QUALITY IMPROVEMENT METHODS FOR IDENTIFICATION AND SOLVING OF LARGE AND COMPLEX PROBLEMS

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Abstract: This article is analyzing three methodologies used for identification and resolving of large and complex quality problems: Six Sigma, Shainin and Kepner-Tregoe problem management. To compare these three methodologies the general quality improvement roadmap was defined consisting of 5 phases: Problem definition, Diagnosis, Generation and selection of solutions, Enhancement and New routines. The aim of comparison was to identify whether the methodologies, methods and tools can supplement each other. This would allow to work on quality improvement within one general problem solving pattern. The Six Sigma as the most generic methodology can serve as the base to develop such pattern while DMAIC roadmap can be used as the backbone.

Keywords: Shainin, Six Sigma, Lean Six Sigma, Kepner-Tregoe, quality improvement, problem solving.

1 Introduction

In today's business environment defined by increased globalization, rapid development of technologies and other competitive pressures the shareholders expectations are becoming stronger in respect of the costs reduction and improvement of business performance while customer satisfaction is increasing. One of the main contributors to meet the mentioned business expectations is quality. Quality integrated in all processes which are necessary to run the business. The activities to assure quality in each company consist of three basic groups (Juran, 1989): quality planning, quality control and quality improvement. We will focus on quality improvement area. Quality improvement is playing important role in business as the successful quality improvement project leads to the decrease of the production costs, improved market share, higher pricing and increase of customer value. No wonder today the most of the companies and organizations are interested in the continuous quality improvement. Quality improvement process is based on proactive identification of the process variation, structured way of the root cause identification and systematic implementation of the appropriate action to improve and stabilize the situation.

In each business the quality problems appears sometimes. Some of them are easy to correct on day-to-day basis but the most critical for each business are the large, complex quality problems which are usually leading to long-term variation or reoccurrence of the symptoms with heavy impact to business performance. Typical large, complex quality problem is difficult to correct, there are several attempts done to resolve the problem, several root causes can be identified and corrected but the effect of the problem persists. It indicates that the real root cause is not identified and properly corrected. The large, complex quality problems are kind of special cause problems, problems that prevent restoration of the established level of performance or the status quo (Palady, 2002). They are different from common cause problems. Common cause problem is characterized by the stable performance level and the problem solution lies in the optimization of the performance level. Special cause problems must be resolved before common cause problems. Large, complex special cause problem has to be solved using a systematic quality improvement methodology. We will focus on three methodologies: Six Sigma (Lean Six Sigma), Shainin RedX® strategy and Kepner-Tregoe problem management.

2 Methodologies to approach large and complex quality problems

2.1 Six Sigma and Lean Six Sigma

Six Sigma was originally developed by Motorola in 1985 as the set of the tools for process improvement.

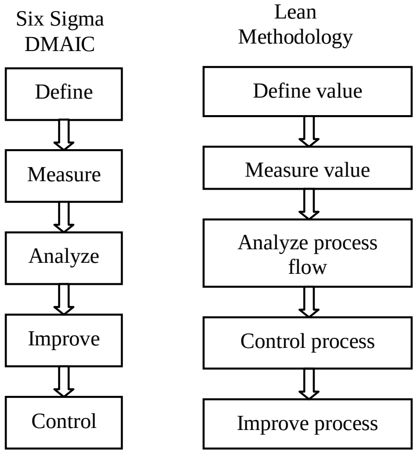
Table 1 DMAIC roadmap of Six Sigma methodology

Define	▪ Define the customer and their "Critical To Quality" characteristics (VOC) ▪ Define the business processes that are involved (VOB) ▪ Create a process map ▪ Decide on the metrics ▪ Form a project team and develop a project charter ▪ Evaluate the financial savings of the six sigma project
Measure	▪ Establish and measure Ys ▪ Create sampling plan for data collection ▪ Validate measurement system ▪ Identify possible Xs
Analyze	▪ Data analysis ▪ Gap analysis between current and required performance ▪ Indentify the sources of variation ▪ Test hypotheses ▪ Decide on the processes to be improved
Improve	▪ Propose solutions ▪ Perform pilot studies, design of experiments etc. to evaluate proposed solution ▪ Create an implementation plan ▪ Implement changes and prove effectiveness
Control	▪ Implement controls to ensure improvement is reached and stable ▪ Develop procedures and train the staff ▪ Update control plan, FMEA and related quality documentation ▪ Evaluate the financial savings of the six sigma project ▪ Define feedback loop

Six Sigma is a robust continuous improvement strategy focused on improvement of the quality of process outputs by identifying and removing the causes of defects and minimizing process variability. Six Sigma provides a structured data-driven methodology with set of tools and techniques which are used to measure process performance both before and after corrective action implementation, to analyze the data, to find a most effective solution and implement it. No changes are made until the current process and its individual steps are completely understood, documented and measured. The revised process is measured and verified as soon as correction is done. We have to consider Six Sigma is strongly focused on the customer requirements by translation customer needs into operational terms and definition of the processes critical to quality (Juran, De Feo, 2010). Six Sigma's roadmap consists of five steps known as DMAIC roadmap (Table 1).

Lean Six Sigma is a problem solving concept combining Lean and Six Sigma approach which was first published by Michael George in 2002 (George, 2002). Lean Six Sigma applies the Six Sigma DMAIC (Define, Measure, Analyze, Improve, Control) roadmap where the tools are based on combination of the Lean and Six Sigma tool kit. The aim is to improve quality and efficiency of the process which is defined as the value stream (Nave, 2002). This approach allows us to evaluate process as the costs flow and identification of the waste in the process while defects are considered as waste. It means a Lean Six Sigma project is the fusion of the Lean waste elimination project and the Six Sigma project (Scheme 1). The joint point where both methodologies meet are the Six Sigma's critical to quality characteristics which represents waste in the lean concept. Target of Lean Six Sigma is a sustainable improvement of quality, decrease of costs, reduction of waste, improved metrics and introduction of the change in company culture.

Scheme 1 Six Sigma DMAIC concept and Lean Methodology concept



2.2 Shainin Red X® strategy

The Shainin Red X® methodology was developed by Dorian Shainin from 1950s to 1990s. The basic concept can be summarized by 6 statements:

- Variation exists in all processes
- Understanding and reducing variation are keys to success
- In the real world nothing happens without a mason
- There is always a Red X® (the main root cause)
- Finding and controlling the Red X® is the only way to reduce variation
- Executing a progressive search by "talking to the parts" is the best way to find the Red X®

Today the Shainin Red X® methodology consists of about 30 techniques and tools – the known as well as newly developed techniques – which create the comprehensive stepwise system for process improvement (Shainin, 1993). Shainin problem solving roadmap is called FACTUAL™ (Focus, Approach, Converge, Test, Understand, Apply, Leverage) is shown in Table 2. (Hysong, Shainin and Six Sigma).

Table 2 Shainin roadmap: FACTUAL™

Focus	▪ Leverage probable events ▪ Project Definition ▪ Estimate the impact
Approach	▪ Green Y Identification and Description ▪ Development of Investigation Strategy ▪ Measurement System Verification
Converge	▪ Converging on the Red X ▪ Compare best and worst case ▪ Red X Candidate Identification
Test	▪ Risk Assessment ▪ Red X Confirmed by Trial
Understand	▪ Green Y to Red X Relationship Understood ▪ Optimization of interactions ▪ Customer needs translated to limits ▪ Appropriate Tolerance Limits Established
Apply	▪ Corrective Action Implemented and Verified ▪ Procedures updated ▪ Green Y monitoring ▪ Project Benefits and Cost Savings
Leverage	▪ Read Across Red X Control ▪ Savings Calculated ▪ Lessons Learned

The Shainin methodology is established on convergent approach. What does it mean? It is absolutely necessary to understand the output – the Green Y® – of the process. No problem can be solved without knowledge of the output and related processes, symptoms of the failure as well as difference between good and bad parts. This is ensured by approach which is described as "talking to parts", set of techniques used to converge the problem as elimination of suspects, comparison between good and bad parts, finding extremes. To express this approach mathematically we have to understand the relation $\Delta Y = f(\Delta X)$. The key difference between Shainin Red X® strategy (FACTUAL™) and Six Sigma methodology (DMAIC) is the phase Approach. The problem solver develops a strategy based upon the physics of the problem and the comparison of BOB (Best of Best) and WOW (Worst of Worst) parts (Dao, 2009).

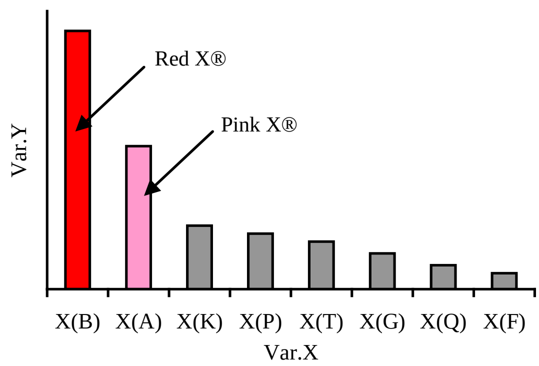
The key idea of Shainin Red X® methodology is Red X® paradigm. This paradigm is coming out of the application of the Pareto principle to the causes of the variation (picture 1). By application Pareto 80/20 principle you would get contribution of the Xs (process inputs) to the ΔY (increment of the output) as shown on picture. There could be cases three causes are identified - called Pink X and Pale Pink X - which are usually in the interaction with Red X. The RedX paradigm is in strong contradiction with so called Quincunx paradigm where all factors contribute equally to the change of the Y. If we express the variance of the output Y as

$\sigma(y)^2 = f(\sigma(x)^2)$ therefore

$$\sigma(y)^2 = A_1^2\sigma_{x_1}^2 + A_2^2\sigma_{x_2}^2 + \cdots + A_{12}^2\sigma_{x_1}^2\sigma_{x_2}^2 + \cdots . + \varepsilon^2.$$

Following the Quincunx paradigm the contributions of each process input is absolutely equal. This is unlikely in the real conditions taking in account the coefficients depend on the chemical, physical, geometrical and mechanical properties of a system and its component.

Picture 1 Red X® paradigm



Source: www.shainin.com

2.3 Kepner-Tregoe problem management

This methodology has been developed in 1958 by Benjamin Tregoe and Charles Kepner (Kepner, 1981). They discovered that successful decision making depends on the logical process to gather, organize, and analyze information before taking action. Their research focused on observing the practices of both effective and ineffective decision makers who acted in critical business situations was published in the book The Rational Manager (McGraw Hill, 1965).

The Kepner-Tregoe problem management consists of four methods (Scheme 2) which can be used independently. The roadmap (Table 3) shows the related tools.

The problem analysis phase is most important regarding quality improvement. We gather and analyze just the information needed to find and correct the true cause of a problem in this phase. Intention is to understand the explaining the observed effects in order to take proper corrective action. To specify the problem correctly four areas are questioned: What - Identity, Where - Location, When - Timing, Extent - Size. The most frequently used tool within the Kepner-Tregoe method is so called Is/Is Not analysis used for detail description of problem in order to identify the real root cause.

Scheme 2 Four methods of Kepner-Tregoe problem management

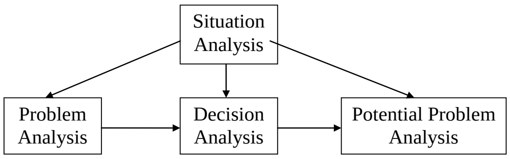


Table 3 Roadmap of Kepner-Tregoe analysis

Situation Analysis	▪ Identify Concerns ▪ Set Priority ▪ Plan Next Steps ▪ Plan Involvement
Problem Analysis	▪ Describe Problem ▪ Identify Possible Causes ▪ Evaluate Possible Causes ▪ Confirm True Cause
Decision Analysis	▪ Clarify Purpose ▪ Evaluate Alternatives ▪ Assess Risks ▪ Make Decision
Potential Problem Analysis	▪ Identify Potential Problem (Opportunities) ▪ Identify Likely Causes ▪ Take Preventive Action ▪ Plan Contingent Action and Set Triggers

3 Comparison of the techniques

Looking at the overview mentioned before we have three powerful methods available to solve the quality problem or to improve the quality. Lets assume there is a quality engineer staying in front of requested quality improvement action. This is already a challenge itself. The question is how to apply the above mentioned techniques in a most effective way? Do we need a decision tree to pick the most powerful technique for a particular problem? I do not think this is the case. If we look on the application of the methodologies in practice we would find the boundaries are not strict. Six Sigma is probably the most generic methodology among these three as we are talking about set of tools as described earlier in this article. The Six Sigma set of tools is not exactly defined . This reflects the real quality improvement process: we will use the most valuable tool which will help us to move project further. In other words we can use a Shainin tool or a Kepner-Tregoe tool in frame of DMAIC method in a related phase.

To have an option of tool choice we have to align these techniques in a common framework as each methodology used different terminology as well as project planning. There are several ways to categorize the phases of the problem solving methodologies within one common framework in order to make comparison of the different techniques (de Mast, 2000)(de Mast, 2004). We can define the general quality improvement program consists of 5 phases: Problem definition, Diagnosis, Generation and selection of solutions, Enhancement and New routines (Table 4).

The most critical phase is diagnosis. The efficiency in this step strongly depends on the chosen investigation strategy which predetermines the set of tools to be used for diagnostics purposes. Elimination strategy contained in Shainin methodology and Kepner - Tregoe problem management is based on strategy called branch-and-prune (De Maast, 2012). Branch-and-prune strategies seek to balance between excessive divergence of the search space and excessive convergence by treating the search space as a hierarchical tree structure, in which high-level and general causal directions are branched into more detailed causal explanations. The problem solver works top-down, aiming to prune high-level branches in their entirety, before elaborating only a limited number of branches into more detail..

There are some limitations to use the tools independently. The first one is related to the type of data. We have to consider preference in the Shainin methodology is the work with quantitative data. Other limitation can be related to “key user” of the methodology: Six Sigma and Kepner-Tregoe projects are usually designated for multidisciplinary teams while Shainin project can be done by an individual engineer.

4 Conclusion

This paper compares three main methodologies which are most frequently used to solve large, complex quality problems. The aim of the comparison is not to find the best one but to find out whether these methodologies can supplement each other. The general quality improvement roadmap was defined consisting of 5 phases: Problem definition, Diagnosis, Generation and selection of solutions, Enhancement and New routines. If we align all three methodologies within this framework we can recognize the individual steps as supplementary. This would allow us to combine the tools which are normally used by within individual methodologies. The most generic methodology - Six Sigma – and the related roadmap DMAIC (Define, Measure, Analyze, Improve, Check) can be used as the backbone. The next step of the research will be selection of suitable tools to develop a system which could be used for quality improvement of the products consisting of large quantity of the components.

Note: Red X®, Green Y®, FACTUAL™ are legally protected marks of Shainin LLC.

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Table 4 Definition of the common framework and related phases

Phase	Six Sigma	Shainin	Kepner-Tregoe
Problem definition	▪ Project definition ▪ Definition CTQs ▪ Estimation of financial benefits	▪ Define project ▪ Establish measurement system ▪ Green Y® description	▪ Strategy Formulation ▪ Situation Appraisal ▪ Project Selection
Diagnosis	▪ Validate measurement system ▪ Create sampling plan ▪ Measure characteristics	▪ Validate measurement system ▪ Investigation Strategy Selected ▪ Converging on RedX®	▪ True Cost Analysis ▪ Statistical Process Control
Generation and selection of solutions	▪ Statistical analysis ▪ Gap analysis ▪ Indentify the sources of variation ▪ Identification of processes to be improved ▪ Propose solutions ▪ Perform pilot studies to evaluate proposed solution	▪ Red X® Candidate Identified ▪ Trial to confirm RedX® ▪ RedX® Confirmed ▪ Green Y® to RedX® relationship understood	▪ Problem Analysis ▪ Performance System Analysis
Enhancement	▪ Plan implementation ▪ Implement changes ▪ Prove effectiveness	▪ Appropriate Tolerances Defined ▪ Corrective Action Implemented and Verified ▪ Related Procedures Created	▪ Decision Analysis ▪ Potential Problem Analysis
New routines	▪ Implement controls Develop procedures Update control plan Modify FMEA ▪ Evaluate the financial savings ▪ Define feedback loop	▪ Process control implemented ▪ Lessons learned ▪ Project Benefits Calculated	▪ Performance System Design ▪ Gatekeeper

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