Using Six Sigma methodology to improve telecommunication software maintenance process

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Abstract: **In the fast changes of telecommunication environment, only those companies which are capable of permanent and fast adaptation to quickly-changing conditions can survive. The customers expects an excellent quality of products or services offered to him, and pays only those prices which are more favorable than the competition in the market. In order for a company to remain competitive and maintain maximal efficiency and effectiveness of software, what is needed is an approach different from the traditional concept of software maintenance. Software maintenance costs often total twice the original development cost in lifetime of an telecommunication software. The concept which enables maximal efficiency of software maintenance process applies continual measures to prevent all defects, whereby the software maintenance process is permanently improved. This is possible to achieve by applying Six Sigma concept in the maintenance of telecommunication software. This paper proposes an applying six Sigma concept to measure, analyze and improve telecommunication software maintenance process.**

I. INTRODUCTION

This article describes applying Six Sigma concept in telecommunication organization with aim to improve efficiency and effectiveness of the software maintenance. It is well known that, in the market, only those companies with sufficient flexibility, i.e. ability to permanently and quickly adapt to the ever changing conditions, can survive. What permanently increases are mobility and output of companies, from whom the customer expects exceptional quality and prices lower than those of their competitors. In order for a company to remain competitive, what it needs are several concepts so that it may achieve and maintain maximal efficiency of its software maintenance processes. The process of maintenance becomes of increasing importance for companies, as it directly affects other relevant processes leading to customer's satisfaction or dissatisfaction. It is no longer possible for companies to uncontrollably spend their resources in the maintenance process (time, material means, money, etc.). The companies existing in today's market are forced to eliminate all unrequired steps from their processes, i.e. all "trash" from processes. Only those companies doing the right thing (effectively) in the right way (efficiently), thus managing to eliminate the losses which occur in processes, can survive in the market. To reach the Six Sigma level in the maintenance process, it is necessary to model a software maintenance process which would result in increased productivity, improvement of quality, reduction of expenses and creation of better working conditions. Such effects are achieved through permanent improvement of maintenance activities, coupled with increased morals of employees and their motivation for work, which includes a radical change of culture of companies. Continual improvement of process is based on the opinions that, however good something may be, it can always be better. To improve the maintenance process Six Sigma concept may be used as a simple model of improving performance based on the DMAIC (Define-measure-Analyze-Improve-Control) method. This model of improvement and design/redesign of processes enables reaching Six Sigma process performances, with planned result of 3,4 defects per million opportunities. In the organization where we implemented improvement program the Six Sigma is used to improve maintenance process and main goals are to reduce maintenance cost and to increase customer satisfaction.

II. SOFTWARE MAINTENANCE PROCESS OVERVIEW

Software maintenance is central to the mission of many organizations. Thus, it is natural for managers to characterize and measure those aspects of products and processes that seem to affect cost, schedule, quality and functionality of a software maintenance delivery. Software maintenance is defined as the process of modifying existing operational software. The software community has started to recognize software maintenance as a crucial discipline within software engineering. This is due to the fact that we do maintain more than develop today. Maintenance has become dominating cost factor in most of the software organization. The importance of maintenance has for many years been ignored and this has lead to the fact that maintenance is still considered to be a very immature area. It has become one of the most complex, costly, and the least understood activities within software engineering. The importance of software maintenance in today's software industry cannot be overestimated. It is widely recognized as the highest cost phase of the software life cycle with estimated costs of between 60% and 80% of the total software budget. It has also been noted that over 50% of programmer effort is dedicated to maintenance [1]. Given this high cost, some organizations are beginning to look at their maintenance processes as areas for competitive advantage.

Maintenance is the latest stage of the software life cycle. The model of maintenance is organized in the five main tasks of the phase: isolating and analyzing problem, designing a fix, implementing this fix, testing the resulting system and updating documentation to reflect the changes made. After the product has been released, the maintenance phase keeps the software up to date with environment changes and changing user requirements. Maintenance can only happen efficiently if the earlier phases of the software life cycle are done properly. There are four major problems that can slow down the maintenance process: unstructured code, maintenance programmers having insufficient knowledge of the system, documentation being absent, and software maintenance having a bad image. The success of the maintenance phase relies on these problems being fixed earlier in the life cycle.

There are four types of maintenance according to Lientz and Swanson: corrective, adaptive, perfective and preventive. [5]

Corrective maintenance deals with the repair of faults or defects found. A defect can result from design errors, logic errors and coding errors. All these errors, sometimes called 'residula errors' or 'bugs', prevent the software from confirming to its agreed specification. The need for corrective maintenance is usually initiated by defect reports drawn up by the end users.

Adaptive maintenance consists of adapting software to changes in the environment, such as the hardware or the operating system. The term environment in this context refers to the totality of all conditions and influences which act from outside upon the system. The need for adaptive maintenance can only be recognized by monitoring the environment.

Perfective maintenance mainly deals with accommodating to new or changed user requirements and it concerns functional enhancements to the system and activities to increase the system's performance. As the software becomes useful, the users tend to experiment with new cases beyond the scope for which it was initially developed and that resulting in an increase in the number of requirements.

Preventive maintenance concerns activities aimed at increasing the system's maintainability, such as updating documentation, adding comments, and improving the modular structure of the system.

The long term effect of corrective, adaptive and perfective changes increases the system's complexity. As a large program is continuously changed, its complexity increases unless work is done to maintain or reduce it. This work is known as preventive change. The change is usually initiated from within the maintenance organization with the intention of making programs easier to understand and hence facilitating future maintenance work.

Among these four types of maintenance, only corrective maintenance is traditional maintenance. The other types can be considered as software evolution. Corrective maintenance is a small percentage of overall maintenance costs. Over 80% of maintenance costs are for providing enhancements in the form of adaptive and perfective maintenance [1].

III. SIX SIGMA OVERVIEW

Six Sigma is a disciplined approach to continuous process improvement designed to increase customer satisfaction and profits while reducing defects and cost [2]. The name derives from the ideal of 3,4 defects per million opportunities and for each sigma level it is defined DPMO (number of defects per million opportunities). The definition of sigma levels is shown in Table 1. [6] Organization with a three sigma level of defects (typical of software) is candidate for improvement. Beyond, six sigma, the investment is assumed not to be cost effective. Originally developed at Motorola, it has been popularized by many high profile companies including Honeywell, GE, 3M, Kodak and Allied Signal. Today it is wifely applied to manufacturing and service-related processes [4].

Table 1. Six Sigma conversation table

Sigma level σ	Defects per Million Opportunities (DPMO)	Percentage of defect free output
6	3,4	99.9996%
5	233	99.98%
4	6 210	99.40%
3	67 000	93.30%
2	310 000	69.00%
1	690 000	31.00%

The origins of Six Sigma are instructive for software development. In 1985, Bill Smith argued that if a product was found defective and corrected during production process, other defects were bound to be missed and found later by the customer during use of the product. This raised question was the effort to achieve quality really dependent on detecting and fixing defects, or could quality be achieved by preventing defects in the first place through manufacturing controls and product design.

To make Six Sigma a success in organization it must affect everyone in the organization. Six sigma is teaching everyone in the organization to become more effective and efficient. The path to becoming more effective and efficient using six sigma contains three components. The first component deals with the strategy of Six sigma which is called Business Process management. This strategic component is the responsibility of the management. The second component deals with the tactics of how project teams improve process. It utilizes a methodology similar to the scientific method refers to defining and measuring a problem, analyzing its root cause and testing theories of improvements. And last but not the least is cultural component since Six sigma has an impact on organizational culture.

Six Sigma is an iterative approach based on undertaking a continuous series of initiatives to improve performance over time. The process improvement model is called DMAIC, an acronym for the following 5 steps, Fig1.:

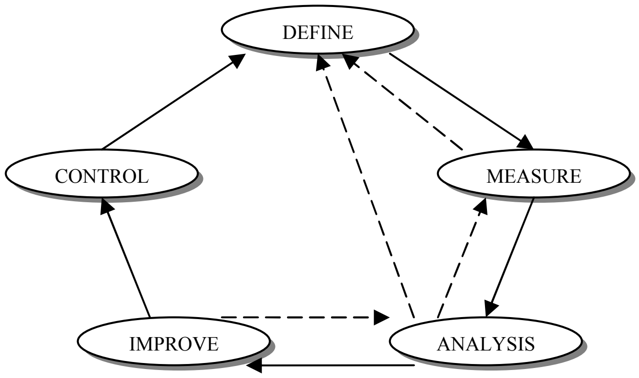


Fig. 1. High-level DMAIC Improvement methodology

- *Define* what is important. What matters to the customer? In this phase of improving the performance of the maintenance process it is necessary to identify the problems which occur in processes, determine requirements and define the planned result of improving the maintenance process.
- *Measure* performance. How are we doing? What aspects of the process are affecting customer value? This phase is applied when recording the existing maintenance process and determining the processes relevant for maintenance. Detailed knowledge of the existing maintenance process includes description of the maintenance process, drawing process chard and completing the SIPOC (suppliers-inputs-process-outputs-customers) table. This phase of the DMAIC model includes applications of the following quality tools and advance tools of Six Sigma concept [7]:
    - *Statistical Process Control - SPC*
    - *Failure Mode and Effects Analysis – FMEA*
    - *Measuring Customer satisfaction - MSC*
- *Analyze* opportunity. What could we be doing better? What are the variables that affect performance? The purpose of analyzing the process of maintenance is to determine what is not good in the process, what the cause of its inefficiency are, as well as to propose how it can be improved. Assumptions on possible causes of problems are made, and "vital minorities" of the root of causes are identified and these assumptions are confirmed or denied. For this phase it is required application of quality and Six sigma tools:
    - *Pareto-analysis*
    - *Cause-effect diagram (Ishikawa-diagram)*
    - *Design of Experiment - DoE*
- *Improve* the process. Plan a strategy for improvement and test it out. Process improvement includes making a proposal for improving the process, defining a strategy of improvement, recording "to-be" process, elimination of activities which do not create extra values, elimination of possible causes of variations in the process, assessment of risk and testing.
- *Control* the process. Institutionalize practices to sustain the improvement. The control phase is very important, as it enables confirmation of introduced improvements. Control of the entire maintenance process is based on measuring process performances, which are continually tracked over time, with the goal to observe trends, the best and worst practices, and possible fields for improvement. Each process has the possibility to get out of control and cause problems.

Six Sigma can be implemented in the more iteration and at the beginning of each initiative iteration the process is analyzed to final threats to customer satisfaction and opportunities for improvement [3]. Traditionally, the measurement part of the process is based on practices of statistical quality control.

Six Sigma is sometimes criticized for being inappropriate for development processes characterized by the unique intellectual efforts of knowledge workers. DMAIC's strength is its focus on continuous process improvement and its iterative and incremental approach to achieving it.

IV. SIX SIGMA CASE STUDY IN TELECOMMUNICATION COMPANY

Six Sigma is implemented in telecommunication organization which develop telecommunication software products an it is responsible for maintenance of those products. The maintenance organization has KPI's (key performance indicators) defined as Closure rate, TR (trouble report) cost and AC (approved correction) quality. The KPI's represents organizational goals and they are measured on the yearly base:

- Closure rate - the average overtime, if TR is finished after defined period, according to the TR priority level
- TR Cost – the average effort in man hours spent to finish TR
- AC quality – number of delivered corrections that has been founded as faulty in total number of corrections

When maintenance organization received fault report (TR) the first phase is selection of TRs according to the priorities which indicate how the reported problem impacts system. Priorities are defined as A/B/C and according to the maintenance, the organization should solve reported problem in certain number of days which is defined as for A/7, B/14 and C/21. The next phases are analyzing fault, reproducing fault, correction preparation, correction verification, answering of TRs.

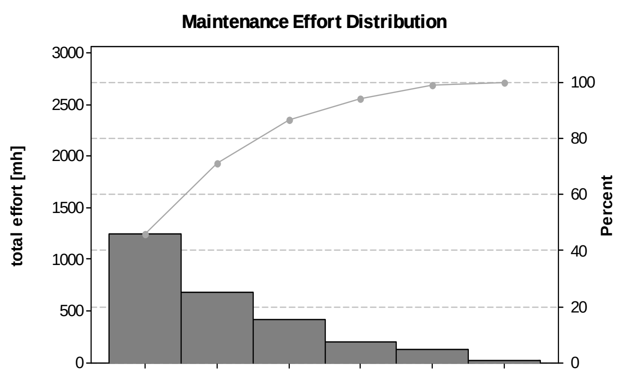
The TRs can be answered with correction (B code) and with some other answer code which indicate that fault can't be solved with correction (D code) or that fault is already solved. In the case that the fault can't be solved with corrections the solution will be implemented in the next revision of product.

The maintenance organization has decided to implement Six Sigma because it was defined that customer perception and satisfaction with software products should be improved. Also the market situations indicate low cost competitors and price erosion of 10% yearly. Since maintenance has high impact on costs it was decide that organization should improve maintenance efficiency which means that closure rate and TR cost should be decreased. The goal is to increase maintenance efficiency measured by closure rate decrease for 20% and TR cost decrease by

10% in a ten months period. At the same time organization should keep or even improve quality measured by correction quality.

Since maintenance organization has defined measurement tools and process for defining KPIs, it was used to collect data for baseline analyze. The data has been collected by using existed TR data base which provide detail information about TR status at any moment and lead time for any activities in maintenance process. Since, process should be more detailed analyze to detect critical phases and more detailed measurement has been collected using measurement protocols (questionnaire), which provide information about effort distribution for all major activities in maintenance process, filled-in by the maintenance engineers who were responsible for specific maintenance activities.

Analyze based on effort distribution, Figure 2, present on what do we spend time and what is the cost of a TR differences for TRs with and without corrections. The cost for TR include correction preparation cost, TR analyze cost, desk check cost, TR closure cost and cost for the screening activities. In this project, it has been measured that 77% of TRs are answered with corrections and the main cost driver for the TR is correction, since 46,1% of cost is for correction preparation and 15,5% is for DC (desk check) of corrections. When we exclude those activities cost structure is the same for the TRs with corrections and without it. All other activities as analysis, screening and TR closure has almost the same cost for TR with or without AC. According to the Figure 2 for TR with AC in total cost those activities participating with 25,2% for analysis, 7,5% for screening and 4,8% for TR closure



label	AC prep.	analysis	DC	screening	TR closure	Other
Count	1251	683	421	205	131	22
Percent	46,1	25,2	15,5	7,5	4,8	0,8
Cum %	46,1	71,3	86,8	94,4	99,2	100,0

Fig. 2. Maintenance Effort Distribution

According to the answer code distribution approximately 50% of TRs not requiring corrections are answered with D-code. This corresponds to 15% of all TRs handled by maintenance organization and it is recognized as critical point.

Almost 5% TRs with corrections get D answer, what means that a correction is prepared but later is not released as correction that will be delivered to customers. This figure is small but since the cost for such TRs is as three costs of TRs without corrections, these TRs contribute the same costs of the total COPQ (cost of poor quality).

During the analyze of the reported faults 63% of time is spend on fault reproduction what in overall TR cost contribute with 14% of costs. FMEA (Failure Modes and Effects Analysis) indicate that fault reproduction is critical and time consuming activities in maintenance process for TRs with corrections and for TRs without corrections.

During the improvement phase, the improvement actions that will improve TR cost, closure rate and maintenance efficiency have been defined:

- Reduction of D answers by 50%. The faults answered with D code are in most cases system faults and it is not possible to fix problem with correction or it is not sufficient data in TR observation field for analysis. To reduce number of TRs that can't be solved it should be organized cross functional team for stinker areas that has competences for system faults. This type of faults should be indicated as soon as possible.
- Decrease effort for fault reproduction by 30%. The fault reproduction should be simple if TR author provide all necessary data, traces, test configuration from originally fault when it occur. That information's help maintenance engineer to reproduce fault without loosing time. A specific template was prepared for TR author which data should be collected within TRs. Since maintenance organization can't have all different test configurations as customers because products are deployed all around the world it should be made possible to reproduce fault on customer environment with aim to collect additional data for troubleshooting.
- Increase productivity by 10%. Reduction of D answers, especially for TRs supposed to be answered with corrections, and decreasing effort for fault reproduction.

Those improvements are implemented in maintenance organization as an action plan provided by Six Sigma improvement project. During the control phase KPIs and effort distribution have been measured in six months period and results confirmed that Six Sigma is successfully implemented in maintenance organization.

V. CONCLUSION

The advantage of Six Sigma methodology implemented in maintenance organization in comparison with the existing improvement programs is that it creates the awareness of need to change the existing maintenance concept by abandoning old models of thinking, forgetting wrong and outdate things, which changes the culture of the company and the focus of the company shifts towards the market and user of services. Also, Six Sigma identifies important processes in maintenance which have a decisive effect on the company's business and give measurable effects with respect of the requirements of customers.

Through the implementation of the Six sigma project in maintenance organization it has been observed that it enables continual improvement of the maintenance process, which always results in increased effectiveness and efficiency of the company, reduced maintenance costs and increased profit. Beside the financial aspect, Six Sigma provides "soft" savings what is visible through maintenance organization as increased customer satisfaction, less overtime, increased motivation, increased predictability of maintenance, better planning and utilization.

Six Sigma is continual improvement program and investments are higher during the first implementation, the next phases are expected to bring the higher cost savings and efficiency improvement.

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