Implementing Lean Six Sigma to Improve the Turnaround Time of Blood Samples in a Private Hospital of India

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Abstract

Healthcare organizations implement the Lean Six Sigma (LSS) methodology to achieve performance in terms of cost, quality, and productivity. The purpose of this paper is to implement LSS in the casualty of a private hospital in India to mitigate the issue of high turnaround time (TAT) of the blood samples. The DMAIC (Define-Measure-Analyse-Improve-Control) strategy was utilized as the model of problem-solving during LSS implementation. A team comprising two doctors, three nursing staff, and two support staff was formed to carry out the project. In this work, we found that multiple variables could impact the high TAT of the blood samples in casualty, thereby prolonging the patient stay and crowding. In a phased manner, the casualty workforce under the guidance of the LSS professional could able to utilize the power of simple LSS tools like Process Flow Map, Ishikawa Diagram, SIPOC, 5-Why analysis, SPC, etc, to find the root causes and take corrective actions during the implementation process. As a result, the average TAT is reduced from 164 minutes to a new average of 84 minutes. This study was restricted to a specific area in a multispecialty hospital in India. Hence the validity can be built on by including other departments in the same hospital or doing similar studies in other hospitals. The findings will empower the researchers, professionals, and managers in the healthcare sector to incorporate a similar way of hands-on training and simultaneous LSS implementation for continuous process improvement.

Keywords
Lean Six Sigma, healthcare, casualty, turnaround time and implementation.

1. Introduction
Timely and effective care is essential for good patient outcomes in any healthcare organization. Delays in providing timely care to patients in the casualty can reduce the quality of care and increase risks and discomfort for patients with serious illnesses or injuries and this issue will lead to crowding. Crowding is an increasingly common occurrence in hospital-based casualties across the globe (Vashi *et al.*, 2019). Hospitals continue to face growing problems with crowding, delays in providing various services, and cost containment (Vashi *et al.*, 2019)). In particular, patient wait times for getting the laboratory test results in the casualty have come under scrutiny (Busby et al., 2013).

The foremost part of a clinical laboratory is to produce consistent, reproducible, valid, timely, and correctly interpreted test results to help in clinical decision-making. To attain this goal, laboratories should essentially create and sustain quality in all laboratory procedures, while concentrating on cost-effectiveness. Presently, clinical laboratories need to handle the raising workloads with the same or fewer number of staff and must still supply constant results with improved turnaround times (TATs) and with supreme quality. Even though there are multiple

policies and methods which we follow to contain and avoid the crowding and decrease the laboratory TAT in the casualty, we are unable to avoid situations due to multiple causes. Increased laboratory TAT not only reduces the overall quality of care and optimal use of human resources but also increases the financial burden on patients and leads to decreased customer satisfaction. Like the manufacturing sector, healthcare also has been prone to huge competition worldwide for increased quality with limited cost and resources (Migita *et al.*, 2018). During the past 20 years, budding regard has been given in the healthcare sector to Lean Six Sigma (LSS) for process reorganization to enhance the effectiveness of services and organizations (Henrique and Godinho Filho, 2020). We focused on first providing basic training on the LSS tools to the hospital workforce in the casualty then utilizing the lesson learned in the training programs to improve the process and reduce TAT by the actual implementation of LSS.

1.1 Objectives

The main objective of this paper is to implement LSS in the casualty of a private hospital in India to mitigate the issue of high turnaround time (TAT) of the blood samples. The second objective is to ensure smooth patient flow in the casualty.

2. Review of literature

Emergency Department Crowding (Morley *et al.*, 2018) is a major global healthcare issue. It is both a patient safety issue and a worldwide public health problem. Crowding deters providing quality patient care and makes it difficult for the healthcare staff to adhere to guideline-recommended treatment. It has widely resulted in patient dissatisfaction and loss of revenue for the healthcare system. Crowding in the casualty can occur due to the volume of patients waiting to be seen, delays in assessing or treating patients already in the casualty, or impediments to patients leaving the ED once their treatment has been completed (Leite, 2020). Healthcare providers across the world have tried to formally assess casualty crowding and one of the finest techniques employed for the same is the LSS methodology.

The Lean approach derived from the Toyota production system aims to systematically reduce waste and streamline the value of the business (Cherrafi *et al.*, 2016). Waste in Lean symbolizes defects, overproduction, inventories, waiting, delays, unnecessary processing, movement of people, and transportation. Sigma (σ) is a letter in the Greek alphabet used in statistics to measure the variability in any process. Six Sigma is a rigorous, focused, highly effective, and proven quality technique to improve the process. Six Sigma, developed by Motorola in the mid-1980s, gained its momentum as a revolution in the manufacturing industry when Motorola won the Malcolm Baldrige National Quality Award in 1988 and emerged as a quality leader and profit leader (Trakulsunti *et al.*, 2021). Six Sigma focuses on customer requirements, defect prevention, cycle time reduction, and cost savings. Thus, the benefits from Six Sigma go straight to the bottom line. Six Sigma's simple performance improvement model known as Define-Measure-Analyse-Improve-Control (DMAIC), is fundamental in its application

A study at Texas Children's Hospital Texas aimed to reduce the number of insurance claim denials using the LSS methodology which was a major cause of plummeting profit margins for the hospital (Kovach and Borikar, 2018). Even though most denials can be appealed, the administrative burden of sorting through and appealing them can be time-consuming and delays the revenue collection process. Results indicated that the revised registration form reduced missing/incomplete fields by 67%. As a result, the revised form was implemented, which helped greatly reduce insurance claim denials. A study conducted by "Federico II" of Naples (Italy) focused on the application of LSS Methodology in reducing the risk of Healthcare-Associated Infections (HAIs) which is one of the growing healthcare concerns today and a primary indicator of the quality of services (Montella *et al.*, 2017).

3. Methods

A case study method is adopted to carry out the study in the case hospital.

Background

This study is based on the principles of LSS. The main strategy utilized in the case organization to implement LSS is DMAIC. It is a data-driven process and involves an incremental strategy to improve various processes used by the principle. Each step in the DMAIC strategy is a cyclical process and following the cycle is of utmost importance to achieve the best results. Before the starting of the LSS implementation, the entire casualty workforce was provided training on LSS tools and techniques by one LSS black belt professional.

Research Question

1. What is the present Lab turnaround time of common lab investigations in the emergency department, namely CBC, Electrolytes, ESR, Creatinine, LFT, Urea, and RBS?
2. What are the various factors and root causes that increase the laboratory turnaround time in Casualty?
3. Impact of LSS methodology in improving the laboratory turnaround time in the ED?

a. LSS Implementation stages

i. Define

The first phase in the DMAIC strategy is the Define phase. Define involves defining the needs of the customer and the various requirements put forward by the customer. The expectations of the customer are clearly outlined in this stage. Along with customer needs, the scope of the project is also defined. The process flow to be improved is understood and various opportunities to improve the processes are defined. In this study a project charter (Table 1) with a stakeholder analysis is done in the define stage. The project charter is a semi-detailed table portraying the project overview, problem statement, the goals of the project, the scope of the project, and the stakeholder analysis (Brown *et al.*, 2019). Defining all these key factors in advance is an important step in the LSS methodology. This table provides a space to get an overall idea about the study.

Table 1. Project Charter

Project Overview	This project is focused on reducing turnaround time (TAT) of blood samples in the casualty of a hospital. TAT is defined as the total time taken from ordering a test to result updating in system.
Problem Statement	The casualty is experiencing delays in laboratory turnaround time. This study helps to address key issues of emergency departments and also provides a framework using the DMAIC methodology that can be implemented universally which ultimately results in better service quality and patient satisfaction.
Project Goal	Reduce average laboratory turnaround time from 180 minutes to 120 minutes for admitted patients and hence reducing patients' length of stay.
Project Scope	This project will focus on identifying the major constraints of high TAT, the root causes of delay happening in the timely movement of laboratory sample and giving improvement recommendations to the department.
Project Team	Project leader: Senior Resident Project Mentor: Casualty head Project Sponsor: Hospital Management Project Support: LSS Black belt professional

ii. Measure

This is the phase in the DMAIC strategy where the baselines are set. The baseline is important to compare the current baseline with the improved results in the Improve phase. The impact of every small change made in the coming stages will stand out with proper interpretation of the current measures of the project. The process of data collection is planned in this stage. Pinning down these collection processes at an early stage is essential for good decision-making and reliable data.

The Supplier-Input-Process-Output-Customer (SIPOC) is the primary tool in the Measure phase which helps in defining the boundaries about what is to be studied (Asif, 2019). The SIPOC (Table 2) shows the key players and the inputs in the study. The processes which are to be improved are also highlighted in detail. The outputs and the customers receiving the output at every stage of the process are also portrayed. The table portrays the whole process the patient undergoes from ordering tests to laboratory results updating in the system. The various processes involved are highlighted and the time for each process is marked in the data collection form (Table 2).

Table 2. SIPOC

Suppliers	**Input**	**Process**	**Output**	**Customer**

Doctor	Patient	Ordering of test	Lab test required	Nurse
Nurse	Blood samples and patients	Sample collection	Specimen	Attendee
Attendee	Blood samples transport	Sample dispatch	Sample arrival in the lab	Laboratory
Lab receptionist	Lab assignment	Sample received in the lab	Sample processing	Lab technician
Lab technician	Lab test	Result updating in system	Report generation	Doctor and patient

iii. Analyze

The main aim of the Analyze phase is to identify the root causes of the problem. Most of the time, a project is begun with an existing notion of why a project has its problems. Starting from this step can lead to missing the actual root causes of the problem. Therefore, in this phase, the process is closely examined to identify any potential problems that can lead to a dissatisfactory result. Through this process, a proper understanding of the problems as well as the possible solutions are also identified. Firstly, the fishbone diagram or the Cause-and-Effect diagram is created (Figure 1). The cause-and-effect diagram is a living document that culminates all the findings up to this stage and tries to form relationships between different causal theories.

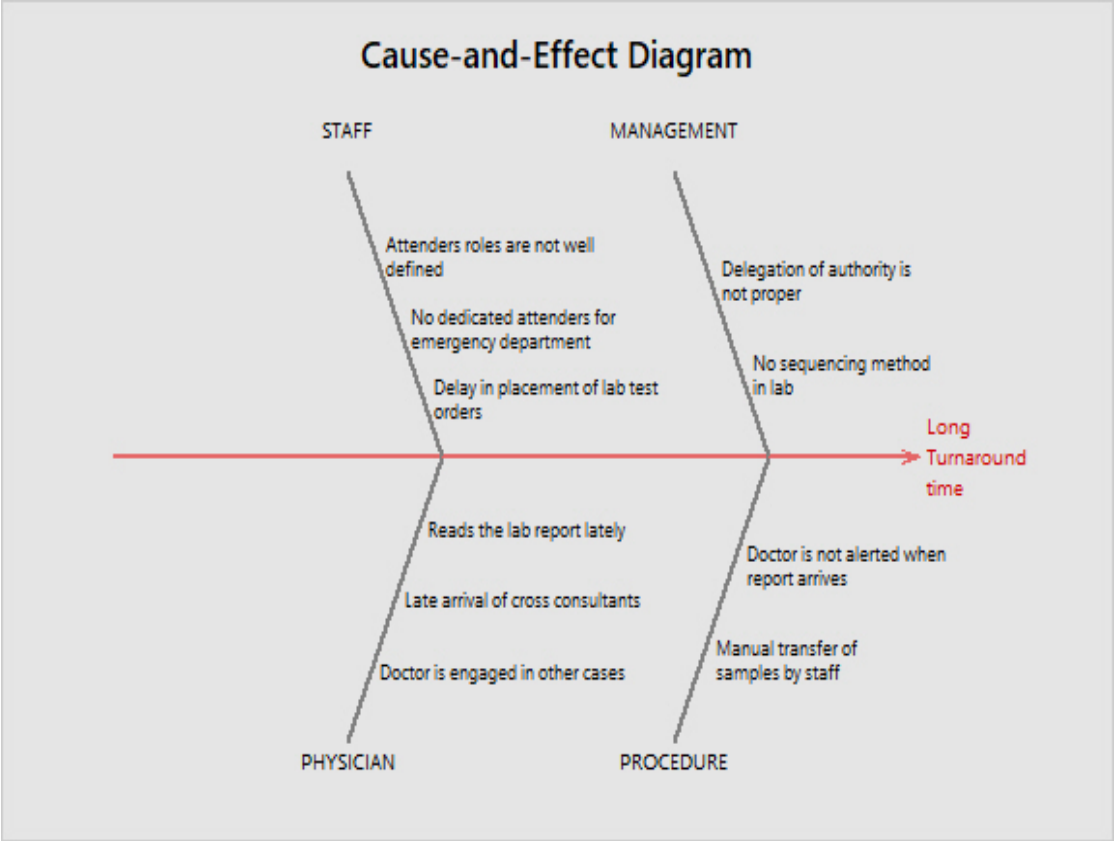

Figure 1. Cause-and-Effect Diagram

Different factors such as staff, management, program, and procedure may lead to small causes but the complexity of the healthcare system will increase the laboratory turnaround time and thus lead to the effect of delaying patient treatment. This fishbone diagram gives a glance at all the potential causes (Taner *et al.*, 2007)that can increase the laboratory turnaround time. For example, the late arrival of cross consultants can potentially lead to an increase in the delay of processing the sample. Analyzing the method used can help make the process more effective and help save a lot of time as well as get to more patients faster.

The next tool used is the why-why analysis or the 5 why analysis. This process works by asking the question of "Why?" multiple times for a certain problem to reach its root cause (Table 3). The multiple questioning analyses the problem at a deeper level and hence helps identify the cause of the problem at the most basic level. Each layer of the problem is important to find its underlying cause (Table 3).

Table 3. Why-Why Analysis

Sr No	**Reason**	**Why**	**Why**	**Why**	**Why**	**Why**
1	Delay in sample collection	Sample collecting nurses have to wait for a consultant	Delay in consultant order	Busy in attending another patient	More number of patients in the ED	Only 3 senior residents per shift

2	Delay in sample dispatch	Poor coordination	Staff transfers the sample collection bin as and when they want	No SOP is provided/followed for this process	Dispatching staff waits till the sample collection bin is full	NO SOP decided
3	Delay in sample processing	Waiting for samples in the lab	The lab is busy as there is only one lab for testing	No importance to ED samples	Lab follows the FIFO rule	Priority of ED samples is not communicated
4	Delay in report verification	The communication gap between lab and ED	No immediate information from the lab upon report uploading in the database	The doctor waits for the arrival of the report by checking the ED computer intermittently	No system to inform the reported arrival from Lab	Poor information system

iv. Improve:

The Improve phase is where the solutions are implemented. The work done in the previous stages set up a good platform for ideation to improve the current process. These ideas and tweaks are implemented into the current process and output changes are measured again. The data collected after the Improve phase is compared with the initial baseline to see if there are improvements due to the applied solutions.

In this study, after the successful completion of the first three stages of the DMAIC strategy through the use of various tools, the improvement table highlights the changes to be made along with the reason for each change. These solutions have been formulated through a careful understanding of the various problems in the process. After the implementation of these solutions, the Laboratory turnaround time is measured again to see the improvement. The detailed description of the reasons for the cause of the problem has led to clear-cut solutions that can be implemented successfully. As the Analyze phase was implemented well, this stage has led to many fruitful solutions to existing bottlenecks that lead to increased laboratory TAT.

V. Control

The Control phase aims to see how the improved process can be sustained over time. Sustaining the process to achieve continued and consistent results in the future. Relying only on the improvements is not recommended rather aiming to continue getting good results through implementing the process is far more important in the long run. It is essential to predict if the positive results obtained after the improvements have been applied are future-proof. This is what the control phase aims to achieve.

The statistical tool Minitab performs various calculations to check if the results before and after the study follow a normal distribution. This normal distribution is identified using a Normal Probability Plot. In this plot, the various Laboratory TATs collected from each patient are plotted against the percentage of their occurrence. Once this is done, it is simple to obtain both the mean Laboratory TAT as well as identify if the data follows a normal distribution if a straight line is obtained after plotting the values. Ensuring a normal distribution is important to see that the data near the mean is more consistent than the data far from the mean. The results are then analyzed to see if they are consistent and fall within the given expectation through the IMR Chart. The IMR Chart ensures the stability of the process. If the data points fall inside both the Upper Control Limit (UCL) and the Lower Control Limit (LCL), it is safe to say that the process is very stable and can be trusted to perform as expected over time. The chart is used to monitor the process data over time for individual measurements of Laboratory TAT. The variation of the data is identified through the IMR chart and seen if it is stable. The process capability report depicts how capable the process is in terms of meeting expectations and also how the process can provide continued results in the future. The values falling between the Lower Specification Limit (LSL) and the Upper Specification Limit (USL) are considered.

4. Results and Discussion

3.1Probability distribution

The data on TAT was checked for the normality of the distribution. This was to ensure that the values near the mean are consistent (Persis *et al.*, 2020). The probability plot at the initial data collection before LSS implementation is given below (Figure 2). A total of 150 participants were assessed for TAT in our study. It is observed from the probability plot of the initial Turnaround time was following a normal distribution as the points lie more or less on the line with slight outliers towards the extreme points. The mean Turnaround Time was 164 minutes and a standard deviation of 10.

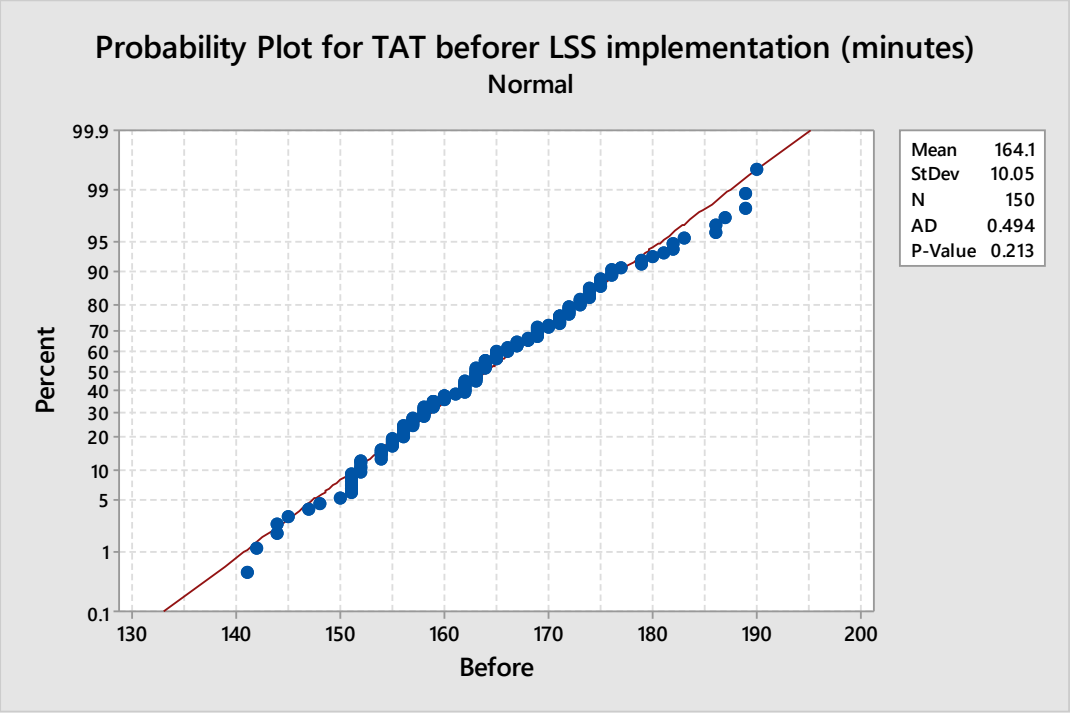

Figure 2. Probability Plot before LSS implementation

Similarly, the probability distribution after implementing the proposed changes was also checked to ensure normality. A total of 150 participant data was included in this assessment. Figure 3 shows the normality plot for the TAT following LSS implementation. The observed TAT values more closely follow the straight distribution line, indicating that the normal distribution appears to be a good fit for this data. The mean Turnaround time for the laboratory was reduced to 84 with a standard deviation of 8. There was a decrease of 80 minutes in the TAT following the intervention.

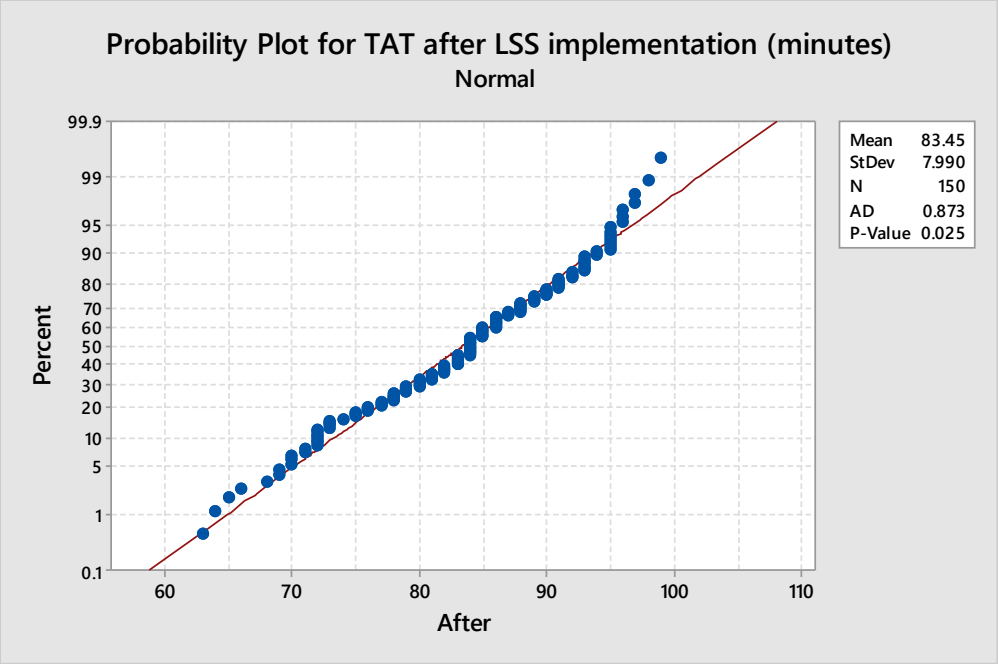

Figure 3. Probability Plot after LSS implementation

3.2 Process stability

The next procedure is to ensure that the data and the process is stable. The Individual-Moving Range (IMR) Chart is used to monitor this stability. The Individual chart plots the value of each observation and provides information about stability of process (Antony *et al.*, 2017) The Moving Range Chart plots process variation as calculated from the ranges of two or more successive observations.

The initial IMR Chart for Turnaround time (Figure 4) observes that the individual value observations average 164 minutes and the readings vary between an upper control limit of 190 and a lower control limit of 137. The moving range chart has an average value of 9.87 minutes, with variations between the Upper Control Limit of 32.26 and a lower control limit of 0. As the values fall inside both the limits, it is seen that the initial process is stable.

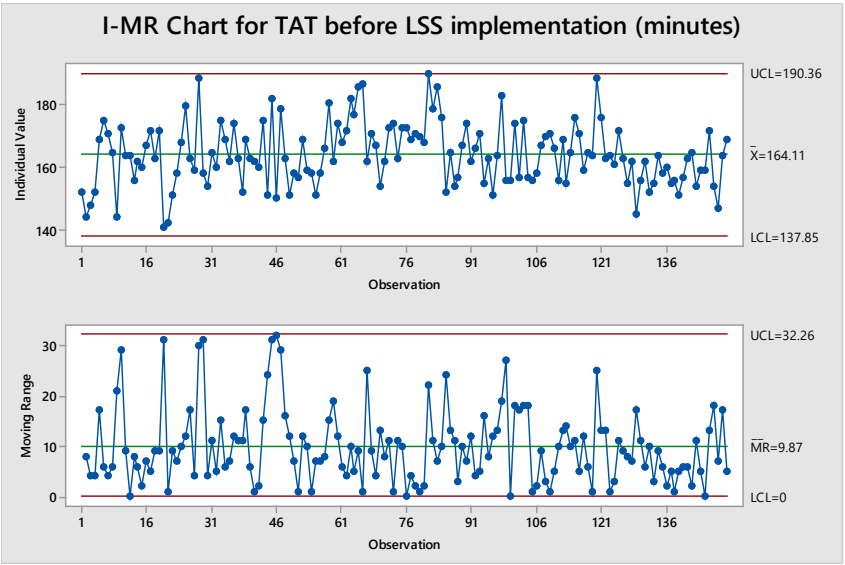

Figure 4. I-MR Chart before LSS implementation

Figure 5 depicts the individual values and moving range values for the Turnaround time following the implementation of the proposed changes. The new individual value has a mean of 83.45 with all observed readings lying within an upper control limit of 105.95 and a lower control limit of 60.94. The moving range chart averages at a value of 8.46, and readings are lying within an upper control limit of 27.65 and a lower control limit of 0. As all the values fall inside both limits, the process is said to be stable. This ensures that the process will perform as expected over time. The process variation for Turnaround time is thus, observed to be in control.

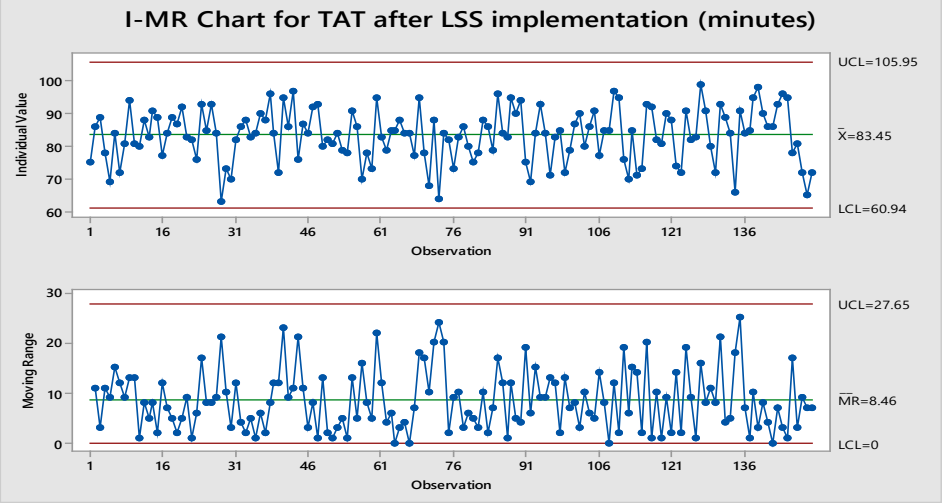

Figure 5. I-MR Chart for TAT after LSS implementation (minutes)

3.3 Process capability

Process Capability Report is used to analyze the ability of the process to give outputs that satisfy certain constraints. In our case, we need to see if the process is capable of ensuring the expected results. The Lower Specification Limit (LSL) is the lowest value Turnaround time (TAT) which is set at 60 minutes considering the management's feedback. The Upper Specification Limit (USL) is set at 150 minutes. Any value falling beyond this limit is a defect. The measurement used to determine whether a process is capable or not is the process capability index "Cpk". The Cpk value for a capable process should be greater than1 as per industry standards (Sunder *et al.,* 2020).

Figure 6 presents the process capability report before implementing LSS. It is observed that the value of Cpk is negative (-0.54). It indicates that the current process is highly in-capable of meeting the requirements as fixed by the management.

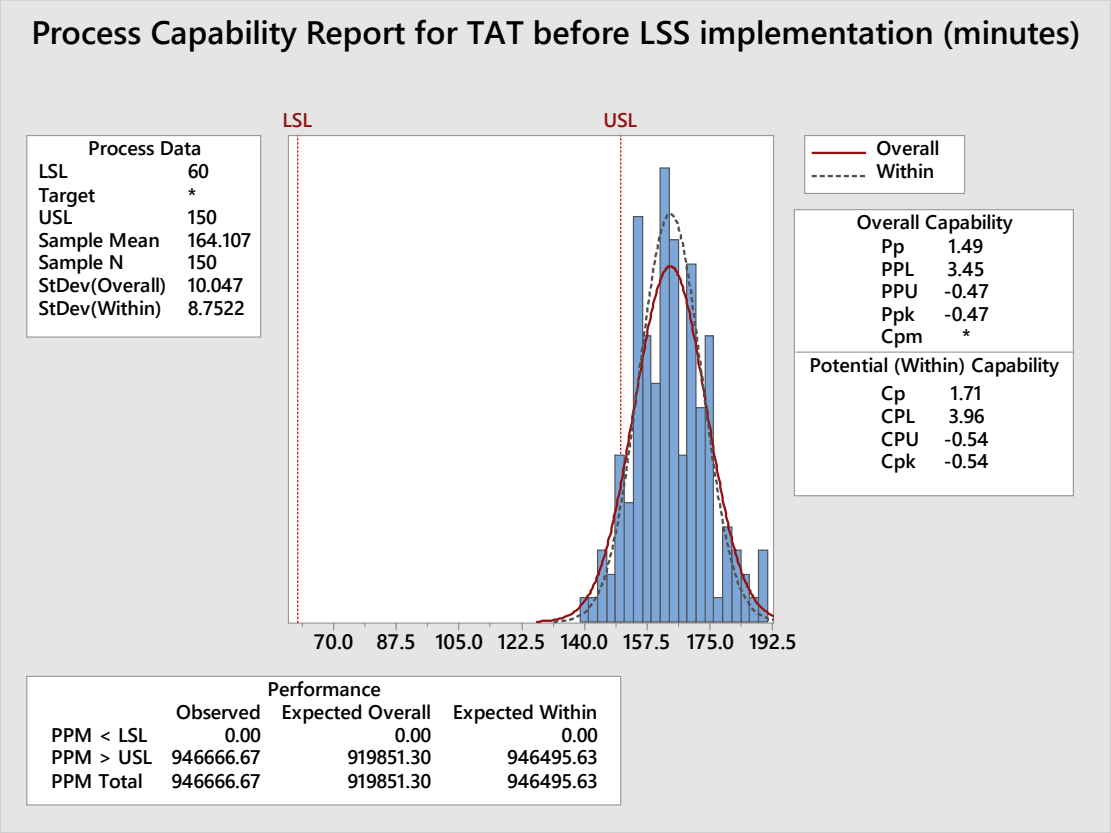

Figure 6. Process Capability Report for TAT before LSS implementation

In contrast to the initial report, Figure 7 shows the process capability report for TAT after implementing the proposed changes. It is revealed that the distribution of the TAT is uniform with a reduced value of overall standard deviation. Most of the readings are significantly reduced and the spread of the measurements is also decreased bringing the values within the expected range of values. The value of Cpk (1.04) indicates that post-implementation of LSS the process is now capable of producing good results.

From the above observations, it is clear that the application of LSS has successfully decreased the turnaround time for the laboratory from a mean of 164 minutes to a new average of 84 minutes. This translates to a reduction of about 80 minutes in the laboratory turnaround time following the implementation of the recommendations. It is also seen that the process is in control and capable of producing expected results in the future as well.

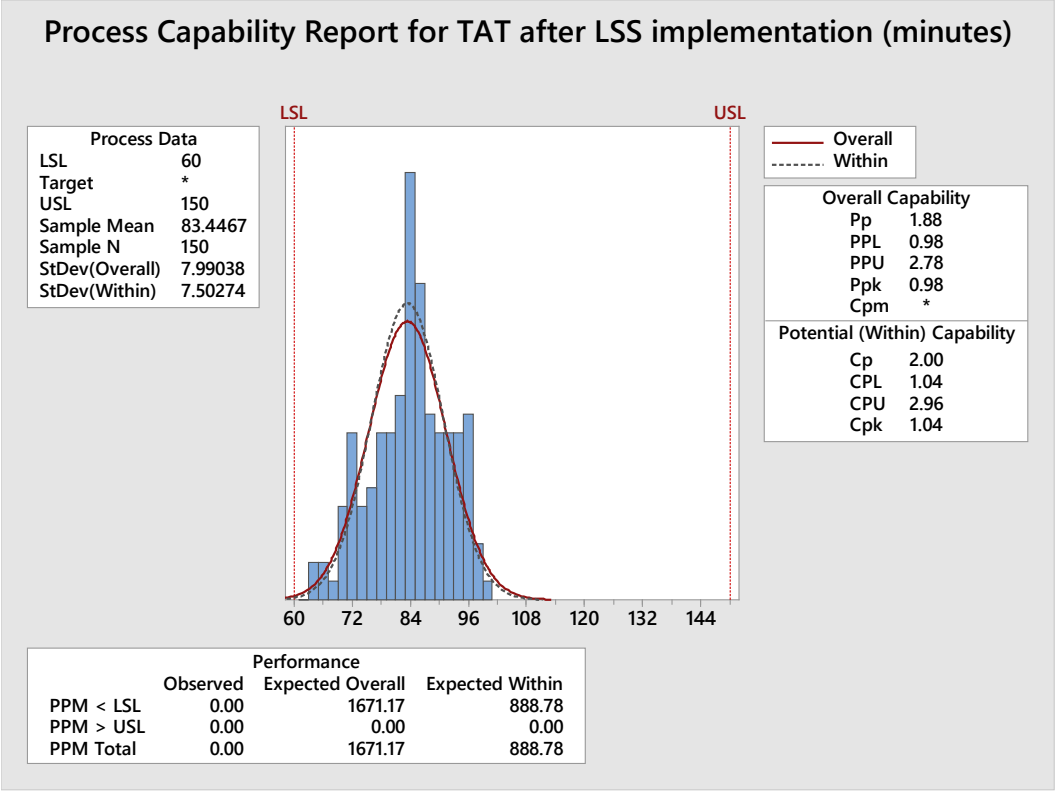

Figure 7. Process Capability Report for TAT after LSS implementation

5. Discussion

The laboratory turnaround time is one of the important factors which influence the course of management in patients visiting casualties. Thus, reducing the laboratory turnaround time will improve the efficiency of the entire unit and result in better patient outcomes. Well-designed laboratories that were accredited by certain agencies will not guarantee to provide quality service without delays and defects. LSS strategy is a viable method for improving the laboratory turnaround time. In our study we found that using the LSS strategy, the lab turnaround time was significantly reduced by more than 1 hour. This was brought about by an effective DMAIC strategy under the LSS approach. A cause-and-effect fishbone diagram was used in the process. The standard deviation of the turnaround time was also reduced from 10 minutes to 8 minutes signifying that the variability in the turnaround time had decreased. Successful implementation of LSS produces beneficial outcomes in terms of cost-effectiveness, higher process quality, and better operational efficiency. This study demonstrated that the application of the LSS strategy is a feasible strategy to improve laboratory turnaround time in casualty and that the same can be used for quality improvement in similar settings.

6. Conclusion and Limitations

The TAT is an important parameter in effective patient care, especially in the setting of a casualty. This study aimed to reduce the TAT based on the DMAIC approach used in LSS. It is seen that every single aspect of DMAIC has been successfully applied to the whole laboratory process in the casualty. After the successful implementation of quality-improvement strategies, the TAT showed significant improvements and process stability during the study period. The reasons for the delay in lab processing time were also identified and rectified during the process. It was observed that the laboratory turnaround time was reduced significantly. The findings from this study demonstrated that DMAIC methods can be used in a different setting to obtain significant improvement in the process.

There were some limitations in our study. First, this study was conducted in a single hospital and the findings may not be generalized to all institutions as they have a different SOP, manpower, etc. for the laboratory process. However, it has to be noted that our findings and implementation of the LSS strategy may be of importance to

another similar laboratory that aims at quality improvement. Second, we did not assess changes in the overall length of stay of the patient in the casualty or the patient satisfaction following the DMAIC strategy implementation. However, a decrease in TAT is likely to decrease the overall stay of the patient in the casualty.

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