster decision-making without the risk of an increase in the number of failures.

KEYWORDS

Agile, Process Performance, Six Sigma, Statistical Indicators

INTRODUCTION: QUALITY TOOLS AND THEIR APPLICATIONS IN INDUSTRY

Companies strive to develop and be sustainable in order to face all challenges (Stojcic et al., 2018). Thus, they implement effective continuous improvement methodologies such as Six Sigma or Agile, which assume the improvement of the existing model at the company level and lead to an increase in the company's ability to reduce the number of timely responses to possible risks that may arise.

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The concept related to the process model starts from the very simple principle that the organization itself represents a process or, rather, a series of coherent and interconnected processes, which allow the creation of a product that satisfies the client and other interested parties (Womack & Jones, 2006; Schwab, 2016).

Based on the definition of the process, presented in Figure 1, the raison d'être of an organization is to transform with the help of coordinated activities, and input data into output data at the same time as bringing added value to each individual process.

LITERATURE REVIEW

Six Sigma is a systematic approach based on data that aims to perfect the existing process. In Six Sigma, the DMAIC methodology (define, measure, analyze, improve, control) is used, and for the development of new products, the Six Sigma DFSS design method is used. (GE, 2004)

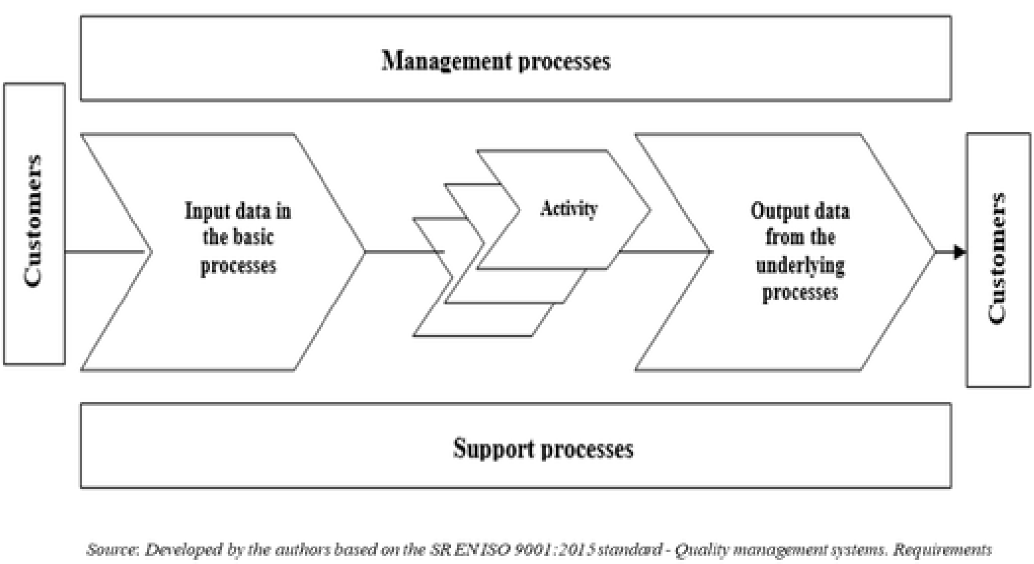
Statistical tools are systematically used in each stage of DMAIC and DFSS in order to find the root cause of the problem and eliminate it by applying effective improvement solutions. Among all these, the following tools are considered most important: SIPOC, Statistical Process Control, Process Capability Analysis, Measurement System Analysis, Experiment Design, Quality function deployment, Fault Tree Analysis, Statistical Regressions, Analysis of means and variances, Root cause analysis, Process mapping (Wanga & Chen, 2020; Pyzdek, 2003).

The application of the tools used in Six Sigma and Agile in cloud-based intelligent production is an element of novelty through the integrated approach of the two methodologies. Cloud-based intelligent manufacturing facilitates a new variety of applications and services to analyze a large volume of data and enable large-scale collaboration in manufacturing (Qinglin & Tao, 2019).

RESEARCH METHODOLOGY

The main objective of the proposed model is the integration of the concepts of Six Sigma and Agile. The proposed research methodology, from a quantitative but also a qualitative point of view, requires

Figure 1. The general model of a process



Source: Developed by the authors based on the SR EN ISO 9001:2015 standard - Quality management systems. Requirements a practical approach as well. Quantitative methods were applied for statistical calculations of process performance measurement during the application of Six Sigma projects and the interpretation of the data from the collected questionnaires. Qualitative methods were applied to analyze a wide range of specialized literature in order to propose a new model that integrates Six Sigma and Agile methodologies (Black & Revere, 2006; Chang et al., 2012; Chen et al., 2005).

Six Sigma is a strategy for continuous process quality improvement used in many fields of activity. In general, Six Sigma is a process improvement methodology that reduces product defects, minimizes process variations and improves capabilities in manufacturing processes. Six Sigma offers two major perspectives: One is the statistical perspective, and the other is the managerial perspective. From a statistical point of view, the term Six Sigma is defined as having less than 3.4 defects per million products made or a success rate of 99.9997% (Figure 2) (Pande & Holpp, 2002; Pande et al., 2000; Pande et al., 2002).

Six Sigma is a systematic approach based on data that uses the DMAIC methodology in order to perfect the existing process and the Six Sigma DFSS (Design for Six Sigma) design method for the development of new products (GE, 2004). As a structured approach, the DMAIC model (Table 1) can provide an organization with a series of pragmatic solutions from the point of view of the evolution of a process or product (Parast, 2011; Popescu & Mandru, 2016; Psomas et al., 2018).

Figure 2 The normal distribution in the context of six sigma

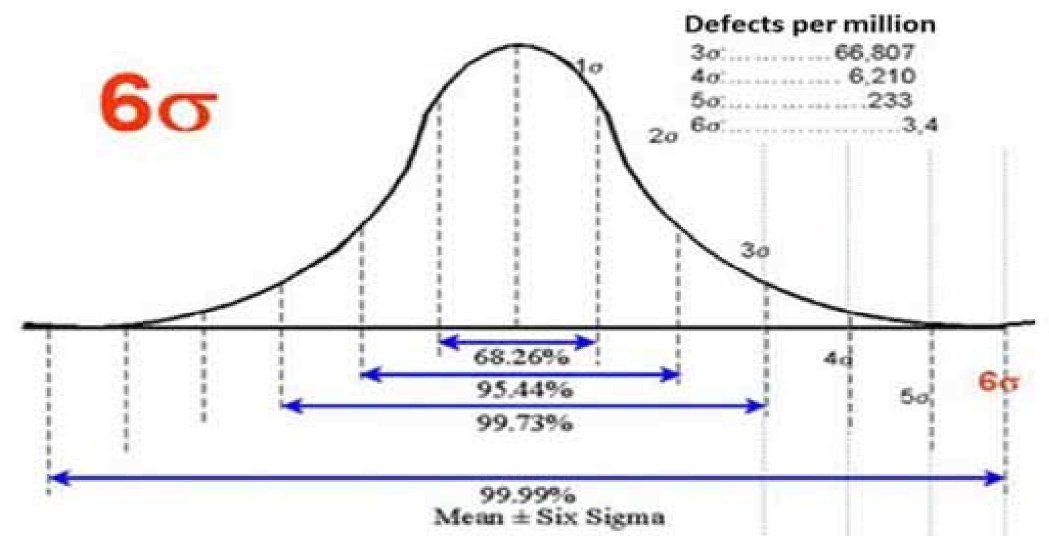


Table 1. The DMAIC model ke

Phases	Definition	Measure	Analysis	Improve	Control
Activity	Defining the current situation ↓ Defining the desired situation	Identification of potential causes ↓ Quantifying the problem	Analysis of possible causes ↓ Selection of initial causes	Identification of potential solutions ↓ Selection / implementation of solutions	Effectiveness control over time ↓ Implementation of means of control
Result	Defining the problem. Potential advantages	The origin of the problem and the list of causes	Quantified causes and selected initial causes	Pilot solutions and their final implementation	Process control and monitoring Confirmed benefits

Source: Six Sigma Institute https://www.6sigma-institute.org/.

Being a process optimization methodology, Six Sigma can be integrated with other improvement methodologies. The integration of the Six Sigma methodology in the Agile methodology leads to the creation of a fairly powerful tool that can bring added value to any process. The Agile model first appeared in the software development industry, wanting to be a Code of Good Practice to which practitioners in this industry adhere.

Since the Agile methodology emphasizes the inclusion of the client's representative in the project implementation team, the integration of this methodology in the Six Sigma methodology helps to obtain meaningful results throughout the entire process. The quality and predictability of the process is increased within the Agile methodology because at any moment of the project it is known what functionalities existed at the end of the previous moment and what functionalities will be at the next moment.

If we analyze the Agile methodology from the point of view of the PDCA cycle in quality management as shown in Figure 1, this can be integrated with other improvement methodologies and can have the graphic form presented in Figure 3 (El Manzani et al., 2019; Troshkova & Levshina, 2018; West & Cianfrani, 2015; SR EN ISO 9000:2015; SR EN ISO 9001:2015).

The main objectives of the proposed model are: (i) the integration of the concepts of Agile and Six Sigma, (ii) the execution of integrated projects, and (iii) recommended tools in order to improve the performance of the process. The new model is an integrated conceptual model, which is developed based on the Six Sigma Methodology (by default DMAIC) integrated with the conceptual requirements of the Agile methodology (Nonaka & Takeuchi, 1995; Pamfilie & Procopie, 2013).

The set of tools used within the DMAIC methodology (Figure 4) will also adapt to the new methodology in such a way that the approach oriented towards concrete results of Six Sigma can also be found in the new model.

In the process of optimizing the activity of an organization, Agile was introduced in all phases of the DMAIC model (Hellman & Liu, 2013; Juhani et al., 2016; Luburić, 2019). This is how the model called DMAICA was developed (the DMAICA model—Integration of Six Sigma, Agile methodologies). This model is presented in Table 2.

As shown in the Table 2, the proposed model is composed of seven stages described as follows:

Figure 3. Agile methodology

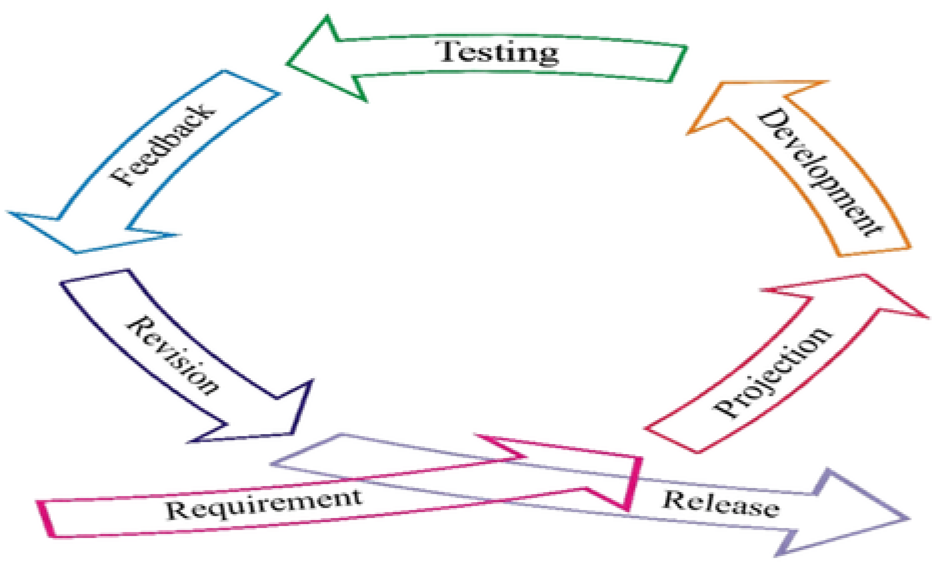
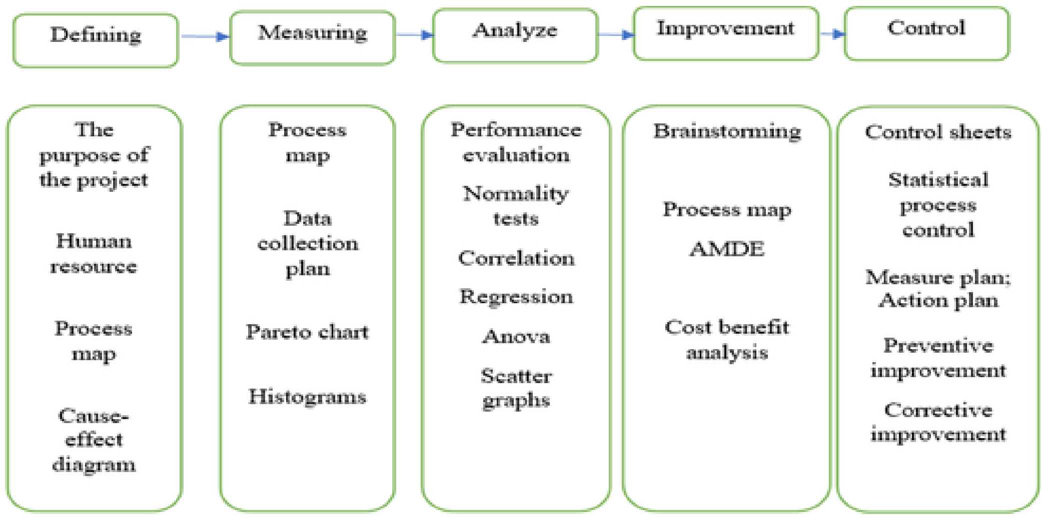


Figure 4. Tools used within the DMAIC methodology



Source: Developed by authors based on https://www.sixsigma-institute.org

Table 2. The DMAICA model: integration of agile, six sigma methodologies

Stages	Activities	Tools and approaches used
Stage 1	Planning the realization of the phases of the AS Methodology	Agile Six Sigma concept Development of the communication methodology within the organization Development of the communication methodology with clients Development of the strategic plan Development of a training plan for the executive management and members of the work teams
Stage 2	Identification of activities for each AS phase	Development of the list of activities for each phase of the analyzed methodology
Stage 3	Using work tools for each activity	Six Sigma tools used for each phase—the use of statistical tools in the context of the need to clarify the analyzed data
Stage 4	Gathering new knowledge and ideas to improve the process	Involvement of the entire team and clients in the process of collecting and identifying new ideas through workshops, brainstorming sessions, priority matrix, histograms, and Pareto
Stage 5	Innovation in the context of Six Sigma and Agile	Establishing the results regarding the sustainability of the organization Innovation project control in the context of Six Sigma and Agile Modifications of the innovation project in the context of Six Sigma and Agile
Stage 6	Use of acquired knowledge	The launch of the project Constantly informing the client about the results of the project
Stage 7	Project performance evaluation	Evaluation of process results Process analysis The impact of project results on the organization Calculating the added value of the organization through project implementation Conclusions regarding the impact the project has on the organization

Source: Authors' own contribution

- *Stage 1*: Planning the realization of the phases of the ASI Methodology. The purpose of the first stage is to develop a common framework in order to implement the proposed methodology according to the recommendations of the Six Sigma standard (Vujović et al., 2017).

In this stage, the context of the implementation of the methodology must be defined, emphasizing the development of a common approach within the implemented projects.

- *Stage 2*: Identification of activities for each AS phase. In this stage, all the specific tasks of the different DMAIC phases should be identified according to the recommendations of the Six Sigma standard (ISO 13053 - 1 & 2, 2011). This standard describes the Six Sigma methodology, which usually includes five phases:
- *Stage 3*: Using the work tools for each activity. The use of statistical tools in the context of the need to clarify the analyzed data is done in order to bring an added value to the process. Thus, concepts such as variation, mean, dispersion, standard deviation, distribution, ANOVA, regression analysis, correlation analysis, adjustment analysis, normality tests, and hypothesis tests will be used.
- *Stage 4*: Gathering new knowledge and ideas to improve the process. Involvement of the entire team and clients in the process of gathering and identifying new ideas through workshops and brainstorming sessions. The specific elements of the Agile methodology will be integrated into the Six Sigma methodology in order to ensure traceability regarding the development and implementation of the project using the new methodology.
- *Stage 5*: Innovation management in the context of Agile Six Sigma. In this stage, emphasis will be placed on the development of the innovation process, the establishment of results regarding the sustainability of the organization, the control of the innovation project in the context of Agile Six Sigma, and changes to the innovation project in the context of Agile Six Sigma. Specific monitoring and control tools will be used in order to identify the possible risks that may appear in the innovation process. The tools used are: SWOT Analysis, Probability - Impact Matrix, AMDE - Fault Tree Analysis and decision trees, Priority Matrix, Cause-Effect Diagram.
- *Stage 6*: Using the acquired knowledge. During this stage, the emphasis is on project execution and permanent communication with the client, which implies that there will be constant feedback from the client. This stage will take place in accordance with the PDCA cycle applied for processes as follows:

Where:

"PLAN" establishes the objectives and processes necessary to obtain results in accordance with the client's requirements and the organization's policies;

"DO" implements the processes;

"CHECK" monitors and measures processes and products against the policies, objectives, and requirements specified for the product and reports the results;

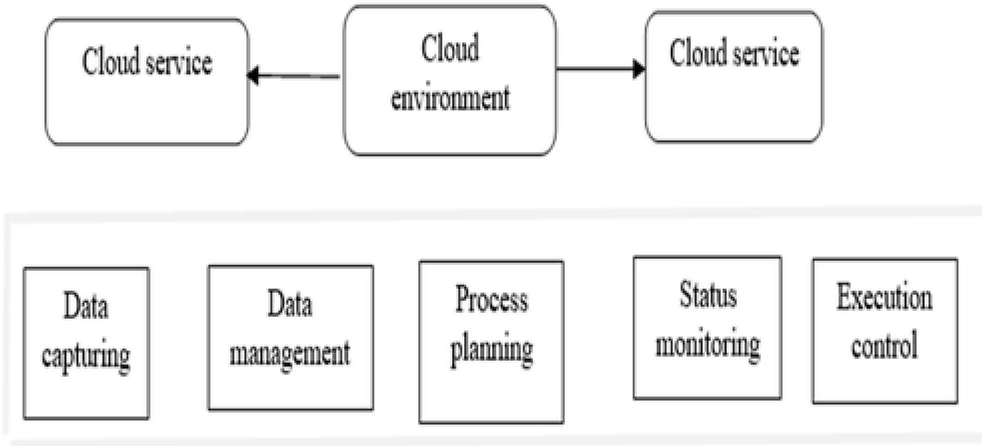
"ACT" applies actions for the continuous improvement of process performance.

- *Stage 7*: Evaluation of project performance. In the framework of this last stage, there is an evaluation of the process results, and the analysis of the process and the impact of the results on the organization are followed. All this is analyzed from the perspective that the added value of the organization will be calculated by analyzing the efficiency and effectiveness indicators and establishing conclusions regarding the impact the project has on the organization.

RESULTS

The application of a DMAICA model within a company whose activity is centralized in the cloud transforms traditional production models into intelligent models, adaptable to each situation. Cloud-based production applications can be shown in Figure 5. The physical production system covers all physical devices as well as all users. The upper layer represents data processing, process control, and

Figure 5. Cloud-based production applications



service management in the cloud environment that provides non-physical services and applications for users in the production life cycle.

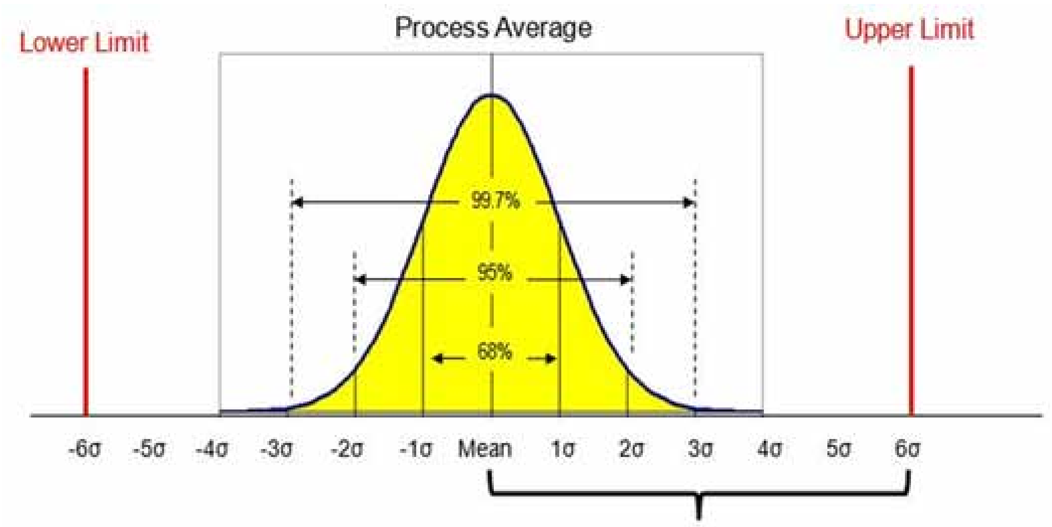
The integration between physical devices, users, and the cloud is possible by introducing data and functions within services. In addition, data is collected from the physical manufacturing system and transmitted through the network. Through cloud-based solutions, manufacturing companies are able to develop better integrated and more efficient processes with lower costs.

The intelligent production system involves several levels. *The base layer* is represented by smart devices, which are the data sources. *The middle layer* is the data transmission network. *The upper layer* is the cloud, where big data is stored and analyzed. Through the computing, storage, and network capabilities of nearby nodes, edge computing and fog computing reduce the data sent to the cloud and the probabilities of service interruption, ensuring the robustness of the intelligent production system. Edge computing, fog computing, and cloud computing cooperate with each other, better fulfilling the requirements of intelligent production applications.

In this sense, the application of the DMAICA methodology is essential in the process of data collection and interpretation in the case of intelligent production applications. The use of statistical tools helps us in the analysis of process variation, which can have two causes: a common cause or a special one. Common cause is given by any unaccepted source as part of random inputs to processes. The special cause is seen as any unaccepted external source that influences the process. The use of statistical tools is essential in the context in which the capacity of the process can be discussed in order to identify its stability. The variation index is used to represent the process capability. There are two indices that help to analyze process capacity: C_p - called process capacity and C_{pk} - sometimes called process performance precisely to be distinguished from process capacity. C_p can be used if the average of the process is centered on the target value, being a measure of the width of a distribution, of the outputs from the process. C_p shows how close the new measurements can be to the characteristics of the product or service. C_{pk} shows the same thing, but also how the average value is compared to the target value.

Also, C_p and C_{pk} suppose that the process is statistically stable and that the data are approximately normally distributed (the normal distribution is one of the most important distribution laws and is known as Gauss's law or Gauss-Laplace–Figure 6).

Figure 6. Gauss's law



To calculate C_p and C_{pk} use the specifications and process widths. The specification width is the difference between the upper specification limit - Ls and the lower specification limit - Li, or the upper tolerance limit and the lower tolerance limit. If it is decreased, Ls - Li, the width of the specifications is obtained.

The width of the process is the difference between the upper control limit Ls and the lower control limit Li, these two limits showing how the process works. If it is decreased, Ls - Li the width of the process is obtained. The width of the process can also be calculated by multiplying the standard deviation by 6.

Process capacity—C_p is usually expressed as the specification width divided by the process width and shows the instantaneous capacity of the process.

C_p = specification width/process width or USL - LSL/6σ

Process capacity indicates the potential short-term performance level that a process can achieve.

If C_p <1, the result of the process exceeds the specifications the process is incapable

If C_p =1, the process hardly meets the existing specifications

If C_p >1, the result of the process falls within the specifications, but defects may occur if the process is not centered towards the expected result.

Thus, the higher the C_p, the less variations there are in the process. C_p is used for continuous data and is based on several assumptions.

As C_p does not take into account the centering of the process, it is not used alone to describe the performance of the process, and together with C_{pk} measures the ability of the process to fulfill the requirements or specifications established by the customers considering its short-term variant. C_{pk} is the ratio of the measured distance between the process average and the specification/tolerance limit closer to half of the total process spread. The tolerance (T) is specified by specifying the upper limits Ls and the lower limit Li:

T= Ls - Li

So that C_{pk} indicates the level of performance that a process can reach, taking into account its average. Cpk is interpreted as:

If $C_{pk} = C_p$, the average of the process is the expected one
If $C_{pk} = 0$, the average of the process falls within one of the specification limits
If $C_{pk} < 1$, the process average is completely outside the specification limits

C_{pk} is used for continuous data and assumes that the process is statistically stable and that its data are normally distributed. If the data distribution is irregular, C_{pk} takes into account the central value of the process and the short-term variance; for this reason it is only used together with C_p. All the statistical information analyzed helps us to identify the performance indicators of the process and implicitly the added value through the application of the methodology.

CONCLUSION

Effective understanding of these methodologies and their relationship will give companies a competitive advantage. Many organizations use one of the methods as a basis for continuous improvement. As such, the relationship between Six Sigma and Agile, as well as the development of an integrated model, is an opportunity for organizations to perform well.

It is known that successful organizations strive to stay ahead of their competition by effectively implementing continuous improvement methodologies. The application of the DMAICA methodology leads to the development of solutions in order to increase the efficiency, effectiveness, and implicitly the productivity of the organization.

CONFLICT OF INTEREST STATEMENT

Ana Maria Ifrim, Cătălin Ionuț Silvestru, Mihai-Alexandru Stoica, Cristina Vasilica Icociu, and Marian Ernuț Lupescu declare no conflicts of interest. Ionica Oncioiu is the Editor-in-Chief of the International Journal of Innovation in the Digital Economy.

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