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Lean Six Sigma Based Quality Improvement in Rural Healthcare Using Virtual Simulation Model

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ABSTRACT

The poor medical service and medical errors in India account for the death of almost 2 million people in a year. The situation of rural healthcare is much pathetic and the quality of service they receive is poor. This paper presents an effective virtual simulation model for quality improvement in rural healthcare using the lean six sigma approach. The paper presents a case study on rural healthcare in Kerala where it focuses on quality improvement. A statistical six sigma data-driven approach was developed using AnyLogic simulation software and was analyzed and interpreted using Minitab. The Lean tool is effectively applied to the virtual real-world world and improvements were analyzed.

Keywords: Six sigma, Lean, Quality, Availability, Consumption, Virtual simulation

1. Introduction

The concept of six sigma was first coined by bill smith who aimed at a statistical problem-solving method that focuses on solving a problem using the D-M-A-I-C methodology of Define, Measure, Analyze, Improve and Control. The Lean process in turn refers to eliminating wastes in a product or service through effective value addition and improving flexibility through a set of lean tools. The combination of lean tools and six -sigma commonly called Lean Six sigma is an effective industrial engineering-based tool that found application in most of production-based Industries. [1] The use of lean six sigma in the service sector started in the 1990s. The NHS Hospital and Virginia Mason are some of the successful lean six sigma-based hospitals but the application of Lean six sigma in rural healthcare is a challenging one because of many reasons. Firstly, data collection is a difficult job as we have to deal with a huge population. Secondly, the credibility of data is also difficult to judge as the chance of error is high. Thirdly the project should aim on maximum simplicity such that changes should not make patients and staff hard to adapt. This paper focuses on how to reduce the length of stay of patients in a hospital such that it improves the quality of medical service they receive.

2. Literature Review

Six sigma refers to a managemental and quality improvement tool that focuses on reducing the error in a product or service by 3.4 parts per million. It is achieved by a five-step process Define, Measure, Analyse, Improve, and control. In the define phase, the requirements of the customer are converted into critical to quality parameters (CTQ) and the specification of our product or service is fixed. In the measure phase, the need is converted into a numerical one for effective normal distribution modelling. The region outside the normal distribution is considered an error and it can be reduced by either reducing the variation or by changing the mean if needed.

In the analyse phase the factors affecting the process are evaluated using techniques like chi-square, regression, ANOVA, and logistic regression. The effective improvements are done and are then regulated using various control charts. [2] The lean process is actually aimed at identifying wastes in a process. According to lean principles, there are eight kinds of waste transportation, inventory, motion, overproduction, overprocessing, waiting, defect, and underutilization of human resources. [5] The lean tools like value stream map, Kanban, kaizen, and takt time aid the six-sigma process to achieve its goal of 3.4 defects per million. The real data collection is a tedious task and the chances of error are high also the constraints reduce the data volume which makes it poor for statistical analysis. The simulation modeling using AnyLogic software help to produce statistical data which resonates with real-world data. In AnyLogic the pedestrian library helps to model the patient behaviours.

3. Methodology

3.1 Define Phase

In the define phase, the problems faced by the patients are effectively tabulated by conducting a random sample survey and a weighted score was calculated a pie chart of the weighted score is shown in figure 1. The common problems are listed and asked and people need to rate the problem as most

often, often, neutral, less often, and never. The score gives 100% weightage to *most often* while *often* and *neutral* get 50 and 20 % respectively. Thus, reducing waiting time and improving capacity can significantly improve the quality of rural healthcare.

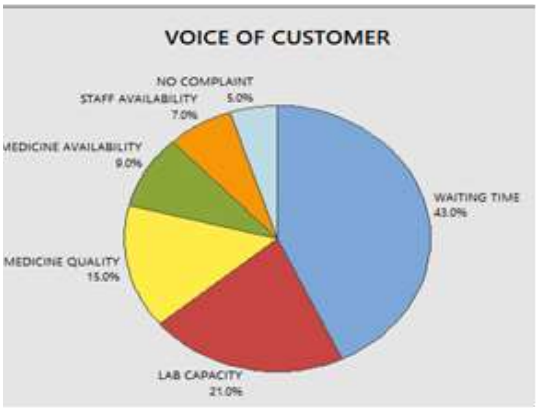

Figure 1: Pie chart showing the weighted score of customer complaints based on the survey

3.2 Measure Phase

In the measure phase, the length of stay of patients is collected using a timer and the time spent by each patient is recorded for a different day and the length of stay vs day was tabulated as shown in figure 2. From the graph, it is clear that Friday has the maximum amount of length of stay followed by Monday and Tuesday. The LOS (Length of Stay) on Sunday is neglected due to minimal service provided on that day.

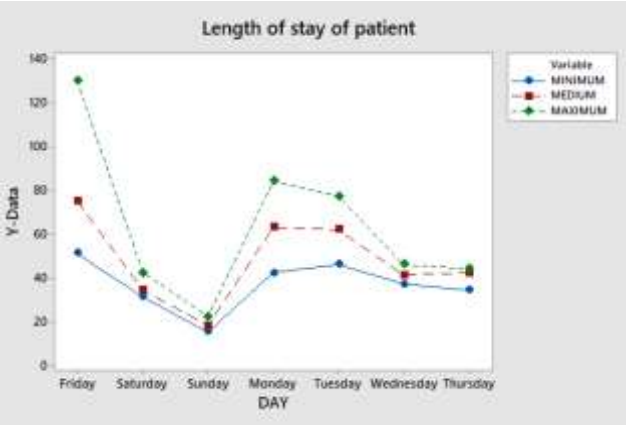

Figure 2: Scatter Plot showing Length of stay of the patient during the different day in a week

The length of stay of the patient during different time intervals on a particular day is also recorded. The length of stay on Friday is as shown in figure 3. The behaviour of LOS is quite interesting as periodic crest and trough can be seen in it. The Los is quite high during 8 o clock and goes on reducing and the high initial LOS is due to queue at the ticket counter. The reduced LOS is then shot up after 10:30 because of the queue that occurred at the pharmacy.

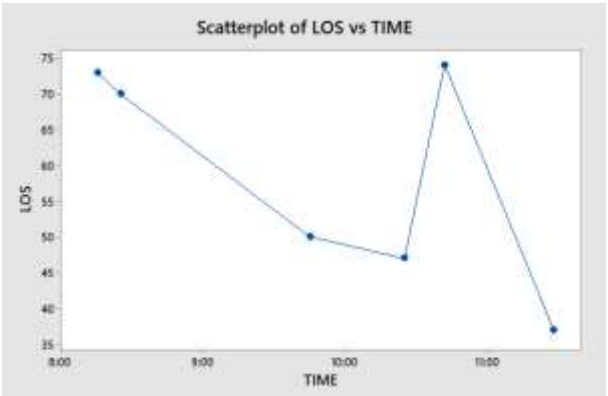

Figure 3: Scatter plot of length of stay on a particular day.

The virtual data collection was carried out with the help of AnyLogic simulation software. The layout of the hospital is used as the base and 3D model is developed. The parameter for patient behaviour is modelled using real data value and thus a 3D simulation is created on AnyLogic using pedestrian library.

Figure 4 shows the 3D model developed using AnyLogic.

The data extraction from the virtual simulation model is achieved both quantitatively and qualitatively. [3] The population density map give information about which place will have population density and to what extent based on the variation in color. The qualitative information gives only a preferential outlook and thus quantified information is needed for statistical analysis. The agent timer is attached to the pedestrian system and thus the total length of stay of every agent is effectively recorded on the datalogger of the system

Figure 5 shows the population density map over a period of time

Value stream mapping is an effective lean tool to analyze the current system and mapping future state it gives information about the wastes in the process and give a good insight about the material flow. The value stream map about the hospital operation is as shown in the figure 6.For a particular hour let the number of patients be 150 and we can see that the ticket counter can process all the patient ticket request within that hour but the number of patient consulted by the doctor is just 90 which means that remaining get treatment after a long waiting time. The bottle neck effect is contributed by the ticket counter and thus improving one phase cause a serious backlog in the other and thus need an effective integrated approach to reduce the Length of stay of patients

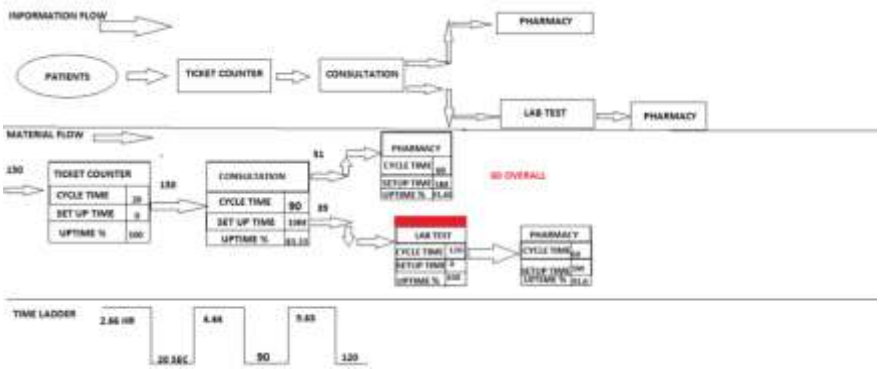

Figure 6: Value stream mapping of hospital's patient flow.

D. Length of stay specification

Thus, from the measure phase it is concluded that the length of stay of patients in Monday, Tuesday and Friday is significantly higher than that of Wednesday, Thursday and Saturday. The patients are comfortable with the later days and thus reducing the length of stay of patients on Monday, Tuesday and Friday can make a significant impact on the length of stay of patients.

3.3 ANALYZE PHASE

3.3.1 Ishikawa fish bone diagram.

The data collected should be effectively interpreted to get a good insight about the current state of the system and about predicting the future. The Ishikawa cause and effect fish bone diagram gives an effective way to analyse the factors that cause the length of stay higher. From the Ishikawa diagram shown in figure 7 it is clear that most of the factors are not easy to control like staff number, potential of medicine, type of medicine etc. Some factors like the variation in population can make a huge difference in the population behaviour.

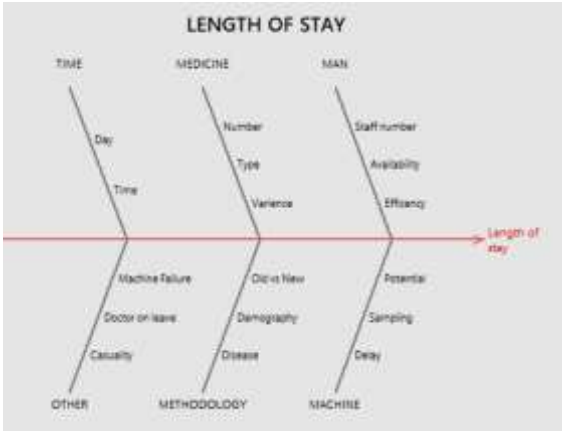

Figure 7: Ishikawa fish bone diagram showing the factors affecting the length of stay of patient in hospital.

To make the length of stay to fall within the specified limit, we have to reduce the variation but we have to know what kind of variation affect the most and to know the factor which affect the most. statistical analysis is need to be conducted to know how much factor affect the length of stay. Thus, we consider three type of variation in the population-firstly the gender-based variation, secondly disease-based variation and finally new and old ticket people's length of stay variation. The tools like ANOVA analysis, T -TEST are conducted on sample population.

3.3.2. Gender based population variation

In the gender based statistical analysis the length of stay of male and female patient over different time period are taken and are effectively analysed using T test. In T-test a null and alternative hypothesis is made about the equivalence of mean and hence compute the P value. The P value in case of gender-based variation is around 0.975 and this value is more than 0.05 and thus we can accept the hypothesis that population samples are almost same and thus a gender based lean improvement tool may not make a significant improvement. The box plot analysis of male and female population shows that they have almost same length of stay as shown in figure 8

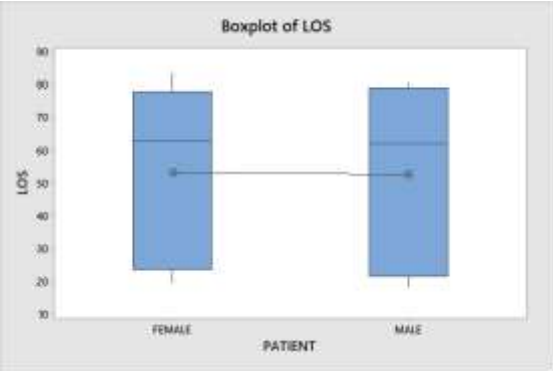

Figure 8: Box-plot diagram showing the length of stay of male and female patients

3.3.3. Disease based population variation.

The disease-based analysis of population variation is carried out by recording length of stay of patients with different diseases. Since the disease of people are not confined to two or three, we have to carry out an ANOVA analysis to know its impact. Figure 9 shows the box plot diagram and it is pretty clear

that the variation is high as the different box are connected by slanting line instead of horizontal line. The ANOVA result also shows that p value based on f ratio is zero which is less than 0.05 so the variation has a significant impact on the length of stay of patient and also the R square value is 70.46% which proves that the lean application by considering disease as a factor can make a significant impact. Figure 10 is a graphical analysis of ANOVA such that variation is clearly shown as peak in observation order and in fitted value.

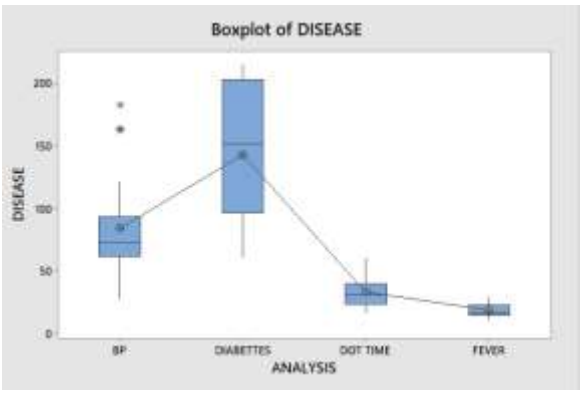

Figure 9: Box plot diagram showing the length of stay of patient

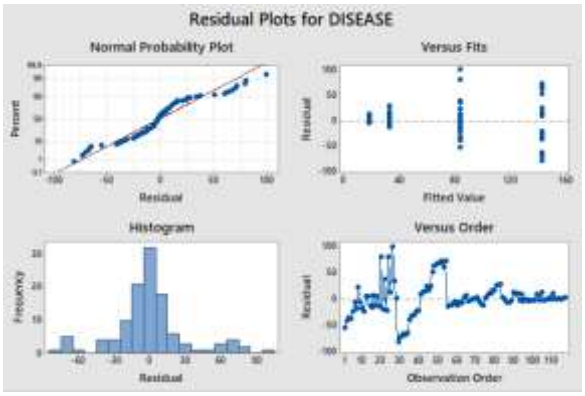

Figure 10: ANOVA analysis of population behavior based on disease

3.3.4. New vs old ticket variation analysis.

The length of stay of patient based on new or old ticket also play an important role. The data is collected from different sample population and are then evaluated based on T test and found that population behavior is quite different for new and old ticket. The variation can be seen in the individual value plot diagram as shown in figure 11 and thus old ticket take less time compared to new ticket. The t-test also proves that the lean application based on new and old ticket can make a significant impact in reducing the length of stay of patient in the hospital.

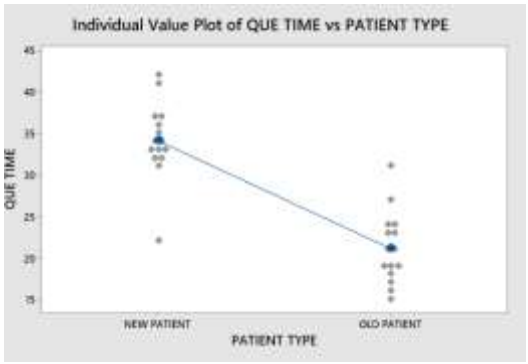

Figure 11: The Individual value plot showing the patient length of stay for new ticket and for old ticket.

Improve Phase

The analyse phase gives a right insight about where lean tools are need to be applied and at what degree. [4] The analyse phase thus made a conclusion that disease type and the type of ticket plays an important role. The improvements which can be brought are as below

- The ticket counter should be changed from male vs female counter to new vs old ticket counter as it will significantly reduce idle time in male counter.
- The ticket should be re designed in such a way that disease symptom is need to be pointed in the ticket counter so as to reduce the bottle neck at consultancy.
- Assigning specialized doctor for diabetes and cholesterol will reduce length of stay of old patient.
- The effective batching can be implemented on diabetes patient so as to reduce the set-up time and thereby improving lab potential.
- The dressing room need to be placed close to ward so as to reduce the motion waste.
- The special counter for diabetes patient can reduce the peak queue at pharmacy.
- The application of 5S principle can make a significant increase in delivering medicine to patient.
- The standardization of work practice can reduce the error in cholesterol and diabetes laboratory.

- The Andon system like LED board can give information regarding medicine inventory

Result and Discussion

The process capability is an effective way in which the capability of the process can be analyzed. The length of stay of patient is the critical to quality parameter and the target limit can't be computed like a product specification. The Length of stay of patients during Wednesday, Thursday and Saturday are optimum and people have minimum complaints on those days. Reducing length of stay on Friday, Monday and Tuesday up to that of other day can create a significant impact on the total operation of the hospital

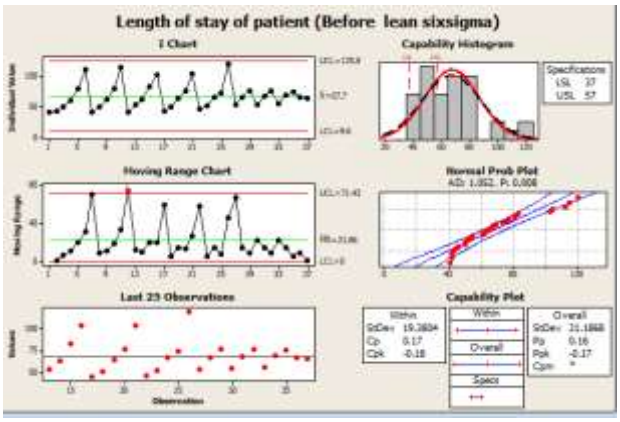

Figure 12: Process capability index of Length of stay of patient before implementing lean six sigma

The upper and lower limit of the length of stay for Wednesday is taken as the reference and the current length of stay of patient during Friday is analysed. Figure 12 shows the process capability of current length of stay in comparison to the length of stay on Wednesday. The majority of the length of stay lie outside the lower and upper specific limit 37 minute and 57 minutes. The capability index improved a lot such that almost 99 % of the length of stay of patient lies effectively within the specific limits and the control chart can guide the hospital to do their operation effectively in future.

Conclusion

Using LSS the process outcomes become more predictable and effective. The LSS targets the efficiency of process, decreasing the wastes, reducing process variation and increasing profitability. The understanding, meeting and exceeding patient's needs and expectations, healthcare organizations can improve patient outcomes and at the same time can remain competitive by cutting costs and improving quality.In health care industry keeping patients satisfied is high priority. LSS focuses on voice of the customers. It provides different techniques such as customer surveys, perception surveys, analysis of complaints, employee research and competitive benchmarking. For example, Six Sigma projects looks into minimizing patient length of stay in hospitals after a certain procedure, helps in reducing therapy cost. Some patients want to go home as soon as possible; however, some patients might not be able to take care of themselves or might be in too critical of a condition to risk leaving the hospital. This is where a patient representative on a Six Sigma team could be beneficial

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References

[1]. George, M. L. (2003). Lean Six Sigma for services. New York: McGraw-Hill.

[2]. Sehwail, L. and DeYong, C. (2003) 'Six Sigma in health care', International Journal of Health Care Quality Assurance Incorporating Leadership in Health Services, Vol. 16, pp. I–v.

[3]. Byrne G., Lubowe D. & Blitz A., (2005). Driving operational innovation using Lean Six Sigma.

[4]. Healthcare, Journal for Healthcare Quality, Vol. 28, No. 2, pp. 4–11.

[5]. Fillingham, D. (2007), "Can lean save lives?", Leadership in Health Services, Vol. 20 No. 4, pp. 231-241