1st Logistics International Conference
Belgrade, Serbia
28 - 30 November 2013

THE SIX SIGMA DMAIC METHODOLOGY IN LOGISTICS

Ana Mijajlevski*
NIS Gazprom Neft, ana_mijajlevski@yahoo.com

Abstract: *Logistics is the base of modern business, providing competitive advantages for companies on the market. Six Sigma is a data driven approach that lead to fact-based decisions, a methodology centered on understanding and eliminating the negative effects of variation it the processes. Great positive effects can be reached by applying this concept to the logistics, leading to the satisfaction of the clients, eighter internal or external, and finally to the financial benefit. This paper proposes the primary method of Six Sigma Logistics- DMAIC (Define-Measure-Analyze-Improve-Control). It presents the improvement of internal logistical processes by applying Six Sigma tools. The result is reduction in the number of defects, a reduction of a route time variability, and the reduction of the mean route time.*

Keywords: *Logistics, Six Sigma, variability, DMAIC.*

* Corresponding author

1. INTRODUCTION

Six Sigma is a highly disciplined method of data collection and treatment that makes use of statistical tool, and requires a significant involvement of senior management and a hierarchy of workers with the necessary training. In technical terms, Six Sigma signifies a defect level below 3.4 defects per million opportunities (DPMO), where sigma is the term used to represent the variation of a process around its mean (Linderman, 2003).

The concept of variation reduction is paramount to the logistician. Logistics is about managing inventory, and managing inventory is about managing variance. Safety or "buffer" stocks are inventories needed to hedge against unknowns (i.e., the variation from the norm). Safety stock is maintained because of variation in supplier quality, transportation reliability, manufacturing process capability, and customer demand patterns. If variation in the processes from supplier to customer can be understood and controlled, a reliance on the buffers will be dramatically reduced. Variances in inbound and outbound logistics and variances in production control lead to the production stoppage, losing customer loyalty and losing customers or to reserving the liquidity in inventory. The principal objective of the Six Sigma methodology consist of the reduction of the variability associated with products/processes. It can be implemented either to forward or reverse logistics.

The Goal of this document is defining the usage of Six Sigma DMAIC methodology in the field of logistics. The document is divided in three sections. The Section 1 gives brief review of Six Sigma literature regarding definitions and the usage of its concepts, the Section 2 defines the DMAIC methodology, while the Section 3 presents the case study that concerns the usage of Six Sigma methodology.

2. LITERATURE REVIEW

The Six Sigma concept was first introduced by Motorola Company in the mid 1980s, built on the philosophy of Total Quality Management. Since its inception, thousands of organizations have become 'Six Sigma companies' and a number of variants on the original concept have been developed, often combining Six Sigma with ideas from other improvement approaches.

Dean and Bowen (1994) defined QM to include techniques and a set of principles and practices. The monetary aspect was then emphasised by Harry (1998), Hahn et al (1999), Montgomery (2001).

The need for a common definition of Six Sigma was first emphasized by Linderman et al (2003). The goal of less than 3.4 defects per million opportunities was suggested, but was not included in the definition because 'Six Sigma advocates establishing goals based on customer requirements'.

A trend of diversification of research topics from primarily manufacturing focused to more general in nature (service-related) included an increasing academic participation and broader focus than solely on manufacturing.

Another trend of omitting the statistical texts and theory and simplifying standard statistical methods was presented by Hahn et al (2001). The Six Sigma became more like a practice than a core method, as defined by Sousa and Voss (2002).

The literature review allows emerging trends and issues in Six Sigma to be highlighted, enabling the future work to progress as Six Sigma continues to develop and evolve. It also open up new opportunities to apply Six Sigma in the fields that are not widely explored before.

3. DMAIC METHODOLOGY

DMAIC is one of the key pillars of achieving Six Sigma. Put simply, DMAIC is a means to an end. It does not necessarily determine the end, but rather provides the roadmap. Developed by using the voice of the customer and voice of the business tools, DMAIC pursues the opportunities for improvement, recognized in strategic analyses.

In order to implement the methodology successfully a company must be aware of the importance of the success factors such as:

- top management commitment
- team training
- data system (the valid data should be fully considered in order to avoid garbage in/garbage out effect)
- standardised procedures (standards allow setting expectations and the assessment of the current processes)
- forming the right team
- bottom line focus
- team involvement
- change management (flexibility) etc.

The methodology includes as its phases Define, Measure, Analyze, Improve, and Control.

3.1 Define

The Define phase consist of:

- Defining the problem by developing a "Problem Statement"
- Defining the goal by developing a "Goal Statement"
- Define process by developing maps of the process
- Defining the customer and their requirements

The Problem Statement should include defining the severity (it can consist of percentage of the time there are errors, the number of late orders per month, etc.), defining the business impact and specific area (what department and what units are involved).

The Goal Statement should be a direct reflection of the Problem Statement. For example, if orders are 10% late, then the goal might be to cut that down to 5% late. This statement defines measurable, time-bound terms of exactly when the team and project will be considered successful.

Defining the process begins with a bird's eye view of the process, also known as a high-level process map. The classic tool here is called a SIPOC which stands for Suppliers, Inputs, Process, Outputs and Customers.

The focus of each project is the customer of the process. Customers can be external to the organization or an internal component of the organization. During the Define phase, the team must contact customers to better understand their requirements of the process, or the "Voice of the Customer."

3.2. Measure

Precision in defining the problem should facilitate the measurement phase. In this phase the objective consist of measuring the actual performance of the process so as to define its actual state. Should a focal problem for a DMAIC project be "improved reliability in delivery", transit time would serve as the primary measure. Not only the average transit time should be measured but also the variance around it. Common areas of measurement include cost, time, quality. The best measures will prove to be those that are: quantifiable, easily measured, robust, reliable, valid. The measures should be prioritized so it is clear to everyone which measures are most important. This phase should reduce a risk of measuring the wrong things or measuring the right things in the wrong way. Bad information is driving bad decision making. It is moreover necessary to establish the measurement system that allows the monitoring of the process evolution under analysis with respect to the objectives established in the previous phase. A well thought out data collection plan is critical as the data that is gathered must be accurate and reliable. The collected data is then incorporated into the Project Charter to more accurately describe the issue.

3.3. Analyse

This phase has as its objective the identification of the causes that could be at the root of the problem and identify the relations of Cause- Effect, i.e., how is it that one of more independent variables affects the dependent variable. It includes identification of the issues that lead to dissatisfied customers, unnecessary costs, dwindling margins, and frustration. In this phase the date collected during the Measure Phase is reviewed. An additional information can be included. The team analyses both the data and the process in an effort to narrow down and verify the root causes of waste and defects. The data is presented visually using charts and graphs for easier identification for problems in the process. The process analyse consist of:

- Time Analyses that focus on the actual time work is being done versus the time spent waiting
- Value Added Analysis that adds another dimension of discovery by looking at the process through the eyes of the customer to uncover the cost of doing business
- Value Stream Mapping combines process data with the map of the value-adding steps to help determine where Waste can be removed

Teams are able to develop theories around possible causes of the problem by brainstorming together. By using a tool called a “Cause & Effect Diagram“, the teams are able to perform structured brainstorming that can help them narrow down to the vital few causes of lost time, defects and waste in the process.

By using Design of experiments, the logistician might examine the variance in delivery reliability by controlling for different factors associated with shipments of interest including, but not limited to, the way in which shipment is tendered, dispatched, and scheduled; the way in which the order is physically prepared, staged, and loaded; the carriers and drivers used to fulfill the delivery; the time of day for pickup and delivery; weather conditions; and the processing of the documentation associated with the shipment. The Charter is then updated with additional detail around process performance and the potential for improvement.

3.4 Improve

This phase has the objective of finding and implementing solutions that eliminate the causes of the problems identified in the Analyze phase, preventing a re-occurrence or reducing the variability of the process. Making effective change is not an easy thing for any organization. Lean Six Sigma thinking is about discipline, and about developing a culture that relishes opportunities for improvement. While there may exist various possible solutions for the same problem, the best, or top two should be selected to be applied. Ideally, these identified solutions should not imply such large investment costs and they should be tested before being implemented such that their efficacy can be checked and to avoid wasting time on solutions that require a great deal of effort for little benefit. In order to ensure the right decision is made, the team may employ mini testing cycles known as “PDCA” or Plan Do Check Act, which can help refine the ideas while collecting valuable stakeholder feedback.

3.5 Control

What can prove even more challenging than bringing a good idea to light in the Improve phase, is sustaining the effort. In Control phase the improvements implemented are controlled, or in other words, the new system. Actions should be defined so as to guarantee that the process is continuously monitored, so as to assure that the key variables maintain within specified limits. New standards and procedures should be defined, workers should be trained for new process and new measures should be defined to ensure the sustainability of the gains. This phase focus on avoiding complacency when the project is going well and goals are being met and taking corrective action when either the projects strays or the environment changes. This phase is a mini version of process management. The team has been building a form of infrastructure throughout the life of the project, and during the Control Phase they begin to document exactly how they want to pass that structure on to the employees who work within the process.

4. CASE STUDY

Case study offers an effective way to comprehend the concept fully. Unfortunately logistics is such a broad function with diverse activities and it is virtually impossible to write a case that will satisfy all customers of the case. In the following case study will be presented the application of the DMAIC methodology to the internal logistics of a company that manufactures domestic water heating equipment, as fundamental to the success of the business. The consequences of not delivering the materials in the right quantity, at the right time and in the right place are lost production and missed delivery deadlines that influence the satisfaction of the client. Internal supply concept includes milk-runs, Point of Use Providers and logistical trains. The milk-runs are the operators that deliver all the materials located in the warehouse to the supermarkets of internal clients. The process starts with the requests from the operators responsible for the movement of the materials from the supermarkets, close to the point of use, to the final point of use for replacement material. An electronic request is made using a barcode reader. These electronic requests are received by the warehouse operators who place the necessary material in the logistic train. The milk-run operator couples up the various carriages to form a train according to the defined route. After delivering all of the requests, the trains is returned to the warehouse, where the empty carriages are being uncoupled, filled ones carriages coupled and a new route is started.

There are three routes for the delivery of materials: A, B, C. A and B routes run cyclically, while C route does not. The duration of A and B routes is fixed at 30 minutes, while the C route is of less duration than other two. The A and B routes that run for more than 30 minutes are considered as a defect. The outcome can be a production stoppage. Also, the variability of the time of the routes leads to a necessity of having a safety stock in the supermarkets.

The objective of this project is to control the duration of the process of the internal restocking of materials.

The problem was defined. "Between January and February 2011, approximately 50% of the routes were found to have an execution time above the maximum allowed time, defined as 30 minutes. This delay in the delivery time negatively affects system confidence and increases the necessary safety stock in the supermarkets of the internal clients."

The objectives are defined in the Table 1.

Table 1. Definition of the project objectives

Objective	Jan.	Feb	Objective
Reduction of the DPMO	345.238	551.020	10.000
Increase in the sigma level	0,4	0	2,3
Reduction in the coefficient of variation (%)	44	36	11,5
Reduction in the average time (min)	27	34	25
Coupling/decoupling (min)	12	12	0

The expectations of the clients served by the route A were taken into a count when defining objectives. The workshops were organised with the Production managers.

The voice of the customer concept was used for a definition of client requirements. Their requirements were 0% of production stoppages due to stoppages, 50% reduction in stock safety margin in the supermarket, 0% of area occupied by the supermarkets-direct delivery to the point of use.

It was concluded that that the duration of the route A had an impact over the production stoppages due to parts stock out in the supermarkets and safety stock necessary in the same supermarkets.

In this case study the duration of the route A was measured. Of the 148 routes that were analyzed for the month of March 77routes ran over the limit of 30 minutes, representing the defect level of 52%, or DPMO of 516.779 (sigma level of 0).

In an analyze phase a Cause-Effect diagram was developed for identification of the factors that can have an impact on the route time (Figure 1). A brainstorming session was organised.

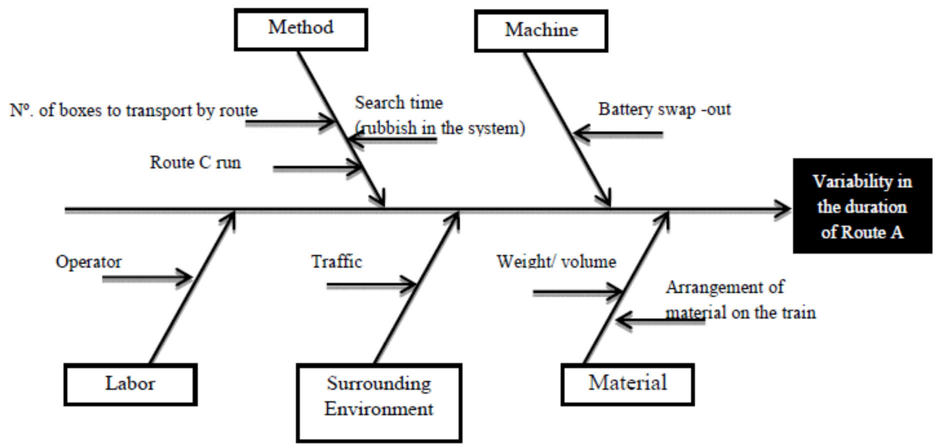

Figure 1. Cause-Effect diagram

An inferential statistics was used to understand both the impact of route C on the running time of the route A and the impact of the cause of 'N of boxes to deliver by route'. By using the hypothesis it was concluded that there exist a significant difference in the time taken to run route A when it is preceded by a run of route C. This happens because runs of route A that follow a run of route C have the tendency to include more boxes to be delivered. A Linear Regression Test was used for quantification of the impact of the cause of 'Number of boxes to deliver by route' on the route time. The relationship between the independent variable 'Number of boxes loaded onto the logistic train' and the dependent variable 'Time necessary to run the route' was tested. It was concluded that the time taken to run route increases with the number of boxes to be delivered.

In the improve phase the solutions to the problem being studied were proposed by the project team. An evaluation of the impact and effort required is shown in the Table 2.

Table 2. Evaluation of the Impact and Effort of the various solutions proposed

Solutions	Impact	Effort	Observations
The milk-run covers only A	9	4	Allocate Route C to another operator
Delivery of a fixed number of boxes per route	8	7	Necessity for a 3rd train
Relocate the heavy and outsized materials	3	4	Analyze in what location the heavy materials are to be found. Locate them as close as possible to the milk-run stop.
Eliminate the obsolete parameterizations from the information system	2	6	Analyze piece by piece the parameterizations in the system that are no longer used. Eliminate contradictory information.

It was decided to make a pilot test with the first two solutions according to their potential impact, as the solutions should be tested before their implementation, so that their effect is checked.

During the test period of 15 days for the solution 'Process Route A w/o C', of the 79 routes that were completed, 12 took longer than 30 minutes, showing the defect rate of 15%, or DPMO of 151899. The variability of the route running times was also reduced from 37% to 26%. There was no positive effect on the stopping time in the warehouse of 12 minutes used for decoupling and coupling operations.

The test of other solution was carried out but in combination with the 'Process Route A w/o C' solution. It resulted with only one of the 30 routes ran during the test period with the duration more than 30 minutes, representing a defect rate of 3%, or DPMO of 33333, representing sigma level of 1,83%. The variability of the route running times was also reduced from 26% to 14%. There was a negative effect on stopping time in the warehouse that rose 60%. The average time of running a route remained at 24 minutes.

In order to reduce stopping time in the warehouse it was decided to test the proposal 'Quick change of carriages' beside other two proposals.

The results obtained from the tests are shown in the Table 3.

Table 3. Client requirements

Objective	Jan.	Feb	Goal	Result	Status
Reduction of the DPMO	345238	551020	10000	33333	x
Increase in the sigma level	0,4	0	2,3	1,8	x
Reduction in the coefficient of variation (%)	44	36	11,5	14	x
Reduction in the average time (min)	27	34	25	24	✓
Coupling/ decoupling (min)	12	12	0	0	✓

Even though some of the goals were not reached, an improvement was made in all of the performances.

As the waiting time for a complete load was long, the project team decided to make a new test with the new solution -'Single Route', resulting from an integration of routes A and B. Even though there was a slight degradation in the average time for the routes and in the variability of the time from 14% to 16%, and in number of routes taking more than 30 minutes (3 routes), a positive effect was found. The stopping time in the warehouse between two route runs reduced from an average value of 30 minutes to 6 minutes , as a full load was achieved more quickly thanks to more stations visited on the route.

For the purpose of control, the automatic card system for registering the time of exit and the time of entry to the warehouse was maintained. Three months after the go-live phase, 7 routes of the 190 were carried out in more than 30 minutes, representing a defect rate of 3,6%. The average duration of the routes run was 24,4 minutes. These results showed that the new process was stabilized.

The safety stock in the supermarkets was reduced, as a result of the improvements in the performances. An integration of two routes into a single route allowed the reduction of two operators per day, as the elimination of one traction device, rented from an external company. These reductions resulted the reduction in costs of around 100 000€ per year.

5. CONCLUSION

The variation reduction and reduction of defects are of big importance to the logistician as managing inventory, customer's trust and sale are about managing variance. Six Sigma is about understanding the origin of defects and variation and finding the solutions for eliminating them and getting as close as possible to 'Zero Defects'. It is a simple, effective, process-oriented and structured way of making improvements with a clear division of responsibility and goal to achieve significant results. It should be seen as a program for continual improvement over the long term. The DMAIC is the 'backbone' methodology applied in Six Sigma improvement efforts. Its implementation within the project described in this article brought a financial benefit to the company of around 100 000€ yearly.

This methodology is an excellent complement to the Lean methodology.

A focus on quality achieved through variation reduction can be a core element of a company's philosophy and strategy.

REFERENCES

[1] Amar, K., Davis, D., 2008. *A reviw of Six Sigma Implementation Frameworks and Related Literature,* Proceedings of the IAENG International Conference on Industrial Engineering, 1559-1564, Hong Kong.

[2] Brady, J.E., Allen, T.T., 2006. *Six Sigma Literature: A Review and Agenda for Future Research*, Quality and reliability engineering international, 22(3), 335-367.

[3] Chow, G., Heaver, T.D. and Henriksson, L.E., 1994. *Logistics performance: Definition and measurement.* International Journal of Physical and Distribution Management 24 (1), 17-28.

[4] Dean, J., Bowen, D., 1994. *Managing theory and total quality: Improving research and practice through theory development,* Academy of Management Review, 19 (3), 392-418.

[5] Ferreira, L.M., Silva C., Mesquita, C., 2013. *Using the Six Sigma DMAIC methodology to improve an internal logistic process,* Proceedings of the 23rd International Conference on FAIM, 1461-1473, Porto.

[6] Goldsby, T., Martichenko, R., 2005. *Lean Six Sigma Logistics*. J. Ross Publishing, Florida.

[7] Hahn, G., Doganaskoy, N., Standard, C., 2001. *Statistical tools for Six Sigma-what to emphasise and de-emphasize in training*, Quality progress, 34 (9), 78-82.

[8] Hahn, G., Hill, W., Hoerl, R., Zinkgraf, S., 1999. *The impact of Six Sigma Improvement- a glimpse into the future of statistics.* The American Statistician, 53 (3), 208-215.

[9] Harry, M., 1998. *Six Sigma: A breakthrough strategy for profitability.* Quality Progress, 31(5), 60-62

[10] Kilibarda, M., Zečević S., 2008. *Upravljanje kvalitetom u logistici*, The Faculty of Transport and Traffic Engineering, Univerity in Belgrade.

[11] Linderman, K., Schroeder, R.G., Zaheer, S. And Choo, A.S., 2003. *Six Sigma: a goal-theoretic perspective.* Journal of Operationas Management, 21 (2), 193-203.

[12] Mijajlevski, A., 2009. *Lean Sest Sigma logistika,* Thesis, The Faculty of Transport and Traffic Engineering, Univerity in Belgrade.

[13] Montgomery, D., Lawson, C., Molnau, W., Elias, R., 2001. *Six Sigma Black Belts: What do they need to know?* Journal of Quality Technology, 33(4), 407-409.

[14] Sousa, R., Voss, C., 2002. *Quality management re-visited: A reflective review and agenda for future research*, Journal of Operations Management, 20, 91-109.

[15] Tjahjono, B., Ball, P., Vitanov, V.I.,Scorzafave, C., Nogueira, J., Calleja, J., Minguet M., Narasimha, L., Rivas, A., Srivastava, A., Srivastava, S., Yadav, A., 2010. *Six Sigma: a literature review*, International Journal of Lean Six Sigma, 1 (3), 216 - 233.

[16] Wei,C.C., Sheen, G.J.,Tai, C.T. and Lee, K.L., 2010. *Using Six Sigma to improve replenishment process in a direct selling company",* Supply Chain Management: An international Journal, 5 (1), 3-9.

[17] www.*GoLeanSixSigma.com*