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APPLICATION AND VALIDATION OF DMAIC SIX SIGMA TOOL FOR ENHANCING CUSTOMER SATISFACTION IN A GOVERNMENT R&D ORGANIZATION

Abstract: *This study was carried out to explore and validate DMAIC six sigma tool to enhance the customer satisfaction in an ISO 9001: 2008 certified government R&D organization. The organization chosen for this study has implemented QMS since last six years with an aim of attaining 85% customer satisfaction. The deficiency in customer satisfaction by 8% has been observed after comprehensive data analysis of the customer feedback. The Lean Six Sigma tools and techniques have been applied followed by solution implementation and effectiveness assessment. The developed solution is found to be effective in enhancing the customer satisfaction by more than 85%. This has established that the designed LSS tools are suitable and effective in an R&D set-up for improving service quality and customer satisfaction. The results give feasible solutions to the emerging service oriented government R&D sector to enhance customer satisfaction. Limitation of the study is that the results are based on the limited inputs from one organization and the tools can vary depending upon the mandate and quality objectives.*

Keywords: *International Organization for Standardization (ISO), Lean Six Sigma (LSS), Quality Management Systems (QMS), Research & Development (R&D)*

1. Introduction

Six Sigma defect is anything outside of customer specifications. Six Sigma is a disciplined approach, data driven and methodologically implemented. It is focused on the elimination and minimizing of the defects in any process. It has wider applications in service industries as well as manufacturing sector. The aim of Six sigma approach is to achieve and maintain the six standard deviations between mean and nearest specifications limit. Statistically, six sigma describes quantitatively on how a process is performing. A process must not produce more than 3.4 defects per million opportunities to achieve Six Sigma.

R&D service providers are in a competitive environment aiming to maximize customer satisfaction and applying the tools of Lean Six Sigma in standardizing the procedure and enhancing the quality of services. This case study is carried out in an ISO 9001: 2008 certified R&D organization working in the development of technologies for mitigation of cryospheric hazards to ensure safe mobility of army personnel and civilians in snow bound treacherous regions of

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Himalayas.

Quality management has been established as an important strategy to achieve competitive advantage in manufacturing sector. The global commitment to quality improvement programmes is underway in all the arenas of economical, technological and military activities. This is a testimony to the importance of Quality in all the arenas and a specific focus is required in R&D sector also. The organizations around the world are increasingly striving to adopt internal management systems and continuous improvement strategies to enable them to produce state-of-the-art technologies and compete in the global marketplace.

Quality Management System is a collection of business processes focused on achieving quality policy and quality objectives to meet Customers' requirements. During the last decade, different quality management concepts, including ISO 9001:2008, Total Quality Management (TQM), Six Sigma and LEAN have been applied by different organizations in order to enhance internal and external customer satisfaction. (El Haik & Roy, 2005).

Six Sigma is a strategic planning tool to boost profit, enhance market share and improve Customer satisfaction through statistical tools that can lead to breakthrough quantum gains in quality (Desai & Shrivastava, 2008). Service providers are implementing Six Sigma in marketing, finance, information systems and human resources processes with a focus on enhancing efficiency and effectiveness. Thus, Six Sigma is a significant tool to identify the root cause of the problem areas and device appropriate solutions (Antony, 2008).

Kumar & Antony (2008) have outlined the critical practices used for achieving quality management in R&D working in service sector. Though Six Sigma was originally developed by Motorola for manufacturing processes, but today service sector is tremendously using Six Sigma to achieve organizational excellence. Lean Six Sigma is a potential tool that can help to trim down the risk and defects in an R&D process, making it more manageable, cost efficient, and more reliable. Using Six Sigma in research, allows to perform reverse research and development in order to streamline processes, although, reverse R&D also reduces the risk of product failure. Elements of Six Sigma like Pareto charts, Statistical Process Control, Failure Mode Effect Analysis (FMEA), Regression, Hypothesis and other tools aim to improve the Customer satisfaction and enhance the quality.

2. Literature review

Even though organizations have accomplished their process improvement through different QMS concepts, the application of six sigma in a knowledge based environment such as R&D institutions is in a nascent stage and is a big challenge (Nakhai & Neves, 2009). It is established that applicability of six sigma tools in an R&D set-up is different when compared to manufacturing sector. As services neither be stored on a shelf, nor be produced in tangible form, whereas they are obtained by engaging an interactive process with the service provider. The proper implementation of Six Sigma tools necessitates the operational strategies along with customer needs/ customer satisfaction. The intended customer requirements must be considered to enhance applicability of QMS tools in service sector (Qureshi et al., 2012).

Recently some studies have been conducted to evaluate the effect of QMS implementation in an R&D unit, whereas very few reported for applicability of LSS tools in an R&D sector.

Kumar & Antony (2008) have outlined the critical practices used for achieving quality management in an R&D environment working for service sector. Many organizations in manufacturing and services, public and private, large and small have

joined the Six Sigma band dray. Though Six Sigma was originally developed for manufacturing processes, but today service organisations, within almost every sector is using Six Sigma to improve profits and performance. Service sectors are implementing Six Sigma in marketing, finance, information systems, and human resources processes in order to solve the problems and find the most appropriate solution. Thus, Six Sigma methodology has a substantial role under these conditions to pin point the major problem areas and device powerful strategies to tackle such problems which improve the customer experience (Antony, 2008).

Lean Six Sigma can help to trim down the risk and defects within an organisation's R&D process, making it more manageable, cost efficient, and more reliable. Six Sigma is an organised and systematic method for strategic process improvement and for development of new products and services that relies on statistical and scientific methods to make remarkable reductions in customer defined defect rates (Abreu & Sousa, 2012). Using Six Sigma in research, allows to perform reverse research and development in order to streamline processes, reduce cost, increase product movement in market by improving process, although, reverse R&D also reduces the risk of product failure.

Elements of Six Sigma like Pareto charts, Statistical Process Control, Failure Mode Effect Analysis (FMEA), Regression, and Hypothesis are in use to improve the customer satisfaction and enhancing the quality in production vis-à-vis in R&D. The applicability of six sigma tools is somewhat different in service sector compared to a production setup, because services could neither be stored on a shelf, nor be produced in tangible form, in fact they are obtained by engaging an interactive process with the service provider. Although organizations have accomplished their process improvement through different QMS concepts (Nakhai & Neves, 2009), upgradation of QMS system and applying six sigma in service sector particularly in knowledge based environment such as R&D institutes is a big challenge. For proper implementation of Six Sigma tools, the operational strategies along with customer needs/ satisfaction must be considered and to enhance applicability of QMS tools differently in service sector (Qureshi et al., 2012). Rusko and Kralikova (2011) reported that six sigma application in EMS design found effective particularly in environmental assessment and labeling of products, life cycle assessment (LCA) and promoted the business in Slovakia.

Various authors have given the applicability details of DMAIC tool inspired by Deming's plan-do-check-act principle and is a regression analysis based closed-loop process to eliminate unproductive steps with a focus for continuous improvement. (Gupta, 2013; Kumar & Kaushik, 2014; Nakhai & Neves, 2009; Patel & Desai, 2014). This study has been carried out with an aim to improve customer satisfaction through process improvement after step-by-step implementation of Six Sigma DMAIC approach, in a prime R&D laboratory working in the field of cryospheric science and engineering to mitigate avalanche disasters in Indian Himalayas.

3. Research methodology & data analysis

The case study organization has five quality objectives and has been continually working for improvement in its services. Each quality objective of the QMS has been analyzed to find out the reasons for non-adherence to 85% customer satisfaction. The lack of customer satisfaction was selected as a problem, wherein we applied six sigma tools to improve the performance of the organization. The study has been carried out in five phases as per six sigma improvement model.

In the define phase, A Pareto chart was prepared for the services that are being provided by the organization to its customers. Various quality objectives of organization, personal interviews with the department heads, interaction with customers and analysis of customer feedback was collected for last two years with the help of voice of process. Majority win approach analysis was carried out to check the suitability of DMAIC tool for the identified problem. Another Pareto chart has been drawn to define factors contributing to identify problem areas. Risk failure Analysis has been also done to support our study design and use of DMAIC as a tool for this study. After Factor characterization table, to identify factor type fish bone diagram has been drawn to categorize the attributes of selected process.

In the measure phase, initially the process map has been drawn for the identified problem. The controllable and uncontrollable factors responsible for the identified problem has been listed and further classified under cause and effect diagram. FMEA has been applied to optimize identified uncontrollable factors. Various factors have been prioritized according to their effect on the attribute with the help of analytical hierarchy plan. The process capability chart has also been drawn to check stability of data as well as to define baseline attribute for selected problem.

In the analyze phase, the actual cause of the problem has been identified and the problem causing factors have been identified using various tests such as chi-square test, Poisson test and logical & analytical tool. The purpose of these tools has been used to test hypothesis and experiment on the process. After proper understanding of the relationship between causes and effects, the best solution to improve the process has been finalized. The benefits expected from the improvement have also been determined in this phase.

In the improve phase, recommended changes have been implemented in the identified process and the performance has been analysed using the developed metrics. The process has been monitored for the expected improvement for the period of six months. Regression analysis, solution prioritizing matrix tools have been used to prioritize different solutions and solution action plan has been proposed for selected solution. To statistically validate improvement, paired test has been conducted.

In Control Phase, a check has been run to analyse the modified process and its ability to maintain a stable state and persistency for long term. Control Charts and Capability Analysis has been implemented to control future process variation to assures that the same problem does not occur in the future.

4. Results and discussions

The present study shows that lean six sigma tools can be applied in service sector for improving the service quality. Based on the analysis we have selected DMAIC tools to reach the desired goal of improving customer satisfaction.

Define: Figure 1 Shows the Pareto chart for the services provided by the R&D Organization.

There are three main services viz. Avalanche Forecasting, Weather Forecasting and Data services to its customers. The prepared Pareto chart shows that out of three services minimum customer satisfaction (62%) is observed in avalanche forecasting. Hence, this service is considered for further study. The voice of processes result shows that avalanche forecasting services attributes are promptness in replying queries (PRQ), timely reception of avalanche warning bulletin (TRAWB), overall avalanche forecasting (OAAF) and content/clarity of forecast bulletin (CFB). Among all attributes majority of dissatisfaction is for PRQ and TRAWB.

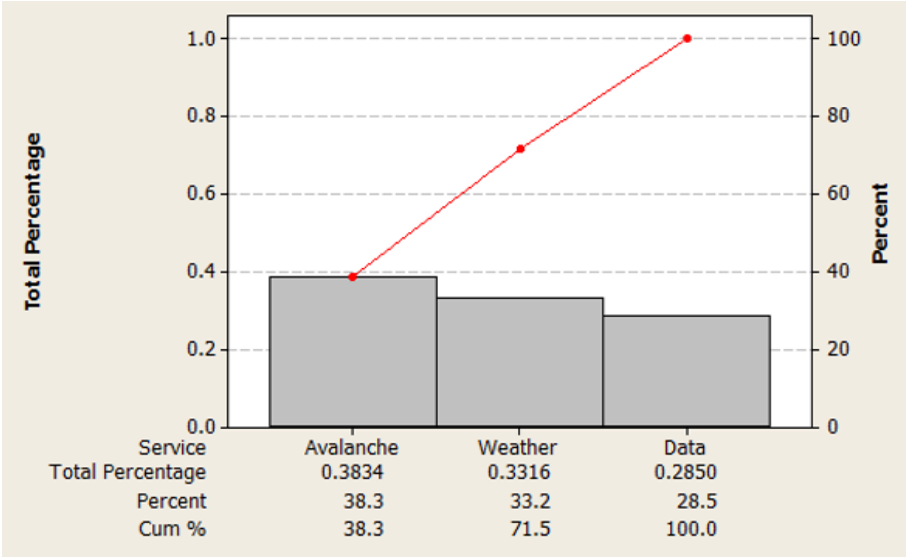

Figure 1. Pareto Chart for the services provided by Organization

The pareto chart on Figure 2 shows that 80% problems for customer dissatisfaction is due to delay in PRQ and TRAWB. Among both selected attributes the percentage of dissatisfaction for PRQ is more. Hence, PRQ is selected for further study.

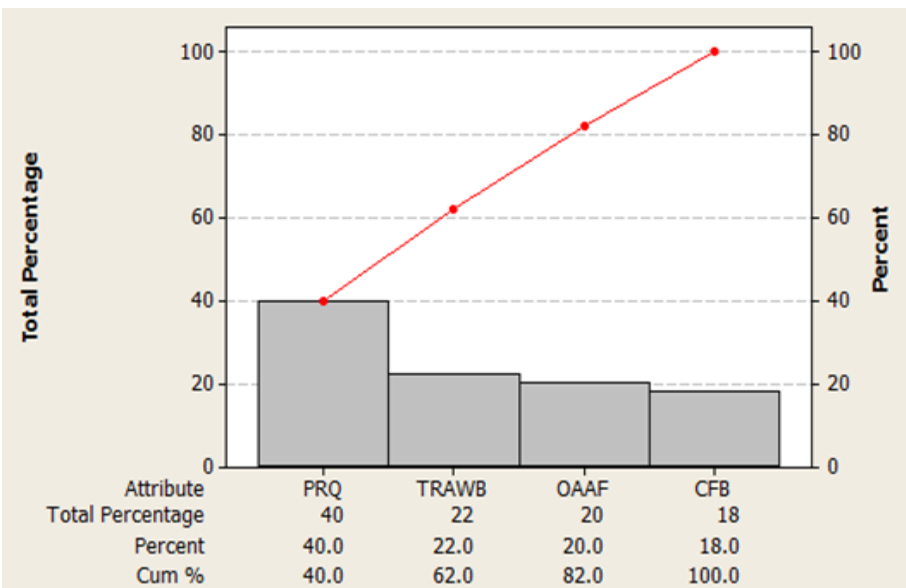

Figure 2: Pareto chart for the attributes of Avalanche Forecasting Services

Figure 3 shows the process map for Promptness in replying of queries from receiving of query to sending the reply to the customer. The map shows the different people and steps are involved in the identified process.

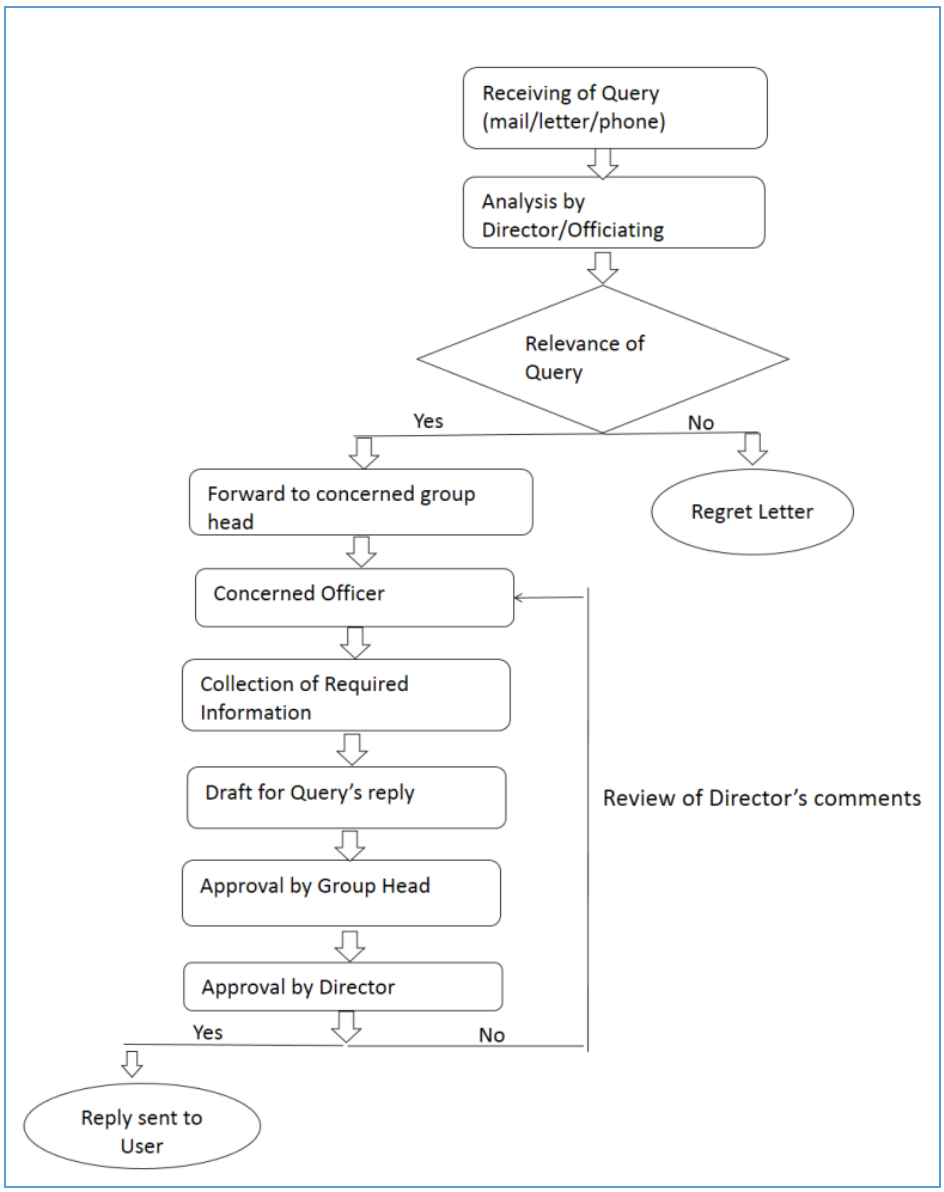

Figure 3: Process Map for Promptness in replying queries

Factor characterization table (Table 1) shows there are six controllable factors and two uncontrollable factors in selected process, one is identified as procedural step in the selected process.

Table 1: Factor Characterization Table to select controllable and uncontrollable factors of the Process

S.No.	Raw List	Group	Factor Type
1	Format of Information	Measurement	C
2	Unavailability of concerned person	Man	C
3	Data Security policies are not clear	Policies	C
4	Irrelevant Queries	Environment	UC
5	Repetition of queries	Environment	C
6	Data Retrieval	Machine	C
7	Multichannel Process	Process	P
8	Weak mode of communication	Machine	UC
9	Incompatibility with relevance of information required	Man	C

Measure: In this phase various LSS tools have been applied to check the process and to list out the various controllable and uncontrollable factors responsible for delay in reply. Analytical hierarchy process was drawn to compare the various factors for delay in queries reply. Figure 4 shows the Cause and Effect Diagram drawn on the basis of factor characterization table for the problem undertaken. In this factors are categorized under Man, Machine, Environment, Policies, Measurement and Process. The developed fish bone diagram gives a better understanding of factors like why these factors affect the process and how they can be improved. Figure 4 shows that the factor for which man is responsible are Unavailability of concerned person and incompatibility of individual w.r.t. information sought for.

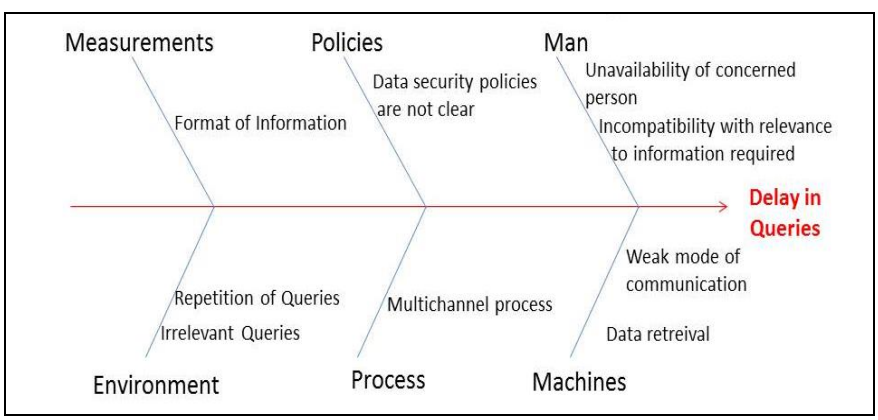

Figure 4: Cause and Effect Diagram

FMEA (Table 2) has been carried out to optimize two uncontrollable factors i.e. weak communication and irrelevant queries and process has been optimized to reduce the effect of these factors on the process.

Table 2. Failure Mode and Effect Analysis (FMEA)

Process step or product part	Irrelevant queries	Weak mode of communication
Potential failure Mode	Failure in providing Required in formation	Delay in queries
Potential failure effects	Customer dissatisfaction	Customer dissatisfaction
SEV	8	8
Potential causes	Lack of information regarding services from customer side	Unavailability of fast communication system at remote locations & poor signals due to extreme weather condition
OCC	4	7
Current controls	Regret letter for asked query or information	Replies sent through alternative mode of communication at that place & delayed replies when signal is weak
DET	3	6
RPN	96	336
Actions recommended		Reply sent according to the available mode of communication
Resp		AFG
Action taken		Increased the number of modes of communication
SEV		8
OCC		5
DET		3
RPN		120

Figure 5 shows the process capability analysis to monitor delayed replies to queries where sample size varies, a p-chart is used to check stability of data (delay in queries reply out of total queries) as well as to define the baseline attribute capability of the delayed reply. Also, as no point is outside the UCL & LCL, thus, with 95% confidence (as alpha=0.05) it says that there is no special cause present. Hence, the process is stable. Proportion defective is at 0.317 which means out of every 100 queries with the current data, 32 delayed replies are expected. This has been taken as baseline capability of delay in replies of queries.

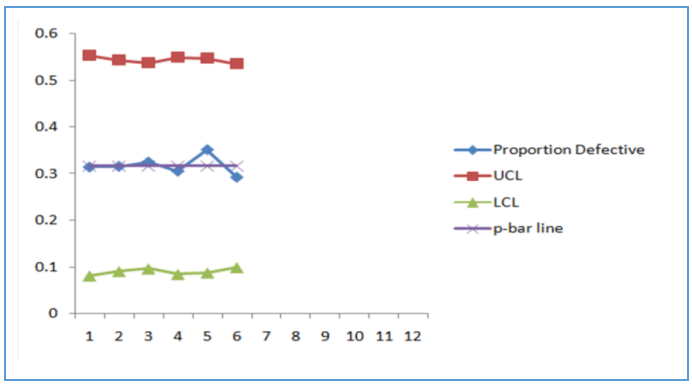

Figure 5. Process Capability Analysis

Analysis: The chi-square hypothesis test was carried out for all the areas where services are provided by the organization. For further confirmation we have carried out two sample poison test, Figure 6 and Figure 7 shows that the p value is 0.608>0.05 and 0.5437>0.05. Hence, 'fail to reject null hypothesis' there is statistical evidence of the occurrence rate goal falls within the 95% confidence band of the occurrence rate from the sample. Practically, there is not much effect of data retrieval on the delay in queries replies.

Test and CI for One-Sample Poisson Rate

Test of rate = 0.025 vs rate not = 0.025

Sample	Total Occurrences	N	Rate of Occurrence	95% CI	Exact P-Value
1	3	73	0.041096	(0.008475, 0.120100)	0.437

"Length" of observation = 1.

Figure 6. One sample poison test (a)

Test and CI for Two-Sample Poisson Rates

Sample	Total Occurrences	N	Rate of Occurrence
1	1	35	0.0285714
2	2	38	0.0526316

Difference = rate(1) - rate(2)
Estimate for difference: -0.0240602
95% CI for difference: (-0.116019, 0.0678989)
Test for difference = 0 (vs not = 0): Z = -0.51 P-Value = 0.608

Exact Test: P-Value = 1.000

Figure 7. Two sample poison test (b)

To understand the root cause of delay in reply of queries, the 5 Why tool is used. Table 3 shows the main reason of the problem by just answering simple why questions.

Table 3. Five 'Why' analysis for identified problem

Why1	Unavailability of concerned person	Multichannel process
	⬇	⬇
Why2	Absence of individual from office	Single portal receiving queries and many people are involved in process
	⬇	⬇
Why3	On official/temporary duty or personal leave	Approval is required at each step
	⬇	⬇
Why4	Duty allotted by director or personal work	Proper authority is required due to data security policies
	⬇	⬇
Why5	Other assigned job completion	Data is confidential
Root Cause	The job is assigned before receiving of query	Seeked data may come into category of restricted data
Recurrence Prevention	Rather than waiting for individual to come, immediately pass on the details of the query to the next competent person.	We can't change the government policies on the data. But we make the process time bound so that time taken by individuals is limited and reply can be sent in a particular time frame.

Figure 8 shows the residual plots for regression. From figure, Regression SS indicates that variability is due to the regression model. As the value is close to 98.2%, variability is explained by the regression model. Same is reflected in the R-squared value which is 98.4% P-value for constant and terms are less than 0.05.

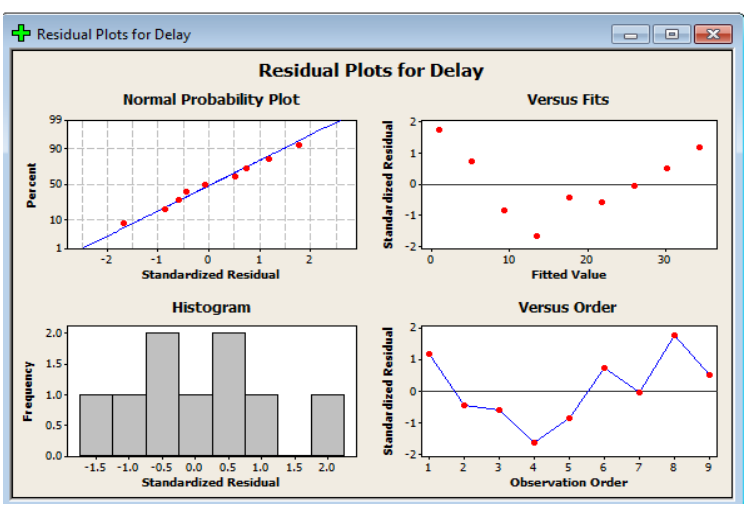

Figure 8. Residual plots for Regression analysis

Thus, reject the null hypothesis is considered. It can be concluded that multichannel process (MP) does have an impact on Delay in queries reply and it does so 98.2% of the times. Practically, the regression equation is Delay = - 3.42 + 42.2 MP. That is, if want delay to be zero, MP should be equal to zero which means multichannel process is eliminated. Hence, the statistical goal of the improve phase and control phase is to eliminate the multichannel process.

Improve: In this phase selected and proposed changes in the identified process has been implemented and performance has been analyzed. LSS tools such as regression analysis, solution prioritizing matrix have been used and solution action plan has been prepared for the selected attributes. Residual plots for regression analysis reflect the relationship between MP and delay in quires as no curvature is present and residuals are normally distributed. After analyzing the effect and feasibility of various recommended solutions a new solution action plan has been drawn and implemented initially for period of six months.

Control: Based on the above data analysis a new process has been suggested with reduced multi channels. In this study we have implemented the solution for specific period (six months) and Figure 9 shows the control chart for the pre and post stage of process. Statistically, the post improvement delayed reply has certainly decreased from an average of about 32% to 6%. The process is also in control after testing it for the entire special cause test.

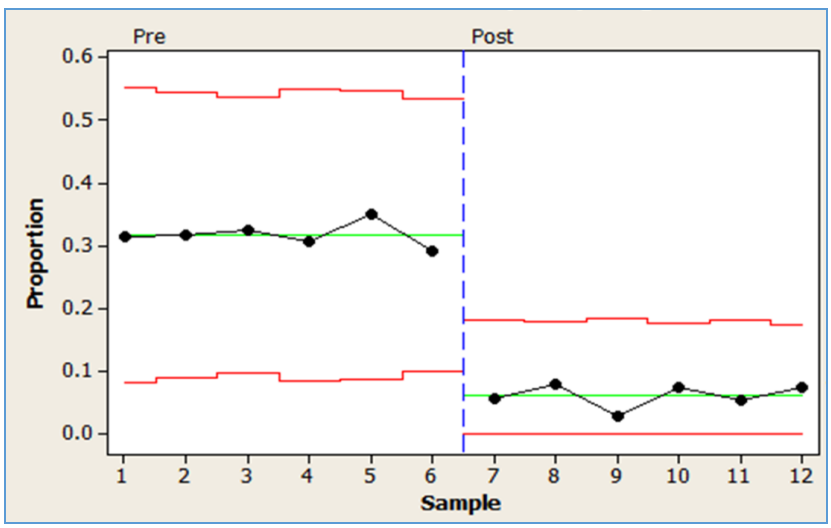

Figure 9. Control Chart for Pre and Post stages of Process

Practically, the goal of the project was to have zero delays to increase the Customer satisfaction. Despite this, there are still some delays in queries but it is acceptable in long run. Capability analysis (same as in measure phase) has been carried out on the revised operating conditions. Final Capability comes out to be 0.06 against the baseline capability of 0.317. Figure 10 shows the process capability chart for the process after implementation of proposed solution. As no point is outside the UCL & LCL, thus with 95% confidence (as alpha=0.05) it shows that there is no special cause present. Hence, the process is stable. Proportion delayed is 0.062 at which means out of every 100 queries with the current data, 6 delayed replies are expected.

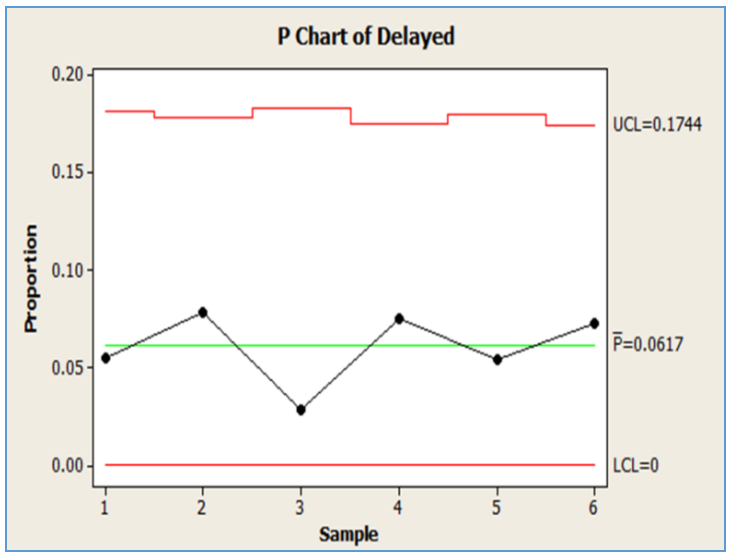

Figure 10. Process Capability Chart for New Process

As literature shows attention to the customer needs and their satisfaction is one of the main target of six sigma projects (Hung & Sung, 2011). This was the first time that any R&D institute working in snow science has applied DMAIC tools for improvement of their customer satisfaction. The problem in implementation of quality in R&D set-up was resistance of people to adopt the practice. The inculcation of quality practice in organization should therefore be embedded into the process of designing rather than just monitoring the quality at the manufacturing level, the more important issue for adaptability of quality practice is the change in organizational culture that puts quality into planning (Pojasek, 2003; Pathak and Desai, 2011).

The study also shows the relationship between QMS and Six Sigma in a R&D Organization, although it has been applied with some modification as per its utility in R&D organization. In this we have concluded that QMS and Six Sigma work hand in hand in any organization Our finding supported by the findings of Wipro where it has been reported that they have enhanced their project completion upto 91% compared to average of 55% after applying DMAIC tool of lean six sigma in their software development process.

For proper implementation of Six Sigma tools, the operational strategies along with customer needs/ satisfaction must be considered and to enhance applicability of QMS tools differently in service sector (Qureshi et al., 2012).

5. Conclusions

In this study we have applied DMAIC approach for a process improvement that leads to customer satisfaction in a R&D unit. Firstly, after analyzing different quality objectives that lead to gap identification, we identified the reasons for these gaps and prioritize them. Finally, we proposed the solutions according to the factors which resulted in customer dissatisfaction and prioritized the solution. After applying the corrective measures, the delay in queries reply is reduced from 32% to 6%, which has enhanced the customer satisfaction levels. The customer satisfaction after applying tools of six sigma in the organization has been increased from 77% to more than 85%. The results indicate that apart from industries, Six Sigma tools can be applied to

R&D organization but with some modifications to the standard tools of Six Sigma. Modification in LSS techniques may change as per requirement as each R&D have different processes and services.

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References:

Antony, J. (2008). Can six sigma be effectively deployed in SMEs. *International Journal of Productivity & Performance Management*, *57*(5), 420-423.

Desai, T., & Shrivastava, R. L. (2008). *Six Sigma – A New Direction to Quality and Productivity Management*. ISBN: 978-988-98671-0-2.

El-Haik, B., & Roy, D. M. (2005). *Service Design for Six Sigma: A Roadmap for Excellence*. Hoboken, New Jersey: John Wiley and Sons Inc.

Gupta, N. (2013). An Overview on Six Sigma: Quality Improvement Program. *International Journal of Technical Research and Application*, *1*(1), 29-39.

Hung, H. C., & Sung, M. H. (2011). Applying six sigma to manufacturing processes in the food industry to reduce quality cost. *Scientific Research & Essays*, *6*(3), 580-591.

Kumar, M., & Antony, J. (2008). Comparing the quality management practices in UK SMEs. *Industrial Management & Data Systems*, *108*(9), 1153-1166.

Lassiter, V. (2007). The Role of Process Improvement in the Nonprofit Organization. (Published master's thesis). *University of Pennsylvania*, Retrieved from: http://repository.upenn.edu/od_theses_msod/5/

Nakhai, B., & Neves, J. S. (2009). The challenges of six sigma in improving service quality. *International Journal of Quality & Reliability Mgmt*, *26*(7), 663-684.

Pathak, J., & Desai, T. (2011). Six Sigma Quality Management Technique –An Overview. Journal of Engineering Research and Studies, 2(3), 64-72.

Pojasek, R. (2003). Lean, Six Sigma, and the Systems Approach (2003): Management Initiatives for Process Improvement. *Environmental Quality Management*, *13*(2), 85-92.

Rumana, P., & Desai, D. (2014). Quality Improvement through Six Sigma DMAIC Methodology. *International Journal of Engineering Sciences & Research Technology*, *3*(12), 2277-9655.

Shaikh, S., & Kazi, J. (2015). A Review on Six Sigma (DMAIC) Methodology. *Journal Of Modern Engineering Research*, *5*(2), 2249-6645.

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