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Six Sigma: A Tool for EMS Design

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***Abstract*-The Six Sigma method is a complex and flexible system of achieving, maintaining and maximizing the business success. Six Sigma is based mainly on understanding the customer needs and expectation, disciplined use of facts and statistics analysis, and responsible approach to managing, improving and establishing new business, manufacturing and service processes.**

Keyword- Management, LCA, Six Sigma, Quality, Environment.

I. INTRODUCTION

Globalization and instant access to information, products and services keep changing the way of customers' behavior. Current policy changes in the economy and society should be carried out in accordance with the principles of sustainable development and environmental protection. Therefore, our country introduces a series of voluntary environmental tools and methods such as environmental audits, Environmental Management Systems (EMS according to ISO 14001), environmental assessment and labeling of products, Life Cycle Assessment (LCA), ecological profile of the product etc. With their introduction, the organizations create the way for a balanced and integrated approach in terms of economic, quality, environmental and security interests. One of the major tools used in practice especially abroad, is Six Sigma.

II. CONCEPT OF SIX SIGMA

The word "Sigma" is a statistical term that measures how far a given process deviates from perfection as a new methodology using old tools. Six Sigma is a comprehensive system for achieving, maintaining and maximizing business success. The basis of Six Sigma is a detailed knowledge of customer requirements, disciplined use of facts and objective data, statistical analysis and ongoing efforts focused on optimizing business processes. Six Sigma revolves around a few key concepts:

- Critical to Quality: Attributes most important to the customer;
- Defect: Failing to deliver what the customer wants;
- Process Capability: What your process can deliver;
- Variation: What the customer sees and feels;
- Stable Operations: Ensuring consistent, predictable processes to improve what the customer sees and feels;
- Design for Six Sigma: Designing to meet customer needs and process capability.

III. PHILOSOPHY AND METHODOLOGY OF IMPROVEMENT BY SIX SIGMA METHOD

It is said, that philosophy and methodology of Six Sigma improvement is a revolution in increasing the efficiency of organizations. In recent years, it has become popular not only with specialists in the field of process improvement, but has become also common on the boards of directors and senior management of the world's largest industrial companies, as well as in programs improving services in banks and hospitals. It has much in common with its predecessors, while there is a new approach in the organization and standardization process improvement projects and measuring their benefits. Six Sigma is a method of improving productivity, efficiency and quality of products and services. Based on perfect understanding of the requirements and expectations of customers, it is a proven tool to eliminate errors in processes leading to customer satisfaction. Six Sigma is implemented through its own employees. The involved employees represent the most important capacity of improvements. Focusing on customers, processes and staff makes Six Sigma a way of building and developing a new corporate culture. The method Six Sigma is a high technological method used by engineers and statisticians to fine-tune products and processes. But that is just a part of the truth. Six Sigma presents a measurement and statistics as an essential part of improving. It aims at nearly complete coverage of all customer expectations. The term Six Sigma is derived from the mode of a control process, which shows less than 3.4 defects per million opportunities. Six Sigma is mainly based on understanding the customer needs and expectations, using the facts, data and statistical analysis and a thorough approach to managing, improving and creating new business, production and service processes. Six Sigma in particular focuses on:

- Method of measuring quality, which allows you to compare different processes according to the achieved level SIGMA – variability of process;
- Project-oriented methodology for solving problems using statistical tools;
- The quality improvement system, aimed at reducing errors and maintaining them at a low value, "Six sigma", meaning DPMO (DPMO = Defects per Million Opportunities);
- Philosophy and managerial strategy oriented on customer satisfaction and making decisions based on verified data.

IV. CHOSEN SIX SIGMA METHODS

Six Sigma is based on six basic principles that help with launching the initiative implementation of Six Sigma method to production companies or service industries. Sigma uses the base tools to improve the quality of products and processes as MSA (Measurement System Analysis), IPO Diagram (Input-process-output), CE (Cause-and-effect diagram), Histogram, Pareto diagram, DMAIC (Define, Measure, Analyze, Improve, Control) , Run chart, Control chart, Scatter diagram, Regression Analysis, DOE (Design of Experiments), FMEA (Failure Mode and effect analysis), SOP (Standard Operating Procedure) and QFD (Quality Function Deployment).

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A. Measurement System Analysis

Diffusion of the watched commodities' parameter can be connected by the commodity itself (deformation, ovality) or the system of measuring. The system of measuring is made by operator, benchmark and the method (the way) of measuring. Measuring System Analysis (MSA) is a tool for the evaluation of accuracy and advisability of the measuring system. It goes with testing (measuring) the chosen parameter by an operator or a group of operators. It monitors the influence of repeatance (one operator copies the measuring of the watched commodity's parameter) and reproducibility (group of operators measures the very same parameter) of the total variance. The goal of MSA is to estimate how the system of measuring contributes to the total variance of watched parameter, Fig.1. Most of the time, analysis of the measurement system is used in the phase of Measurements.

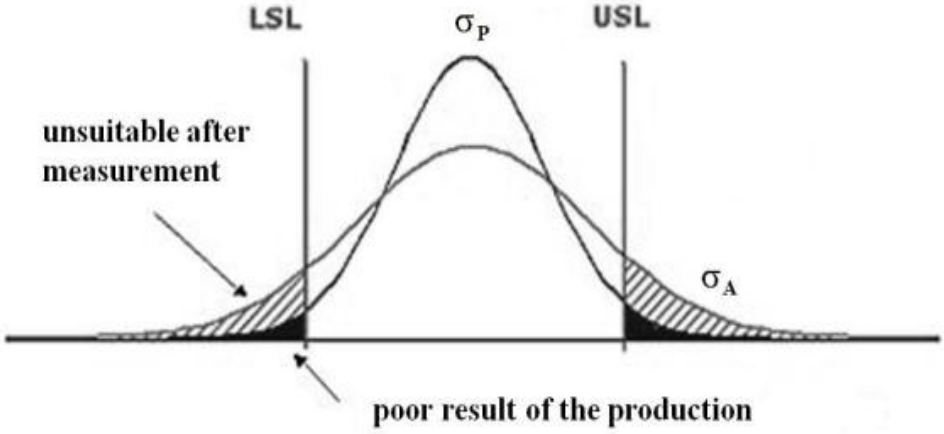

Fig. 1 Measurement System Analysis

Legend: Tolerance = USL – LSL (area of matching values for the customer), LSL – Lower Specification Limit, USL - Upper Specification Limit, σ2A (absolute) = σ2P (of product) + σ2 M (of measurement system),σ2 – variance

B. Analysis Of Cause And Sequences

CE (Cause-and-effect diagram) is a tool to solve problems through finding the cause of their occurence. It helps to find all possible causes, to split causes into categories and organize their relationships and impact on output, and to identify opportunities for improvement. In general, these categories are commonly known as 7M causes:

- Man -people, job;
- Methods and mechanics, process;
- Machine – machines, equipment;
- Measurement;
- Management - system of organization and management;
- Material;
- Mother Nature - environment.

A more detailed analysis of each factor gives a diagram that resembles a fish bone as seen in Figure2.

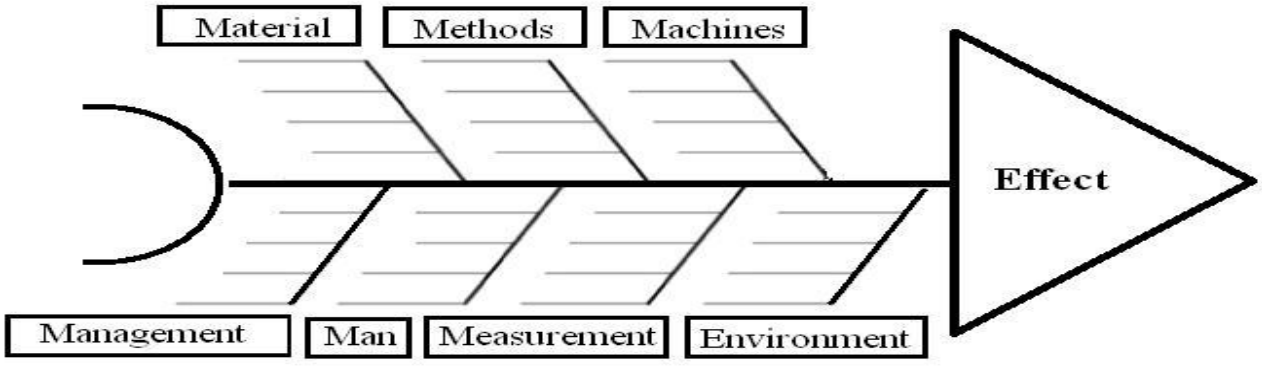

Fig. 2 Fish bone 7M diagram

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C. Histogram

Histogram is a perfect tool for visualization of the frequency of the watched phenomenon in process. It is a bar chart made from number of categories, showing their splitting. Customer tolerance can be added (LSL, USL) to watched process.

D. Pareto Digram

Pareto diagram is a bar chart for discrete data, indicating the frequency of non digital data. These categories are arranged in descending order. The tool that allows determining the impact of input factors to an endpoint.

E. DMAIC

It is the common option for the model of improving the process based on Deming's circle PDCA (Plan-Do-Check-Act). DMAIC (Define-Measure-Analyze-Implement-Control) is in the Six Sigma methodology being used as the standard routine for planning and implementation of the project. The abetment for Six Sigma projects is displayed in Figure 3.

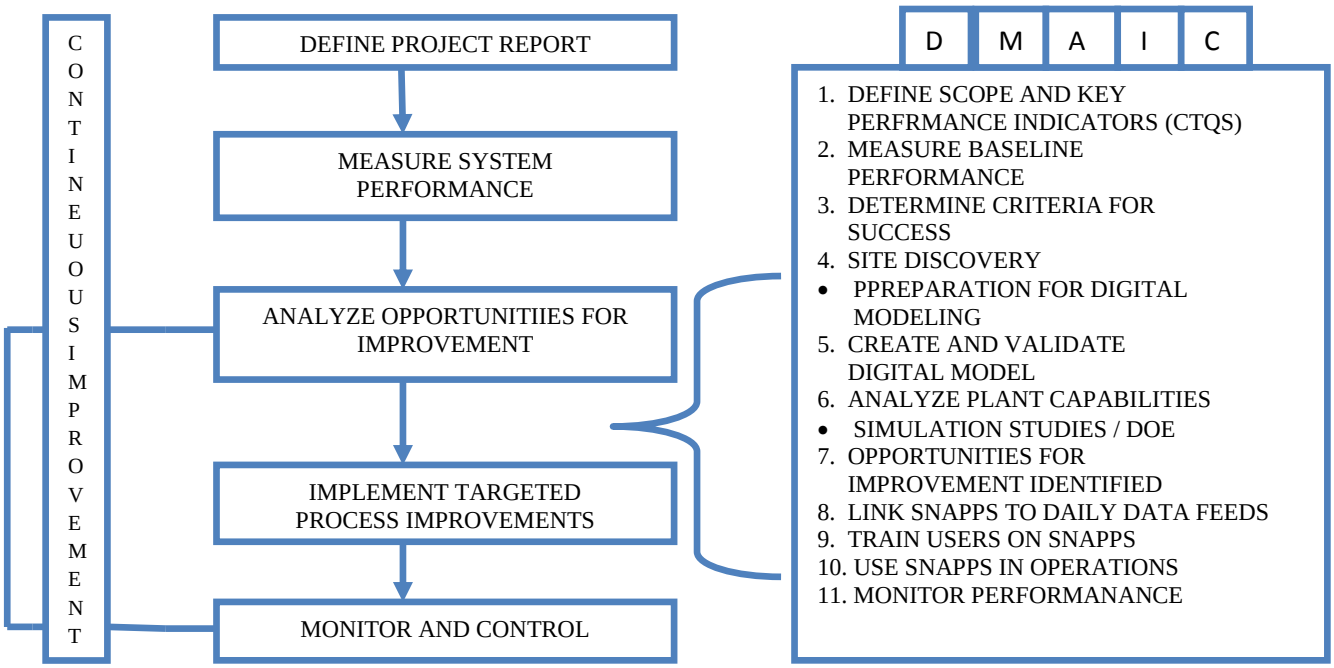

Fig. 3 The abetment for Six Sigma projects

F. Design OF Experiments

Design of experiments (DOE) is a very important element in Six Sigma or Lean methodology. Stat-Ease offers a structured statistical approach to help you understand the factors that affect a process and then create meaningful and effective tests to verify possible improvement ideas or theories.

G. Failure Mode And Effect Analysis

Failure mode and effects analysis (FMEA) is a tool which can use in Six Sigma to quantify and prioritize risk within a process, product, or system and then track actions to mitigate that risk. The step-by-procedure in FMEA are displayed in figure 4.

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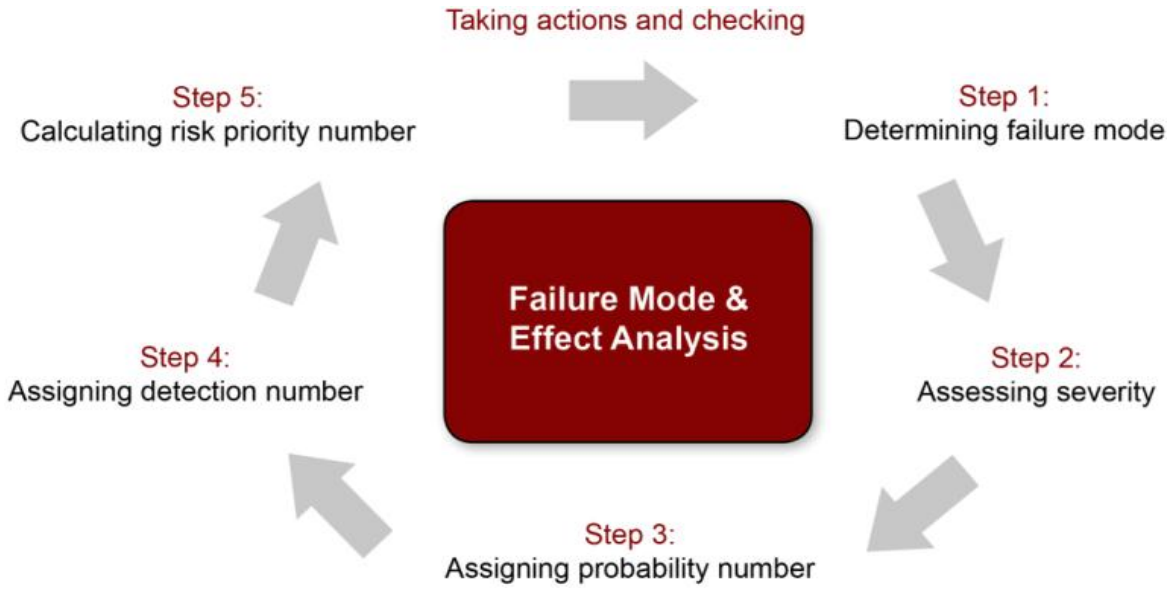

Fig. 4: Steps in FMEA.

H. Standard Operating Procedure

A standard operating procedure is a set of step-by-step instructions compiled by an organization to help workers carry out routine operations. SOPs aim to achieve efficiency, quality output and uniformity of performance, while reducing miscommunication and failure to comply with industry regulations.

I. Quality Function Deployment

Quality function deployment (QFD) is a structured methodology and mathematical tool used to identify and quantify customers' requirements and translate them into key critical parameters. In Six Sigma, QFD helps you to prioritize actions to improve your process or product to meet customers' expectations.

V. DISCUSSION

A. Benefits Of Applying Six Sigma To EMS Design

There were a number of benefits and strengths associated with applying the Six Sigma method EMS design. The first benefit was the use of relatively simple quality tools in a structured process to improve Company A's EMS without having to recreate what may have already been done. More importantly, the Six Sigma method provided a defined method that still allowed for creativity [11]. The Six Sigma method allowed for the examination of what was in place and working in other functions or departments of Company A, as well as leveraging best practices from other companies. For example, existing tools used in other departments such as the EHS Compliance Calendar, coixective action process, and the dashboard tool were used to assist with Company A 's EMS. As well, the use of tables, charts, and simple procedures assisted in this regard. In fact, the use of simplified tools both to identify requirements and to design tasks led to the operationalization of environmental requirements and the EMS in Company A. Instead of one person completing all the tasks, tasks were delegated to different individuals. The development of tools, particularly during the Improve phase, also enabled Company A to generate records and improve its record management. It also allowed Company A to design and implement measurement and tracking tools that aided in monitoring the EMS. Finally, the tools served as an educational resource, particularly the Measure/Assessment checklist and applicable regulatory summary.

Another benefit of the Six Sigma method was in indicating the financial implications o f completing the project. This was important for identifying as well as educating personnel as to the costs involved in EMS design and cost avoidance.

The use of process maps was extremely beneficial in a number of ways. First, use of the process map allowed for the identification of facility process inputs and outputs, and allowed Company A employees to gain a better understanding of the various processes in the facility. It also demonstrated how and where facility processes interacted with the environment such as air emissions, water intake and discharge, raw material and chemical use, and waste generation points. This ultimately led to the identification of applicable environmental legislation for Company A that further permitted the development of a framework in which to design the EMS, as well as identify where stakeholders were connected to Company A 's processes.

Completion o f the process maps could have been used for identification of potential Six Sigma projects to improve environmental performance, pollution prevention opportunities, and well as hazard analysis techniques. Although it was not the scope of the case study, an examination of potential pollution prevention opportunities could have been completed including material substitution, product design or reformulation, equipment or process modifications, spill and leak prevention, on-site re-use, recycling or recovery, improved inventory management or purchasing techniques, good operating practices, and training [12]. The Six Sigma DMAIC process could also be used in completing specific environmental projects. Hazard analysis

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techniques could have also been used once the process maps were completed. For example, a hazard analysis could have been used to evaluate the nature of an accidental release for spill/release response plan development or revisions. Steps would include the review of chemical inventory and storage conditions, chemical properties, dispersion modeling, and consequence analysis [13]. Once this was completed, spill/release response plans could be designed or revised.

The Measure/Improve checklist tool was also beneficial in a number of ways including identifying defects in the EMS process, identifying gaps in the EMS that needed to be addressed, as well as serving as an assessment tool during the Control phase. Perhaps the most important benefit of applying the Six Sigma method to EMS design was the development of a Roadmap as outlined in Table 1 below.

TABLE 1: SIX SIGMA ROADMAP FOR EMS DESIGN

Six Sigma Phase	Tools
Organizing Ideas and Information	
Define Phase	• Team Charter • Project Plan • High Level Process Map • Tollgate Checklist
Data Gathering	
Measure Phase	• Measure Phase Checklist • Measurement Tool Analysis • Process Sigma Calculator/Six Sigma Conversion Chart • Tollgate Checklist
Process and Data Analysis	
Analyze Phase	• Bar Graph • Pareto Chart • Cause and Effect Diagram • Brainstorming • Payoff Matrix • Tollgate Checklist
Implementation and Process Management	
Improve Phase	• Bar Graph • Brainstorming • Improve Action Plan Matrix • Applicable Legislation Table with • File Setup • C of A (Air) Requirements Table • Substances with Key Reporting • Requirements Table • NPRI/0. Reg. 127 Reporting • Determination Worksheets • Procedure Revision Summary Table • Training • Improve Phase Checklist • Process Sigma Calculator/Six • Sigma Conversion Chart • Tollgate Checklist
Monitoring and Maintaining Process Changes	
Control Phase	• EHS Compliance Calendar • Schedule • Assessment Checklist • 4-Blocker Project Summary • EMS Dashboard • Tollgate Checklist

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Development of this tool provides a consistent, structured, and rigorous process that can be used over and over again by Company A to constantly improve the EMS, and allow it to become more efficient [14]. It provided instructions for company personnel in order to move from identifying the problem/opportunity to addressing it. It also prevented the team from jumping directly from problem/opportunity identification to solution implementation.

B. Limitations Associated With Six Sigma For EMS Design

Limitations in the Six Sigma method occurred primarily in the Measure and Analyze phases. First, discrete data were used in the project, and this type of data has limitations in that sigma improvement could only reach a four sigma. Continuous data would be required in order to reach five and six sigma levels. Decisions made in the Six Sigma project were only as good as the measurement system used. One way to address this weakness would be for Company A to change the measurement tool so that it could measure the percent completion of the EMS. The data collected could then be treated as continuous data, and could be used to provide further defect reduction and process sigma improvement.

The measurement system analysis was also a weak area. A statistically-based analysis could not be carried out because only one set of data was obtained during the Measure phase. In order to improve this area, a number of assessments could be completed over a defined period of time, thereby generating a number of data sets. A more comprehensive measurement system analysis could then be completed to determine if any measurement system bias or flaws exist.

A similar type of weakness was also identified during the Analyze phase. As previously highlighted, the team could not determine whether the defects identified were statistically significant, or whether they were due to a random effect. This was because only one set of data was collected during the Measure phase. Hypothesis testing could have been completed if more than one set of data were collected. This would have allowed improvement decisions to be based on objective information as oppose to subjective information.

Identification of applicable environmental requirements was facilitated because the project Green Belt worked as a specialist in the environmental management field. Therefore, identification of environmental requirements could have been problematic if none of the team members had an environmental background. However, such an obstacle could be overcome by ensuring more involvement of the business level EHS Manager to assist with identifying applicable environmental regulations. An environmental consultant would have to be used for smaller companies with no in-house environmental expertise.

The biggest potential limitation in applying the Six Sigma method for EMS design was commitment. This project was completed because Company A has already embraced Six Sigma as a way to do business. This, however, came after eight years of aggressive implementation efforts [15]. This may not be the case in an organization that does not use Six Sigma. Six Sigma acceptance is often an ignored element when attempting to implement it in organizations [16]. Even if Six Sigma was implemented in Company A, team dynamics were critical in order to complete the project. In particular, the Champion had a crucial role throughout the whole process, and therefore management commitment was imperative in order for Six Sigma to work [17].

C. Further Research

More research is needed to examine how Six Sigma is being applied to pollution prevention projects, and to projects that focus on improving environmental performance. There is also an opportunity to examine the use of Six Sigma in implementing an ISO 14001-based EMS, since ISO 14001 is an internationally recognized Standard. Although there has been some preliminary work in this area, the idea needs to be tested for its effectiveness. Further research is also needed in order to determine how companies are currently using Six Sigma in the environmental management field. This is especially true in discovering how companies are capturing financial benefits associated with Six Sigma use in the environmental field. Finally, there is a need for more studies regarding how to implement an EMS. Once this information becomes available, more companies will truly begin to integrate environmental management into their businesses.

VI. CONCLUSION

Some Six Sigma tools may not be appropriate to apply to EMS design. However, Six Sigma does provide a defined and structured method that allows a problem or opportunity to be defined, measured, analyzed, improved, and controlled. This results in a method that can be used over and over again to design or improve an EMS. This is a concept that not been thoroughly developed in EMS literature to date.

At this point, the structured process of Six Sigma itself is probably more beneficial in EMS design as opposed to focusing on which tools are used during the DMAIC process. The Six Sigma method also promoted team involvement from a number of people with varying backgrounds. This especially helped during brainstorming and identification of activities in order to have a more comprehensive analysis of an issue.

Although a structured method was used, there was still room for creative thinking, as well as flexibility in selecting the tools used during the DMAIC process. However, it was important to ensure that the appropriate tools were selected in order to effect meaningful change.

In conclusion, Six Sigma can be applied as a structured and consistent method in EMS design.

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