SIX SIGMA: A METRIC, A METHODOLOGY AND A MANAGEMENT SYSTEM

Crişan Emil
Babeş Bolyai University Cluj-Napoca, Faculty of Economics and Business Administration

Ilieş Liviu
Babeş Bolyai University Cluj-Napoca, Faculty of Economics and Business Administration

Mureşan Ioana
Babeş Bolyai University Cluj-Napoca, Faculty of Economics and Business Administration

This article is a theoretical article regarding Six Sigma. Six Sigma has been interpreted over time within quality theory as a metric, methodology or a management system.
We explain Six Sigma using a logistics context: Delivery-On-Time (DOT) rate problem. It is a theoretical context useful both for academic users and practitioners.
At the beginning of the paper the DOT problem is generally described, while Sigma is presented according to statisticians view in the second part of the paper. Six Sigma is then presented as a metric for process' capability. The fourth part of this article contains details regarding Six Sigma usage as a methodology for improvement, while the fifth part of this article refers to Six Sigma as a management system which can be used at firms' level.
The last chapter is dedicated to conclusions regarding the possible use of Six Sigma in Romania.

Key words: Six Sigma, delivered-on-time, metric

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1. Introduction

Logistics – the movement of goods at global level has become an important subject on the agenda of economists, politicians and ecologists especially after 2000 and once more with the actual economic crisis. Logistics has been perceived as a cost once with the introduction from military field to business in 1950-1960 by Americans. At the present moment discussions suggest that 10 percent from the final price is paid for logistics by the high performing nations (Crişan et al., 2010). Logistics can be considered a part of operations. There are several managerial problems which are to be solved by logistics managers, from logistics network design and performance management (as strategic problems) to daily problems related to customer service.

As logistics insures the movement of goods to the customer, one of the measurements of logistics performance is the delivery-on-time (DOT) rate. It is a proportion between the number of orders delivered on time and total orders delivered. There are discussions that the number of delivered orders is not a relevant performance measure for delivery, but the value or volume delivered. We shall not insist further on this aspect, for this article DOT refers to the number of orders delivered on time.

DOT is a result, is a measure of logistics performance. According to a previous research we have performed in 2009 (Crişan, 2009), only 43,14% Romanian logistics managers use such a measure. Measurement is not a goal itself, but improving performance. The main goal of this article is to present Six Sigma as a metric, a methodology for problem solving or a management system using the DOT example.

The paper has six parts: introduction; Sigma presentation as a statistics' measure for central tendency; Six Sigma presentation as a metric for process capability; Six Sigma description as a methodology for improving the capability of a process; Six Sigma as a management system useful at firms' level. The sixth part contains conclusions regarding Six Sigma possible usage within Romanian business.

2. Sigma
Sigma (σ) is a Greek letter used by statisticians to denote the standard deviation for a set of data. Let's consider the variable X- the values of daily DOT for a given company A for 365 days. If variable X has the mean μ, then the variance of X is given by:

$$Var(X) = \frac{\sum_{i=1}^{n}(x_i-\mu)^2}{n},$$

where n represents the volume of the population (in this case 365), $i = \overline{1,n}$ denotes each value (day in our case) of the population.
The standard variation (σ) is the square root of variance.

3. Six Sigma as a metric
Six Sigma concept comes from statistics. A process which has a normal distribution[493] is represented as a bell-shaped distribution, also called a Gaussian distribution (figure 1) (Breyfogle et al. 2001, p.38). The shape of this normal curve depends solely on the process, equipment, personnel, and so on, which can affect companies' A delivery activity. This normal curve represents the spread of DOT resulting from daily delivery, using current equipment, materials, workers, and so forth. The normal curve says nothing about the range of DOT acceptable to the customer. This curve is the empirical quantification for the variability that exists within the DOT delivery process.

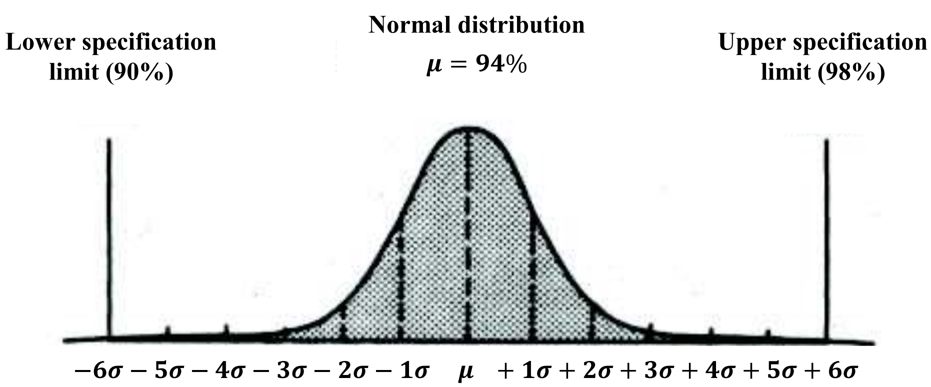

Figure 1: A capable process

The normal curve is represented by statisticians considering the value of σ regarding this variable and the average DOT value, which is shown as the middle of the curve on the x–axis. The standard deviation is expressed in percentages in this case. The total area under the normal curve is assumed to be equal to a proportion (decimal value) of one. This means that all possible DOT values range from -infinity to + infinity on the X-axis. Although this normal distribution theoretically allows for DOT to have 10% or 100% values, this is a practical impossibility and has such a low probability of occurring that it is irrelevant.
We do not have to deal with the infinite properties of the normal distribution. The normal distribution in science, engineering, and manufacturing is typically between $\pm 3\sigma$ about the target mean. $\pm 3\sigma$ represent 99.73 percent of the total area under the normal distribution (Breyfogle et al. 2001, p.39). The difference of 0.27% is the probability of our firm to obtain DOT values outside of the interval $\pm 3\sigma$. If a process is centered, for every 100 days, 99.73 of them, approximately 99,8 days, will have DOT values that fall within the interval $\pm 3\sigma$. Still this corresponds to 2,700 defective DOT per million DOT

[493] Not all processes are normal distributed, but most of them are. Specific statistical tests should be used to establish this aspect for specific processes.

measured. Just imagine 2700 organs not delivered on time in 1 million opportunities. For the interval $\pm 6\sigma$, the ppm (parts per million) value is 0.002. In Motorola Six Sigma quality program the number of errors expected is 3.4 ppm because they have considered a possible mean variation of $\pm 1{,}5\sigma$ (Brigham, 2005).

According to figure 1 each process can be considered a Six Sigma process. Any process normal distributed can be represented using a normal curve and has the values in 99.9999998% of the cases within the interval $\pm 6\sigma$. The problem is weather the values -6σ and $+6\sigma$ from the mean are below or upper real needs.

Things are more specific in business: any process has to generate an output considering requirements. In order to understand the Six Sigma concept in business, we have to explain the term customer requirement. In quality management literature the goal of economic organizations is to satisfy customer needs. As customer needs are intangible, economists and engineers use measurable features for defining customer needs. These measurable features are called requirements and refer to products which firms manufacture in order to satisfy customer needs. Products are now described using sets of requirements – measurable features. Requirements are set for a product considering customer needs (the so-called VOC – voice of customer) regarding the product, but also other stakeholders' (for example the VOB – voice of business, which is the voice of the shareholders) requirements regarding the product but also the process. DOT is a service requirement generated from VOC. Considering VOC, the management establishes lower specification limit (LSL) for the DOT requirement (it could be 90%) and upper specification limit (USL) (98% - quality costs and performing better than 98% means that the company spends more than it has been planned for better deliveries). The value of DOTs without management's specification limits are defined as defects, failures, or nonconformities.

The mean for this interval is 94%. Figure 1 describes a process which has the DOTs values between 90% and 98% in 99.9999998% cases.

It is a capable business process because LSL and USL are exactly -6σ and $+6\sigma$. A **capable process** is that one where customer requirements objectives (LSL and USL) are both within the interval $[\mu - 6\sigma, \mu + 6\sigma]$.

It is also **a centered process** because the mean of the requirements interval [LSL,USL] is the same as the mean of the population $[\mu - 6\sigma, \mu + 6\sigma]$. This means that DOT values are between -6σ and $+6\sigma$ and it also takes into account customers' specifications.

Six Sigma is now in business a metric of process capability. The capability of a process is related to the standard deviation of a process and it can be measured by the following expression:

$$C_p = \frac{USL - LSL}{12\sigma}.$$

If C_p is higher than 1 and the process is centered, we deal with a capable process - it means that the difference between LSL and USL is bigger than 12σ, which, if the process is centered, means that the number of errors is below 0.002 ppm. In figure 1 C_p is exactly 1 because LSL=$\mu - 6\sigma$ and USL=$\mu + 6\sigma$.

If C_p is smaller than 1 and the process is centered, we deal with non-capable process - it means that the difference between LSL and USL is smaller than 12σ, which, if the process is centered, means that the number of errors is greater than 0.002 ppm. In figure 2 LSL=$\mu - 4\sigma$ and USL=$\mu + 4\sigma$. C_p is:

$$C_p = \frac{USL - LSL}{12\sigma} = \frac{(\mu + 4\sigma) - (\mu - 4\sigma)}{12\sigma} = \frac{8\sigma}{12\sigma} = 66.66$$

Normally, the process will have results within the interval $[\mu - 6\sigma, \mu + 6\sigma]$, while the customer asks for values within the interval $[\mu - 4\sigma, \mu + 4\sigma]$. Considering $C_p$value, our process is capable on 66.66% of the interval $[\mu - 6\sigma, \mu + 6\sigma]$. The probability of appearance for values without the interval $[\mu - 4\sigma, \mu + 4\sigma]$ is only 63 DPMO (Defects per Million Opportunities), or 0.63%.

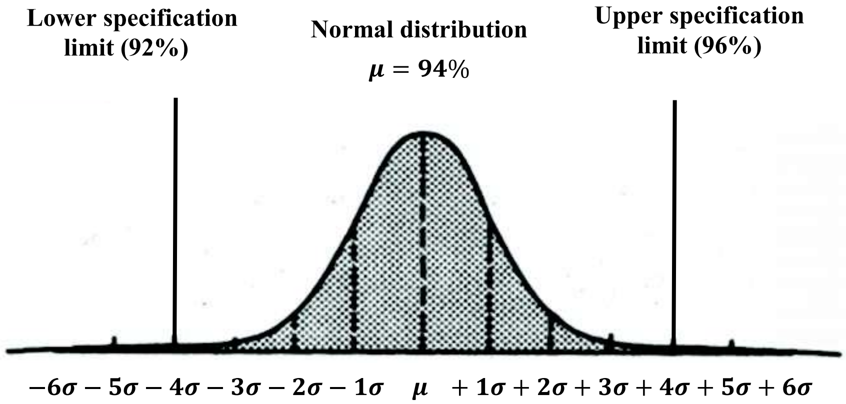

Figure 2: A non-capable process

In figure 2 we have a 4σ capable process. The process capability measured in σ values can be interpreted according to the next table:

Sigma level	Percentage of the total area under the normal distribution	Defective ppm
1σ	68,27	317.300,000
2σ	95,45	45.500,000
3σ	99,73	2.700,000
4σ	99,9937	63,000
5σ	99,999943	0,570
6σ	99,9999998	0,002

Six Sigma has become in this way a metric for any process capabilities. It can refer to any requirement established by the management, considering only the value of sigma (measured in processes' units) and the values of LSL and USL, both measured in processes' units. It is relevant weather these units are liters, centimeters, percentages or anything else.

4. Six Sigma as a methodology

Measuring is not a goal itself, but improvement. Six Sigma practitioners use Six Sigma to measure the capability of a process, but they also used specific tools for improving the level of quality, usually for decreasing the variation within processes (diminishing sigma and bringing processes at capability levels). Six Sigma has its own steps for improving a process capability, which are denoted by the acronym DMAIC (Define, Measure, Analyze, Improve and Control), established at Motorola. DMAIC is recognized as a methodology to analyze processes in order to root out sources of unacceptable variation, and develop alternatives to eliminate or reduce errors and variation.

While processes not capable are identified, management and statisticians can work for improving the capability gaps using this methodology. In our case the process is delivery and figure 2 denotes that we have a problem with delivering on time. We further present the general goals of each step within DMAIC methodology, the main outputs and the main tools which can be used:

The goal of the **Define** step is to define the project's purpose (goal – DOT in our case) and scope (area where we shall focus - delivery) and obtain background information about the process and its customers.

The outputs of the Define step consist of the following:

• The team charter - a clear statement of the intended improvement and how you will measure it, containing also the scope, the goal and the team which is going to perform this action;

• A process map.

• A translation of the voice of VOC into critical to quality measures (DOT is transformed from CCR – Critical Customer Requirements or CBR – Critical to Business Requirements).

For performing this step several statistical and management tools can be used: affinity diagrams, team charters, communication plans, control charts, critical to quality trees, data collection, Kano model, Pareto charts, Run Charts, SIPOC diagrams, tollgate review questions (Brassard et al., 2002). In our case, the goal of define should be describing how this low level of DOT is perceived by customers and which is the process behind DOT level (DOT is only a result of delivery process).

The goal of the **Measure** step is to focus your improvement effort by measuring the current situation. The outputs of the Measure step include the following:

• Data that pinpoints the problem's location or rate of occurrence.

• Measure the actual capability (sigma) of the process considering the chosen performance metrics (DOT).

• An understanding of how the current process operates.

• A more focused problem statement.

For this step several tools can be used: control charts, data selection, flowcharts, histograms, Pareto charts, process sigma, run charts, Taguchi loss function, tollgate review questions.

The goal of the **Analyze** step is to identify root causes and measure them with data. The output of this step is a theory that you have tested and confirmed whether there is a relation between the great Y (in our case DOT value) and small steps within the process which influence delivery on time (documentation on time, order packaging, order manipulation).

The Analyze step pinpoints the specific cause(s) of the focused problem. Several tools can be used: brainstorming, cause-and-effect diagrams, design-of-experiments, histogram, hypotheses testing, scatter diagrams, tree diagrams, tollgate review questions.

The root cause(s) are addressed through solutions implementation in the Improve step. The goal of the **Improve** step is to develop, try out, and implement solutions that address root causes and to use data to evaluate the solutions as well as the plans you use to carry them out.

The outputs of the Improve step include the following:

• Planned, tested actions that eliminate or reduce the impact of the identified root cause(s) of a problem (such as changing delivery routes considering several alternatives).

• "Before" and "after" data analysis that shows how much of the initial gap was closed.

• A comparison of the plan to the actual implementation.

It is a data driven approach: DOT is influenced in different percentages by different causes. Eliminating these causes DOT level shall be improved.

Several tools can be used: Gantt charts, brainstorming, control charts, FMEA (Failure Mode and Effect Analysis), histograms, involvement matrix, Pareto charts, PDCA (Plan-Do-Check-Act) matrix, process sigma, run charts, tollgate review questions.

The goal of the **Control** step is to maintain the gains you have made by standardizing your work methods or processes, anticipating future improvements, and preserving the lessons you learn from this project.

The outputs of the Control step include the following:

• Documentation of the new method – changing the documentation regarding delivery process.

• Training of fellow employees in the new method – new routing methods, new ways for preparing documentation, order manipulation or delivery).

• A system for monitoring the consistent use of the new method and for checking the results (introducing new forms useful for capturing several performance measures regarding delivery process).

• Completed documentation and communication of the results, leanings, and recommendations. The Six Sigma projects should be perceived by the whole organization, they shall become a part of firms' knowledge.

In this phase the tools which can be used are: communication plans, control charts, PDCA cycles, process management charts, run charts, Six Sigma storyboards and tollgate review questions.

The DMAIC methodology has been built as a managerial and statistical tool for solving problems within business. The main advantage is that this new set of tools can be used for any problem at any level. The question is whether this methodology is to be used by companies at all levels and if this can become a management best practice.

5. Six sigma as a management system

Six Sigma comes from statistics, but it is now the best practice for problem solving within several companies: Motorola, General Electric, Allied Signal, Nokia or other big companies have adopted Six Sigma projects using this name or making specific "rebrandings".

As a best practice, it is more than a set of metric-based problem solving and process improvement tools. Six Sigma offers the opportunity for management to make data driven decisions (Pyzdek and Keller, 2009, p.87).

Six Sigma has been implemented at firms' level by projects with 4 to 6 months to be completed. The objectives of these projects were chosen considering key results related to stakeholders needs. The priorities are developed based on analysis of key stakeholder needs and wants, including the customer, shareholder, and employee groups. In this way, data-driven management provides a means of achieving organizational objectives by quantifying needs or wants of stakeholder groups relative to current level, and acting upon the data to reduce those critical gaps in performance. Methodologies for performance management, such as the Balanced Scorecard, Tableau de Bord and Benchmarking are now completed with this data driven methodology.

The main advantage of this management system is making aware steps to improvements. As such, the *Six Sigma Management System* encompasses both the Six Sigma metric and the Six Sigma methodology. It is when Six Sigma is implemented as a management system that organizations see the greatest impact (Breyfogle et al., 2001, p.45).

6. Conclusions

Though we have focused on this article more on the metric side of Six Sigma, Six Sigma is a powerful tool for problem solving within business. As we have discovered in previous researches, we believe that the problem for Romanian managers is not whether they use or not Six Sigma, but is whether they make general measurements of business performance. DOT value is measured by 43.14% logistics professionals. Six Sigma is a metric, methodology and management system which helps you to improve performance if you are aware by the poor level of performance. More awareness is what we need, more focus on numbers and on data driven improvements. Six Sigma can then become a best practice within Romanian companies.

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