USE OF STATISTICAL METHODS IN SIX SIGMA PROJECTS

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Abstract

This paper is focused on the issue of quality improvement projects through Six Sigma methodology. In doing so, we follow the use of various statistical methods and highlight to adapt them to the specific conditions in the company. Adaption of used statistical methods are described and explained in different parts of this paper, including also the identified expected benefits. The term of quality improvement is based on basic quality improvement tools. In this paper we use mainly these tools and also the results of design of experiments and analysis of processes in selected automotive company. The importance of quality improvement is based on the topic of company competitiveness on the market. We reduce the time of completion of vehicle in automotive company in Slovakia significantly with respect on the higher quality.

Key words: statistical methods, Six Sigma, Automotive company, project, Quality tools

JEL Code: C61, M11

Introduction

Design for Six Sigma (DFSS) is a concept developed to improve and structure development processes and their included activities within an organization (Fouquet and Gremyr, 2007). It has its roots in the discipline of systems engineering and its general idea is to develop robust and innovative products that the customers want, are willing to pay for and that are possible to be produced (Gremyr, 2007). DFSS comes from the six sigma methodology, proven over the past couple of decades by companies such as GE, Motorola and Dow Chemical. They use it to improve their ability to meet customer requirements, reduce complexity and/or reduce variability in operations. A subset of Six Sigma, Design for Six Sigma (DFSS) applies Six Sigma principles to the new product development process, emphasizing that decisions made in the early phases of designing and engineering could have a profound effect on subsequent activities to build and deliver new products. At the center of DFSS approach, is a five-step process, DMADV, which is an acronym- Define, Measure, Analyze, Design, and Verify.

According to Yang (2003) original Six Sigma is also called Six Sigma improvement, which aims to improve process without design of complete revision of current system. Design for Six Sigma focuses mostly of design and is trying to „do things right at the first time“. The goal of DFSS is to ensure, that process or product:

- do the right things,
- do the things right all the time.

It is also necessary to mention that DFSS implementation is an expensive undertaking and without understanding this phenomenon, companies may abandon the implementation prematurely without realizing optimum benefits from such an implementation.

1 Six Sigma application project

We decided to implement the Six Sigma project under specific conditions of a trailers producing manufacturing. Prior to the process implementation, the company was attaining 64.1% average customer satisfaction level, whilst the indicator was reaching rating of 70.5% within the competitive environment. Whereas competition is growing in this branch of the machine industry the company management decided to make their manufacturing processes more effective, and thus to attain higher work efficiency, improvement of processes, and subsequently to boost profitability as well. Though the company is introducing their products to the market for competitive prices it is striving with adhering to contractual deadlines for supplying the final products. Devised for the plant under consideration, after performing detailed data analysis was a regressive model parameters of which were the waiting time for production of the new trailers and waiting time to implement claims, and the dependent variable was rise in the number of new customers. The available data rendered the management to be able to compare their company with competitors on the market, when the conclusion was that average on the market operating companies were producing comparable products in 37 days, whilst the top ones in 33 days. The studied plant lagged behind the average, because the production schedule of a single product was stated to be 41.61 days. Therefore, the company management decided to implement the project Six Sigma in terms of DMAIC cycle.

Tab. 1: Description of the Six-Sigma Project

DEFINE	Defining the exact process objective, increasing satisfaction of the customer, identifying the customer, creation of the process map.
MEASURE	Monthly monitoring of satisfaction of the customer, monitoring costs of production of a single product.
ANALYZE	Based on the “measure” phase the customer satisfaction target was set to 87%.
IMPROVE	Upgrading of the production process in terms of rearrangement of the production line in the hall, motivating of employees through higher financial remuneration, devising a model of substitutes for the case of absenteeism.
CONTROL	Monitoring changes after realizing the improvements.

Source: own processing

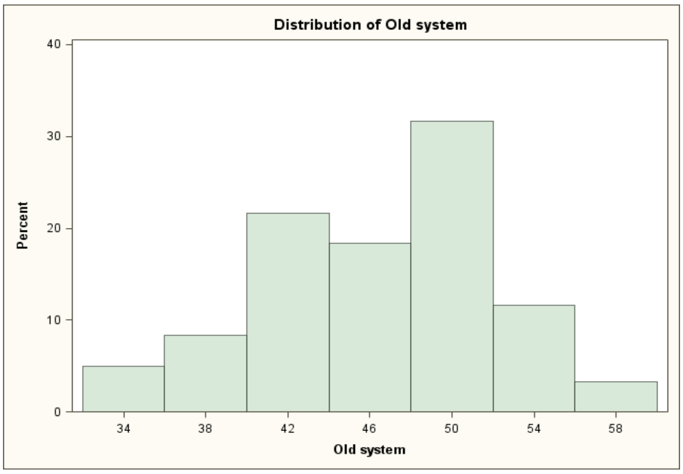
1.1 Technological process of trailers manufacture

As the entire Six Sigma project presents a collection of measures, attention is in this paper primarily paid to changes in design and in the production line from the point of technological processes employed in manufacture of the trailer. Cutting the costs represents the major process of possibilities when looking for the company economic efficiency. At a time, cutting of costs cannot reflect in poorer quality of production, i.e. of the product – the trailer. Therefore it is e.g. necessary to optimize arrangement of some structural elements that would result in enhanced trailer ergonomics and safety of passengers. Apart from the technical solution it is necessary to optimize the assembly procedures to entail future disassembly a recycling, and not only the very product. Based on the above-said, in the paper we intend to optimize technology of the structure. Target of the process optimization is seen in improving the assembling processes allowing for the plant disposable spatial possibilities. Assembly is being realized in a standard rectangular hall in which redundant ineffective relocations of unfinished products were common in the past. Outputs of individual production processes were manipulated, between individual hall sites, manually. For analyzing the selected sub-processes was used design of experiment to verify the possibility of reduction the time of this sub-process based on selected criteria.

Defined in our proposal were two parallel production branches; one was intended for completion of the bodywork, the other one of the trailer chassis, and subsequently the branches merge into common completion operations section. Assembled within the joint section are the interior elements and finalized are parts of the exterior. Working in the assembly process are 4 operators and a foreman who, in the controlled documentation, approves of proper performance of works pursuant to approved procedures by attaching his/her hand. The document is then turned over to the client as the trailer safety-supporting document.

The outlined process changes of the manufacture rearrangement resulted in the trailer assembly time savings by 10 %. Eventually, this surfaced in the form of increase in the company profitability by 7.122 % as compared with the status existing prior to the Six Sigma project implementation. Originally we have, on the sample of 60 trailers, monitored and identified time of their assembling. Whereas within the company operational conditions it is rather problematic to measure the production time in days, it would be very arduous to identify it for as many as 60 trailers when concurrently incorporated into production were changes as well. Therefore, measured in the form of an experiment was time of individual activities or processes, and subsequently calculated was the production time reflecting the changes that were introduced. Within the system, analyzed were minor changes in elements and in the production system that were financially undemanding, and the alternative was to implement the Six Sigma project. For the reason we decided to analyze normality of individual time-sets of the trailer manufacture according to the production manners – the original one and the proposed one, respectively (Fig. 1).

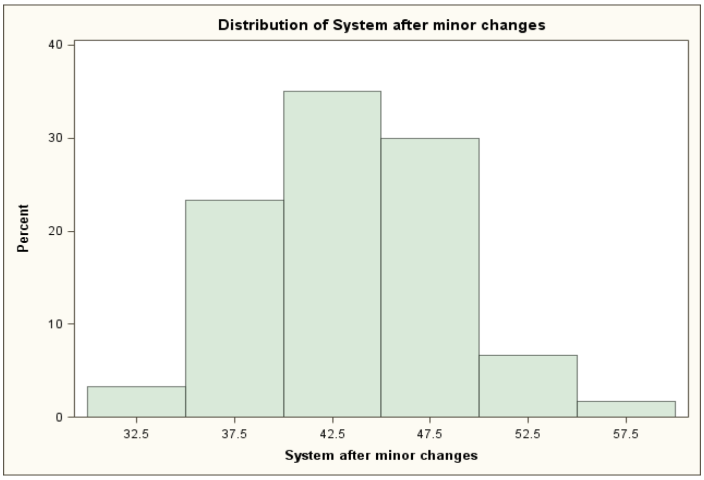
Fig. 1: Histogram of distribution measurements before introducing Six Sigma project



Source: own processing

In our case it is possible to effect minor changes in the company. Based on identifications of these changes defined were subsequent measurements of the trailer assembly times. As it can be seen in Fig. 2, the share of non-centric times is minimized, and the set approximates a normal distribution.

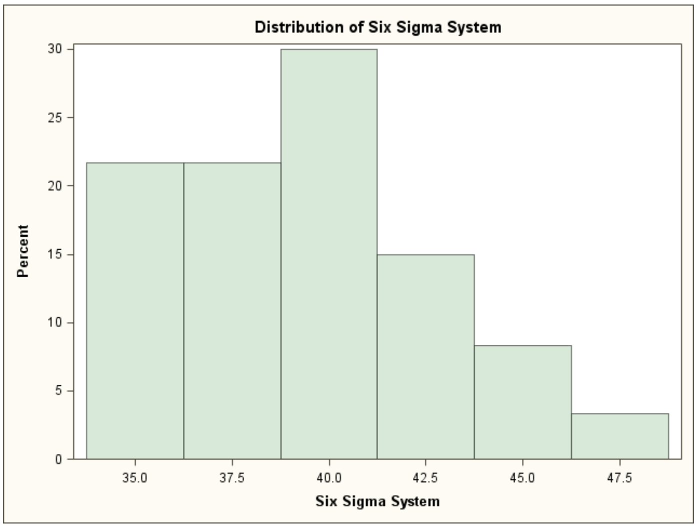
Fig. 2: Histogram of distribution of system measurements at start of the Six Sigma project realization



Source: own processing

Upon introduction of the Six Sigma methodology the trailer assembly time comes shortened. Paradoxically, what we obtain is a rightward skewed set (Fig. 3), and hence the proportional occurrence of trailers whose installation ran longer than the average time, is reduced.

Fig. 3: Histogram of distribution of system measurements after introduction of the Six Sigma project



Source: own processing

For all monitored sets it can be seen (Tab. 2) that they meet by statistical testing verified normality condition.

Tab. 2: Normality tests

Goodness-of-Fit Tests for Normal Distribution				
Test	**Statistic**		**p Value**	
Old system (OS)	**D**	0.11102336	**Pr > D**	0.066
System at the project beginning (SAMC)	**D**	0.08885548	**Pr > D**	>0.150
Six Sigma System (SS)	**D**	0.11009861	**Pr > D**	0.071

Source: own processing

Improvement can be presented also by use of measured data, analytically evaluated by statistical methods. The Six Sigma project brought about improvement in the form of shortened assembly times. Relevant data are presented in Tab. 3.

Tab. 3: Linear regression

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	1313.477778	656.738889	28.15	<.0001
Error	177	4129.916667	23.332863		
Corrected Total	179	5443.394444			

R-Square	CoeffVar	Root MSE	No. of days Mean
0.241298	11.28747	4.830410	42.79444

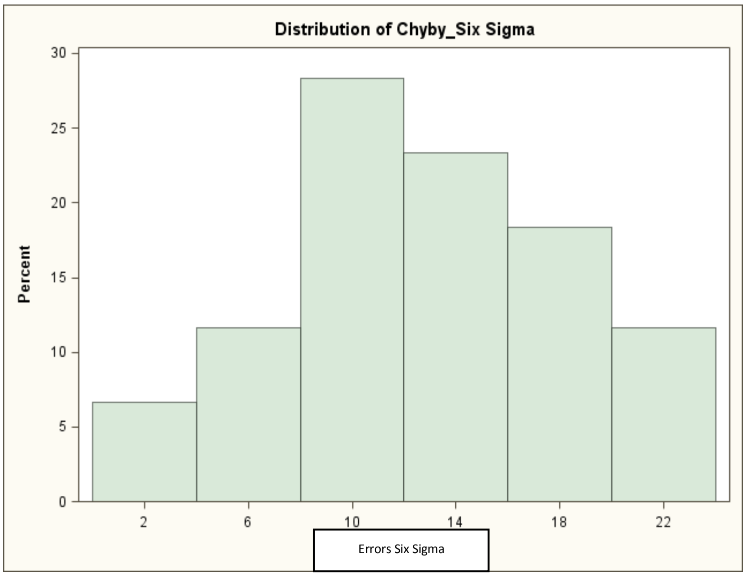
Source: own processing

1.2 Proposal of the model for evaluating economic effectiveness of the Six Sigma project

Implementation of Six Sigma methodology in production and individual processes is a highly important decision of the company management, as it is yet to be ascertained that the change would be economically effective. As it can be seen, originally prolonged trailer assembly time was due also to larger number of faults or discrepancies in the production process. We are finding out that each trailer produced was reported to suffer from 110 recorded faults, anomalies or discrepancies with the process quality criteria in average.

Recorded after implementation of the Six Sigma project reported were, in average, 12 discrepancies or fault and deviations from the criteria per one trailer. The fact was analyzed and verified on 20 trailers produced by new workflow methodology. The differences are graphically illustrated in Fig. 4.

Fig. 4: Histogram of distribution of number of assembly faults after implementation of the Six Sigma methodology



Source: own processing

Significant is the facts that after applying the Six Sigma project the number of faults and defects resulting from poor quality process markedly dropped. Then, it is necessary to exactly analyze effectiveness of individual changes. Within the frame of implementing individual processes we were quantifying the improvements. Thus, we take the reported values for economic effectiveness of the Six Sigma project. The relation between benefits and costs that have to be expended to acquire those benefits defines effectiveness.

Next, defined from the point of overall effectiveness of production can be optimum succession of processes. Like this, we can develop a non-ascending sequence of effectiveness values. We have attained the reported improvements by elimination of redundant assembly processes that were increasing the error rate. From the point of the product, the documented defects or incongruities were not critical. Yet, the redundant steps presented time delays in the trailer assembling. Trailer production capacity was 115 units per year in the original unoptimized system work in the company. In our case, using the Six Sigma methodology optimization steps we reached improvement in the effective production capacity growth on the level of 132 units per year. By introducing the specific Six Sigma project we managed to cut the operating expenses per one trailer through shortening of the production cycle within the frame of wage costs category, whereas eliminated have been redundant assembly processes and operations. In our reported case the average trailer assembly time dropped from 41.51 days to 35.5 days. Using the fact we can calculate savings in the labor costs provided the company would decide not to increase the production volume but to realize optimization through layoffs. We have found out that the reported potential savings amount to, considering the overall labor costs, 2071.12 EUR per month.

Conclusion

Explored in the paper was the issue of Six Sigma methodology and its support by employing more exact methods of evaluating and it's applying in the form of case study within a specific unnamed company. We have verified that Six Sigma can indeed help in attaining economic benefits measurements of which are to be demonstrated and recorded. It is exactly quantification of benefits of these qualitative changes in a company that is extremely arduous and problematic. For the reason we decided to define the process of evaluating improvements using the exact functions that would "standardize" pinpointing of those processes changes in which result in ultimate effects, and hence in the most favorable benefits for the expended project costs. We have attained the above stated by defining the functions that feature unambiguously defined properties. Six Sigma represents an effective way through which can a given company attain competitive advantages. The improvement of assembly process of vehicles in this company will reduce the labor costs per each vehicle and the cut the time of assembling the vehicle from 41.51 days to 35.5 days and based on this fact the capacity of company raise from 115 units (vehicles per year) to 132 vehicles per year.

References

Atmaca, E. & Girenes, S. S. (2011) Lean Six Sigma methodology and application. *Quality & Quantity, 47(4)*, 2107-2127.

Eckes, G. (2003). *Six sigma for Every One*. New York: John Wiley.

Eckes, G. (2003). *Six sigma team dynamics the elusive key to project success*. New York: JohnWiley.

Feigenbaum, A.V. (1983). *Total Quality Control*. McGraw – Hill: New York.

Fouquet, J. (2012). Design for Six Sigma and lean product development. *International Journal of Lean Six Sigma*, *3(1)*, 45-58.

George, M. L. (2003). *Lean Six Sigma for service how to use Lean Speed and Six Sigma Quality to improve services and transactions*. New York: McGraw-Hill.

Chowdhury, S. (2003). *Design for Six Sigma: the revolutionary process for achieving extraordinary profits*. Harlow: Prentice Hall/Financial Times.

Larson, A. (2003). *Demystifying six sigma a company-wide approach to continuous improvement*. New York: AMACOM.

Lee, K., & Su, Y. (2013). Applying Six Sigma to Quality Improvement in Construction. *Journal of Management in Engineering*, *29(4)*, 464-470.

Pande, P., & Cavanagh, R. (2002). *Zavádíme metodu Six Sigma, aneb, Jakým způsobem dosahují renomované světové společnosti špičkové výkonnosti*. Brno: Twins Com.

Ray, S., Das, P., Bhattacharyay, B., & Antony, J. (2012). Measuring Six Sigma Project Effectiveness using Fuzzy Approach. *Quality and Reliability Engineering International*, *29(3)*, 417-430.

Riley, B.W., Kovach, J.V. & Carden, L. (2013). Developing a Policies and Procedures Manual for a Consumer Lending Department. *A Design for Six Sigma Case Study*, *25 (3)*, 1042-9247.

Smith, D., & Blakeslee, J. (2002). *Strategic Six sigma best practices from the executive suite*. Hoboken, N.J.: John Wiley.

Thomsett, M. C. (2005). *Getting started in six sigma*. Hoboken, N.J.: Wiley.

Truscott, W. G. (2003). *Six sigma continual improvement for businesses : a practical guide*. Amsterdam: Butterworth-Heinemann.

Wessel, G. (2002). A Comparison of Traditional TQM Methodologies with the Six Sigma Approach for Quality Management. Retrieved April 20, 2014, <http://www.six-sigma-quality.de>.

Zhang, Y., He, Z., Chen, T., & Zhang, M. (2013). Assembly Process Improvement in Company S: A Lean Six Sigma Case Study. *Advanced Materials Research*, *655 - 657*, 2371-2374.

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