Streamlining Patient Admissions using DMAIC Methodology

Abstract: This project examined a hospital's patient admission process, which can be inefficient due to long wait times, data entry, and an overall lack of positive workflow. Utilizing a Kaggle data set from ABC hospital, we implemented Lean Six Sigma (LSS) approaches and tools to degrade and remove impediments to patient flow via the DMAIC (Define, Measure, Analyze, Improve, Control) framework. To analyze critical bottlenecks caused by the patient admission process for four key areas (registrar, emergency care, ICU admission, discharge), tools involved were Value Stream Mapping (VSM) to graphically reduce lead time from point A to point B; Critical to Quality (CTQ) analysis and DPMO; Fishbone diagrams to identify the root causes happening in all processes; and, Pareto analysis to highlight key areas to focus on. This project identified improved processes through a automation, AI-driven coordination, and real-time tracking of ICU beds led to improved efficiency reducing total lead time by 58%. Sustainability of improvements were maintained using standard operating procedures, control charts, and continuous improvements through approach such as Kaizen. The project illustrates how we can leverage LSS data-driven approaches to improve hospital efficiency, patient experience, and care delivery.

Keywords: Lean Six Sigma, DMAIC, Value Stream Mapping, Critical to Quality (CTQ), Fishbone Diagram, Pareto Analysis, AI-driven coordination, Kaizen.

1. Introduction

The healthcare sector continues to change to support the constantly growing patient needs and challenges of delivering services. Patient admissions represent one of the most integral elements of hospital operational functions in terms of being responsive to patient care immediately with zero interruptions of service from accepted point of contact until the final observations are discharged and contacted back into society. The transition of patients through the admission process can be hindered by many systemic inefficiencies caused by long lead times, delays in transfers between services, and manual data entry errors. These inefficiencies not only disrupt the effective process of patient flow throughout the hospital system as a whole, they impede proper patient care, increase redundancies of requests by healthcare providers, and invite more challenges within institutional operations of the hospital system.

As a means to help address these problems of inefficiency, this project considers applying Lean Six Sigma (LSS) processes as a method of improving the patient admission process. The project will utilize the publicly available Kaggle database, which is an electronic health record (EHR) database of hospitalizations and intensive care unit (ICU) events. The goal of this study is to describe a patient admission process, and through application of data-led change and re-engineering, reduce identified areas of delay and inefficiency.

Lean Six Sigma is a hybrid process improvement methodology that combines two very effective philosophies. The Lean portion tries to eliminate waste by improving efficiency by focusing on things that do not add value to the process, while Six Sigma strives to improve the accuracy of the original process by finding and removing sources of variation and defects. When combined, these methodologies give an organized and data-driven approach to problem-solving in the context of chaotic settings like in healthcare.

A key tool used in this project is Value Stream Mapping (VSM) which is a visual representation of the way information and materials flows through the steps of the patient pathway from the moment of arrival and triage, through the different units to ICU transfer and out of hospital discharge. The current-state VSM identifies the most problematic areas, while the future-state VSM depicts how a better streamlined process, or improved process, would look like. The authors used VSM with the DMAIC (Define, Measure, Analyze, Improve, Control) process to capture a granular analysis to assist in finding bottlenecks, aligning resources, and/or enriching the overall patient experience.

As an integrated methodology, the goal of this project was to not only improve operational efficiencies but also to help with the proper allocation of hospital resources, reduced patient wait times, and ultimately improved patient outcomes. Instead of being specific to this hospital, the results and ideas listed here can be viewed as a model, which could be used on a larger level by other healthcare facilities attempting to transform their admissions system based on Lean Six Sigma principles.

1.1 Significance of the Study

The effectiveness of the patient admission process has a direct impact on hospital throughput, patient satisfaction, and clinical outcomes. Excessive delays in admission, especially in the emergency department (ED) and intensive care unit (ICU) transfers, may result in overcrowding, delayed treatment, resource waste, and adverse patient experiences. In settings with limited resources, these inefficiencies not only undermine the quality of care but also burden medical staff and infrastructure.

This research makes a contribution to healthcare process improvement through the implementation of a formal Lean Six Sigma (LSS) approach to the identification and removal of inefficiencies in the admission process. Through the use of real-time data from the dataset combined with systematic performance analysis tools such as DPMO, Value Stream Mapping, and root cause analysis, the research provides a replicable and scalable model for operational excellence in healthcare facilities. In addition, the introduction of smart automation and real-time coordination systems gives us an idea of how digital interventions can complement classical quality improvement models in a healthcare environment.

1.2 Need for the Study

In spite of major improvements in clinical practice, operational inefficiencies continue to plague many hospitals, most notably in high-dependency settings such as the emergency department and ICUs. Patient admissions are typically marked by excessive waiting times, failure to share information in real time, manual data processing, and disjointed inter-departmental planning. Such inefficiencies translate to patient dissatisfaction, extended length of stay, staff fatigue, and inefficient use of hospital resources.

There is an urgent need for a systematic and data-driven solution to redesign patient admission processes for speed, accuracy, and responsiveness. The COVID-19 pandemic also highlighted the significance of efficient patient flow and resource utilization in emergency and critical care environments. This research fills that void by using the principles of Lean Six Sigma in combination with contemporary data analytics and technology to suggest an operative model for reforming admission processes based on empirical evidence from the actual hospital dataset.

1.3 Objectives of the Study

The main aim of the study is to enhance the hospital patient admission process efficiency through the application of Lean Six Sigma DMAIC (Define, Measure, Analyze, Improve, Control) method. The specific aims are:

1. To map out the major inefficiencies within the existing admission process using the kaggle dataset and stakeholder feedback.
2. To quantitate baseline system performance along all the major parameters like registration time, ED-to-discharge time, delay to ICU admission, and length of stay.
3. To dissect root causes for delays employing disciplined quality tools such as Fishbone diagrams, Pareto charts, and DPMO analysis.
4. To design and enact focused interventions such as process automation, AI-facilitated coordination, and real-time tracking of ICU beds.
5. To measure the effect of interventions on CTQ measurements and show measurable improvement in lead time, process dependability, and patient flow.
6. To recommend a sustainable control model for sustaining gains and enabling ongoing process refinement.

2. Literature review

Title	Author(s) & Year	Methodology	Remarks & Findings
1	Leveraging Lean Six Sigma Principles in an Indian Tertiary Care Hospital: A Case Study *P.R. Srijithesh, E.V. Gijo, Pritam Raja, et al. (2024)*	This study applies Lean Six Sigma (LSS) principles using the DMAIC (Define, Measure, Analyze, Improve, Control) methodology	Limited to a single hospital, reducing generalizability to other settings. Did not analyze the long-term sustainability of the improvements.

2	Lean Process Improvement in Healthcare: A Study Using Value Stream Mapping, Theory of Constraints, and Simulation *Hazal Akbal, Nuri Özgür Doğan (2025)*	The study integrates Value Stream Mapping (VSM), Theory of Constraints (TOC), and simulation modeling to identify and mitigate inefficiencies in hospital workflows.	Requires specialized software and expertise, which may not be available in all hospitals. Findings may not be directly applicable to real-world hospital constraints.
3	Using Lean Six Sigma in a Private Hospital Setting to Reduce Trauma Orthopedic Patient Waiting Times and Associated Administrative and Consultant Caseload *Anthony Pierce, Seán Paul Teeling, et al. (2023)*	process mapping and statistical analysis, are applied to minimize delays in trauma orthopedic care.	Focused only on trauma orthopedic cases, limiting applicability to other specialties. Did not assess patient satisfaction post-implementation.
4	The Use of Lean Six Sigma Methodology in the Reduction of Patient Length of Stay Following Anterior Cruciate Ligament Reconstruction Surgery *Sinead Moffatt, Catherine Garry, et al. (2021)*	The research employs process improvement tools to streamline post-surgical care, optimize bed utilization, and standardize discharge planning.	Limited to elective surgeries, making findings less applicable to emergency cases. Did not explore financial implications of the reduced LOS.
5	Lean Implementation in Healthcare: A Systematic Review *K. Sathish Kumar, R. Venkatesh Babu, K. P. Paranitharan, A. Saravana Kumar (2021)*	This systematic review examines Lean implementation in various healthcare settings, analyzing its impact on efficiency, patient satisfaction, and process standardization.	Limited to qualitative insights without empirical testing of proposed frameworks. Findings rely on secondary data from previously published studies.
6	Application of Lean Six Sigma Methodology in the Registration Process of a Hospital *Shreeranga Bhat, Gijo Ev (2021)*	Lean Six Sigma tools, including process mapping, waste analysis, and cycle time reduction, are used to streamline the patient registration process.	Focused solely on the registration process without addressing downstream impacts. Did not consider potential technological upgrades for further efficiency.
7	Creating a Lean Six Sigma Hospital Discharge Process *Arturo Rangel (2021)*	The research focuses on redesigning the hospital discharge process using Lean Six Sigma methodologies.	Limited to a single department, reducing generalizability to larger hospitals. Did not explore potential resistance from staff in implementing changes.
8	Standardizing the Discharge Process Using Lean Six Sigma One Piece Flow *Howard-Williams E, Liles EA, Lanza-Kaduce K, Stephens JR (2021)*	Lean Six Sigma's One-Piece Flow methodology is applied to discharges, aiming to eliminate batch processing and implement a continuous, standardized approach..	Requires significant staff training and buy-in, which may be difficult to achieve. Did not assess long-term impact on overall hospital operations.
9	Effects of Lean Six Sigma Application in Healthcare Services: A Literature Review *Selim Ahmed, Noor H. A Manaf, Rafikul Islam (2021)*	Analyzes multiple Lean Six Sigma applications in healthcare, identifying key trends, success factors, and common challenges.	Limited to secondary data, as no primary data collection was conducted. Findings depend on the quality and scope of reviewed articles.

10	Application of Lean Six Sigma Method in Hospital Management Process: Performance Optimization and Waste Reduction *Wendra Afriana,Febriyanti Zulyani(2021)*	Applies Lean Six Sigma tools such as value stream mapping, root cause analysis, and Kaizen events to optimize hospital management processes.	Limited to secondary data, making findings dependent on previous studies. Did not provide new empirical evidence or case studies.

*Table 1**:** Literature Review*

The implementation of Lean Six Sigma (LSS) methods within healthcare systems has produced positive results in terms of enhancing the efficiency of a healthcare process, focus in decreasing turn-around time, and promoting better quality of care for patients. This project builds on a few fundamental studies and case studies that have previously examined the application of LSS in hospital practices.

Srijithesh et al. (2024) examined, through a case study, the utilization of LSS tools; in this case, CTQ analysis and Voice of the Customer, within an Indian tertiary care hospital to organize the workflow. They provided an introductory framework for the Define and Measure phases. Similarly, Akbal and Doğan (2025) employed value stream mapping, along with the theory of constraints and simulation, to determine the bottlenecks in the flow of patients and provide recommendations for streamlining processes. Their methodology validated our decision to develop current-state and future-state VSMs to visualize the process for patient admissions and implement an improved process flow.

Pierce et al. (2023) utilized Lean Six Sigma methodologies in a private hospital in order to achieve a reduction in waiting times for orthopedic trauma patients. Their study emphasized the importance of interdisciplinary coordination of the improvements to reduce waiting times. This was coincidentally one of the considerations that guided our approaches to improve ED and ICU workflow efficiencies. Lastly, Bhat and Gijo (2021) utilized Lean Six Sigma strategies to optimize the hospital registration process, resulting in a drop of the intake time by significantly decreasing the turn-around time (TAT) at registration. This was relevant in identifying barriers to optimal registration and directly influenced our discussion to implement automated registration and digitized check-in.

Howard-Williams et al. (2021) discussed how the patient admission process can be standardized into a one-piece flow model for admissions.

They focused on real-time data integration, which spurred our use of live tracking of ICU critical bed availability and AI-based coordinating. Systematic reviews by Kumar et al. (2021) and McDermott et al. (2022) examined issues addressed in developing Lean knowledge and critical success factors for implementation for health systems. Their ideas about organizational readiness, a commitment to leadership, and staff readiness informed our Control phase, including Plans for SOPs and Kaizen. Additionally, Waiman and Achadi (2021) reviewed the implications of Lean Six Sigma studies in outpatient departments, successfully demonstrating reduced time of admission from outpatient primary and specialty clinics, which we adapted for the emergency discharge process. Mistarihi et al. (2022) traced the use of Six Sigma simulations in the paediatric emergency department to correct dysfunctions in treatment and availability of resources. The highlight of this study was the many similarities in findings to the cause we found in our fishbone diagram and pareto point analysis.

3. Research methodology

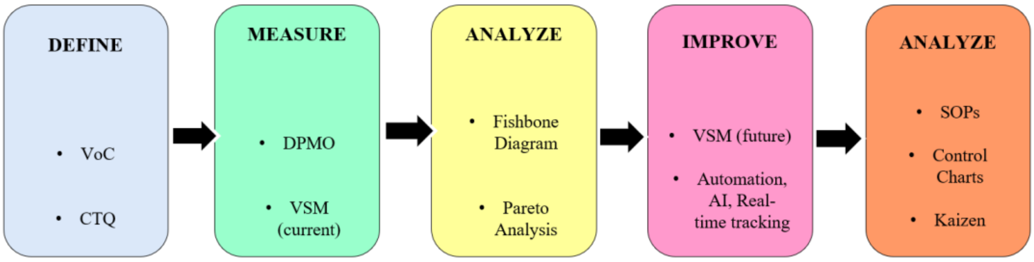

Figure 1: Architecture Diagram

3.1 Define Phase

In order to thoroughly diagnose the hospital admissions process inefficiencies, a Voice of the Customer (VoC) study was completed. Through this process, qualitative data were obtained from the main stakeholders directly or indirectly engaged with patient admissions. The stakeholders were identified according to their impact on and interaction with the admission process. Four key groups were surveyed:

3.1.1 Stakeholder Identification and Voice of the Customer (VoC)

To comprehensively diagnose the inefficiencies in the hospital admission process, a Voice of the Customer (VoC) analysis was conducted. This method captured qualitative data from the primary stakeholders involved directly or indirectly in patient admissions. Stakeholders were identified based on their influence on, and involvement with, the admission workflow. Four main groups were consulted:

Table 2: Stakeholder Needs vs. Challenges

Stakeholder	Needs & Expectations	Challenges Faced
Patients & Families	Quick registration, minimal waiting, clear communication	Long waiting times, unclear process, delayed treatment
Doctors & Nurses	Fast access to patient data, timely test results	Delay in test reports, lack of ICU beds
Hospital Administration	Efficient patient flow, reduced length of stay, cost optimization	Bottlenecks in discharge, resource mismanagement
Emergency Department (ED) Staff	Fast triage, bed availability, streamlined discharge	Overcrowding, lack of coordination with other departments

Table 2 summarizes each stakeholder group's key expectations and the challenges they currently face in the admission process.

- Patients and Families: Expected a seamless and transparent registration process with minimal delays and better communication. They reported frustration due to long waiting times, unclear instructions during admission, and delays in receiving timely treatment or room assignments.
- Doctors and Nurses: Required quick access to patient data and timely diagnostic results to make informed clinical decisions. Delays in the availability of ICU beds and test reports were noted as critical pain points that negatively affected patient care continuity.
- Hospital Administration: Aimed to reduce the overall length of stay and optimize resource utilization across departments. Administrative stakeholders expressed concern over frequent bottlenecks in discharge processes and poor coordination between admission, diagnostic, and discharge units.
- Emergency Department (ED) Staff: Highlighted overcrowding and the absence of real-time communication tools for bed availability and diagnostic prioritization. The lack of streamlined coordination with downstream units often resulted in treatment delays and reduced throughput.

The feedback obtained through structured interviews, surveys, and observational audits was analyzed thematically to isolate recurrent issues, which were then mapped to potential process inefficiencies.

3.1.2 Defining Critical to Quality (CTQ) Characteristics

Table 3: CTQ Metrics Table – showing current vs. target values

CTQ Metric	Current Value	Target Value	Unit
Overall Lead Time	88.40	62.91	Hours
Registration Time	21.50	4.30	Hours
ED to Discharge Time	55.60	33.40	Hours
Admission to ICU Time	53.00	13.20	Hours
Hospital Stay Duration	3.68	2.03	Days
ICU Length of Stay	3.45	1.93	Days

This table outlines each CTQ along with benchmarked values from the existing system and target values post-intervention.

The next step in the Define phase was to distil stakeholder concerns into Critical to Quality (CTQ) metrics—quantifiable measures that reflect the efficiency and effectiveness of the patient admission process. These metrics were selected based on their impact on patient flow, hospital operations, and clinical decision-making.
The six CTQs identified are as follows:

1. Overall Lead Time - The total time taken from patient arrival (registration) to final discharge. Indicates the overall efficiency of the hospital in handling patient flow from entry to exit.

2. Registration Time -Time required for initial intake, including data entry and verification. Directly affects patient satisfaction and downstream service initiation; long registration delays can lead to crowding and stress for both patients and staff.

3. ED to Discharge Duration - Total time a patient spends in the Emergency Department from triage to discharge. Reflects emergency care responsiveness and capacity management; prolonged ED stays can delay critical care access.

4. Admission to ICU Time - Time elapsed between admission to the hospital and transfer to the ICU, if required. Crucial for critical patients where delays can increase morbidity and mortality risks.

5. Hospital Stay Duration - Total number of days a patient is admitted in the hospital, excluding ICU duration. A proxy for treatment efficiency and discharge planning; extended stays often signal procedural inefficiencies or delays in diagnostics/treatment.

6. ICU Length of Stay - Number of days a patient spends in the Intensive Care Unit. Indicates how well critical care resources are utilized and how quickly stabilization and transition to general care occur.

3.1.3 Scope and Goal Definition

According to VoC and CTQ identification, the project scope is established as:

"To streamline delays and inefficiencies in hospital admission process—initial registration through discharge—using Lean Six Sigma principles across patient flow."

Project Objectives:

- Decrease the total lead time by a minimum of 50%
- Automate registration and ICU admission times for minimization
- Enhance bed utilization and lower emergency and ICU unit congestion
- Improve overall patient satisfaction by accelerating processing and reducing delays

These objectives set a definite course for the Measure Phase, wherein every CTQ would be measured and evaluated to inform evidence-based decision-making.

3.2 Measure Phase

The Measure phase aims to establish a data-driven understanding of the existing inefficiencies in the patient admission process. In this phase, each Critical to Quality (CTQ) metric defined earlier is quantified using real-world baseline data extracted from the ABC hospital dataset. This enables accurate identification of bottlenecks and lays the foundation for root cause analysis in the subsequent Analyze phase.

3.2.1 Data Extraction and Measurement Approach

To quantify the hospital admission process performance, data were pulled from the Kaggle-hosted dataset containing more than 546,000 hospital stays and rich event timelines, including registration, emergency department stay, ICU transfers, and discharge data.

For every CTQ, corresponding time-stamp fields and event logs were evaluated through SQL queries and Python code to compute:

- Cycle time for each process step (e.g., registration to ED entry time).
- Overall lead time from registration to discharge.
- ICU-specific measures such as admission delay and length of stay.

All the measurements were averaged over applicable cases to guarantee statistical reliability and to compensate for variations in patient flows per individual.

3.2.2 Process Capability Analysis using DPMO

To impartially assess the quality of the hospital admission process and identify the most vulnerable stages to inefficiencies, this research used the Defects Per Million Opportunities (DPMO) metric—a Six Sigma standard measure that quantifies the performance of processes and determines the variations beyond acceptable limits.

DPMO is especially useful in sophisticated, multi-stage systems such as hospital admissions, where each patient case contains several key stages. By quantifying how often every stage varies from expected standards, DPMO assists in identifying systematic process failures that might not be clear through the use of average cycle times. DPMO translates error frequency into a standardized measure, facilitating comparison between various process stages and by time.

Here, a defect refers to any occurrence where the time required for a particular process step is more than the threshold limit, as determined by clinical experts and stakeholders of the hospital. The thresholds were established during the Define Phase, according to clinical significance and industry standards of best patient care.

Table 4: Defect Criteria for DPMO Calculation

Stage	Defect Definition (Threshold Exceeded)
Registration to ED	> 60 minutes
ED to Discharge	> 12 hours
Hospital Admission to ICU	> 4 hours
Hospital Stay Duration	> 7 days
ICU Stay Duration	> 4 days

These thresholds were used as control limits, beyond which a process instance was flagged as defective Each patient case comprises five monitored CTQs, which means that for every patient, there were five possible opportunities for a defect. Thus, the total number of opportunities is the product of the number of patients and the number of monitored stages per patient:

$$\boldsymbol{DPMO = (Total\ Units \times Opportunities\ per\ UnitTotal\ Defects) \times 1,000,000}$$

In this study:

- Number of patients (units): 431,088
- Opportunities per unit: 5
- Total Opportunities: 431,088 × 5 = 2,155,440

From the dataset analysis, the following figures were computed for the current state of the process:

Table 5: DPMO Calculation for Current State

Metric	Value
Total Defects	1,158,146
Total Patients	431,088
Opportunities per Patient	5
Total Opportunities	2,155,440
DPMO (Before)	**537,313.03**

This high DPMO value indicates that the current process had a very high defect rate, with more than half a million errors per one million opportunities, making it a priority for improvement.

The DPMO analysis confirmed the process was underperforming across several stages, particularly ICU admission and ED discharge. By identifying the frequency and location of these deviations, the DPMO analysis served as a critical diagnostic tool to:

- Justify the need for Lean Six Sigma intervention,
- Prioritize improvement efforts,
- Establish a clear quantitative baseline for comparison in the Improve and Control phases.

3.2.3 Value Stream Mapping – Current State

During the Measure stage of the DMAIC process, Value Stream Mapping (VSM) is an essential tool for evaluating the current state of patient flow through the hospital admission process. The mapped information identifies major inefficiencies at major transition points, specifically the ED-to-discharge and ICU admission phases, which are responsible for extended waiting times and total lead time accumulation. The analysis captures a total lead time of production of 20.76 days, fuelled mostly by manual processes and the lack of real-time coordination mechanisms. With process durations of more than 29,897.96 minutes, the data highlights the critical need for Lean interventions to reduce processes, eliminate delays, and improve patient throughput efficiency. This systematic analysis forms the basis for the identification of bottlenecks and developing targeted process improvements in future phases.

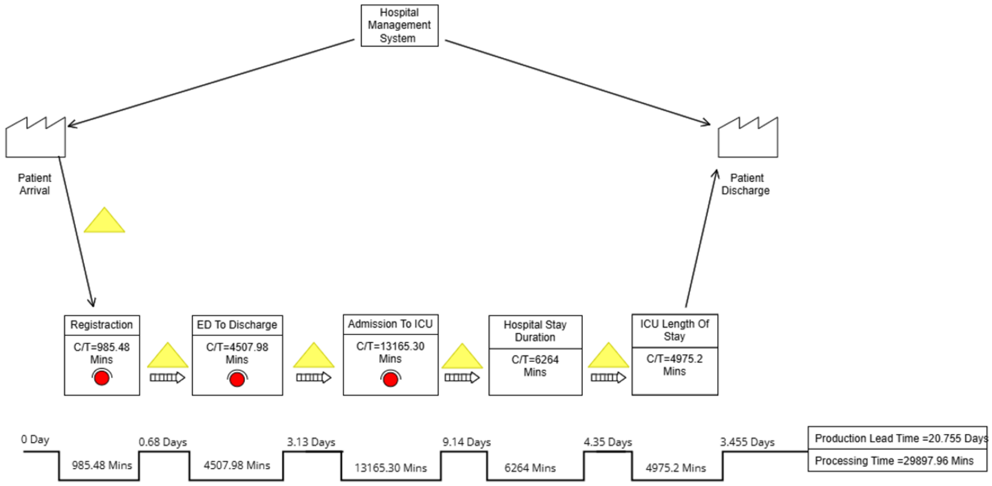

Figure 2 Current State VSM Diagram

This figure illustrates the sequential flow of patient processing and highlights the longest delays.

Table 6: Cycle Time Breakdown (Pre-Improvement)

Process Stage	*Cycle Time (Minutes)*	*Cycle Time (Days)*
Registration	985.48	0.68
ED to Discharge	4,507.98	3.13
Admission to ICU	13,165.30	9.14
Hospital Stay Duration	6,264.00	4.35
ICU Stay Duration	4,975.20	3.46
Total	29,897.96	20.76

The pre-improvement breakdown of cycle times highlights major inefficiencies in ICU admission and transitions from ED-to-discharge within the hospital admission process. In the different process stages, ICU admission has the longest cycle time of 13,165.30 minutes (9.14 days), and ED to discharge contributes 4,507.98 minutes (3.13 days) towards total patient flow delays. The numbers validate results from the current VSM that identify major bottlenecks demanding streamlined interventions.

Additionally, the total lead time for patient admission to discharge is 29,897.96 minutes (20.76 days), emphasizing the need for Lean Six Sigma techniques to streamline workflow efficiency. The unnecessary delays that accrue due to manual procedures and absence of real-time coordination also establish a strong case for automation and AI-based patient flow management. Resolving these inefficiencies via focused Lean interventions will be critical to decreasing overall cycle time as well as improving patient throughput.

3.2.4 Summary of Measurement Insights

Results of the Measure phase yielded quantifiable evidence of inefficiencies:

- More than 1.1 million defects were noted in over 2.1 million opportunities, and pre-intervention DPMO was over 500,000.
- Analysis of cycle time revealed that admission to the ICU alone contributed to over 9 days out of the total lead time.

- The VSM current validated that more than 75% of the total process time was consumed by only two phases, which verified the stakeholder issues found during the Define phase.

These findings provided the research team with strong baseline data for the Analyze Phase, during which root cause investigation and prioritization of improvement activities were conducted.

3.3 Analyse Phase

The Analyze phase works to uncover original factors that produce patient admission process inefficiencies which were previously identified in the Measure phase. Under the Analyze phase using diagnostic Lean Six Sigma tools like Fishbone (Ishikawa) Diagram and Pareto Analysis, healthcare professionals seek to transform data into actionable solutions by pinpointing essential bottlenecks and variation sources reducing process efficiency.

3.3.1 Root Cause Identification – Fishbone Diagram

The project made use of a Fishbone (Ishikawa) Diagram to strategically structure and display the possible causes which led to delays within the ICU admission process as well as in ED to discharge sections and throughout the entire hospital stay.

Key Root Causes Identified:

- People: Inadequate training, staff shortages, and slow manual verification steps.
- Process: The system features poor interdepartmental communication and multiple approval layers together with unstandardized workflows as primary causes.
- Machines/Technology: Delayed diagnostics due to outdated equipment and lack of real-time tracking systems.
- Materials: The delivery of ICU bed resources and essential supply procurements showed constraints during the crisis.
- Environment: Overcrowding in the ED and limited space in critical care units.

The main causes of inefficiencies stem from traditional manual work processes as well as fragmentation in operational coordination and insufficient technological infrastructure.

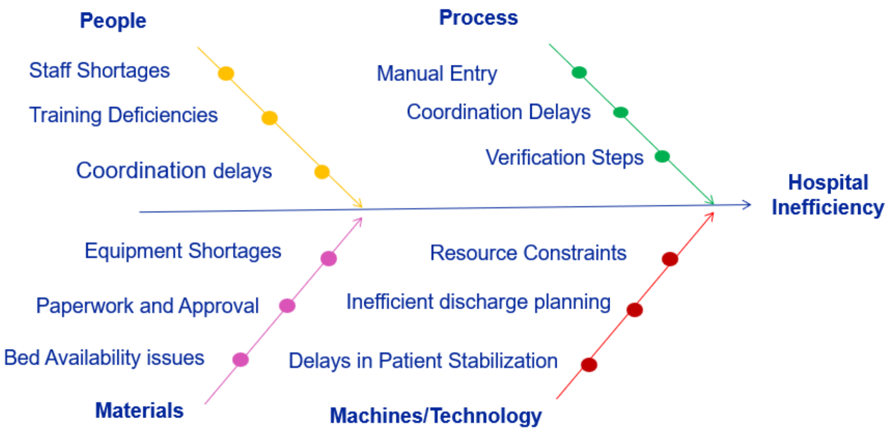

Figure 2: Fishbone Diagram – Delays in ICU Admission and ED Discharge

3.3.2 Prioritization of Issues – Pareto Analysis

The 80/20 principle guided the analysis of delays through a Pareto chart which identified the important stages that caused the most delays. Each CTQ area received numerical evaluation through a chart that analyzed frequency levels as well as severity rates.

Major Delay Contributors:

1. ICU Admission Delays
2. Hospital Stay Duration
3. ED to Discharge Time

Almost 80% of the total process inefficiencies originated from these three stages which demonstrated that investing improvement efforts here would produce the most significant results.

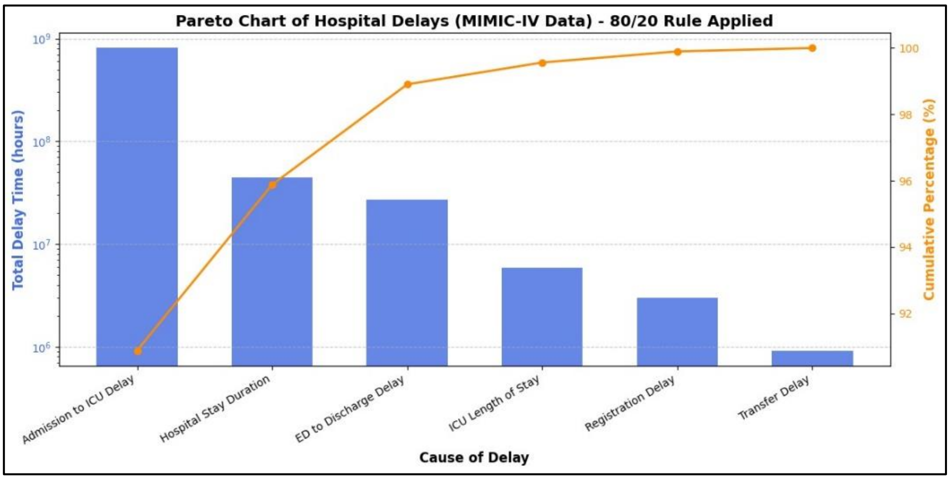

Figure 3: Pareto Chart – Distribution of Delay Sources in Patient Admission

3.3.3 Bottleneck Confirmation and Process Insight

Results from the Measure phase VSM verification along with DPMO analysis confirmed the previous findings about Pareto and Fishbone analysis.

- The admission process into ICU base alone required more than 9 day length of cycle time.
- The transition from ED to Discharge function lengthened patient travel time by more than three days.
- The combined effort of ICU admission together with ED to Discharge processes led to more than 75% of total lead time accumulation.

Key Patterns Identified:

- Worst patient delays surfaced between evening and weekend shifts due to scheduling issues and resource distribution problems during nighttime hours.
- System frameworks that support self-input data during patient registration have demonstrated the necessity for automated registration practices due to their introduction of manual errors and lengthened processing times.

3.3.4 Synthesis of Analyze Phase Insights

The Analyze phase produced the following main conclusions:

- ICU and ED delays stand as the main frustrating factors that need sharp attention during the phase of improvement.
- Three significant drawbacks for hospital operations involve manual procedures, a lack of bed tracking capabilities and insufficient cooperation between different hospital departments.
- Real-time tracking solutions perform in combination with automated systems to efficiently remove causes of delays.
- The process redesign initiative needs to center on standardizing workflows while reallocating resources and integrating technological solutions to solve major system breakdowns.

The analytical findings serve as evidence-led foundations for creating productive intervention solutions in the Improve phase of DMAIC implementation.

3.4 Improve Phase

The Improve Phase of the DMAIC approach concentrated on solution development and implementation to correct the inefficiencies that were discovered in the Analyze Phase. Targeted interventions were brought in based on data collected and process gaps witnessed in the Measure Phase to cut down lead times, remove delays, and improve resource utilization throughout the patient admission process. This stage focused on process redesign and technological integration, as Lean Six Sigma practices dictate eradicating steps that are non-value-adding and minimizing process variation.

3.4.1 Future State Process Design

To conceptualize the desired improvements, a Future State Value Stream Map (VSM) was created. The map was a blueprint for re-arranging the patient flow from registration through discharge. The Future State VSM addressed inefficiencies noted in the Current State VSM, such as prolonged registration lines, delayed ED discharges, and extended ICU admissions. It included structural adjustments like streamlined flows of communication, automation at points of intake, and real-time resource coordination. The new process flow removed sequential dependencies where feasible, promoted concurrent activities (e.g., triage and diagnostic orders), and enhanced information transparency between departments. This new design facilitated smoother transitions between care units, quicker decision-making, and greater throughput efficiency.

3.4.2 Implementation of Targeted Interventions

Interventions were made directly to the previously identified root causes and bottlenecks. The registration process was reengineered through electronic automation by substituting pre-validation and real-time digital patient intake for manual paperwork through integrated digital platforms. This eliminated administrative burdens and sped up initial processing. In the Emergency Department, waiting was erased through deployment of an AI-supported coordination system. This technology used clinical input data like vital signs and symptoms to allocate triage levels and prioritize diagnostic and therapeutic processes. The AI model also enabled dynamic routing by alerting departments concurrently, thus decreasing waiting times and enhancing throughput.

The most egregious delay—admission to ICU—was alleviated by implementing a real-time ICU bed management system. It combined sensor technology on beds that provided occupancy status with a shared dashboard viewable by both the ED and the ICU teams. It allowed tracking of available beds in real-time and enhanced prediction accuracy for ICU turnover, promoting timely and well-informed decisions regarding transfers.

3.4.3 Pilot Testing and Feedback Integration

Prior to full implementation, all of the interventions proposed were pilot-tested in a controlled hospital ward for two weeks. This enabled validation of system performance in real-world conditions and offered a chance to gather feedback from users. Nurses, administrative personnel, and physicians actively participated in pilot evaluation and suggested improvements, especially in user interface design and workflow flexibility.

Refinement was undertaken on the basis of pilot results to assure that interventions were not only technically feasible but also compatible with behavioural and operational hospital staff dynamics. This increased acceptability and preparedness for hospital rollout.

3.4.4 Quantitative Impact of Improvements

The success of the interventions was gauged based on comparison between baseline and post-implementation values for each of the Critical to Quality (CTQ) measures. Registration time decreased by 80%, from 21.5 hours to 4.3 hours. Emergency department to discharge time decreased by 40%, from 55.6 hours to 33.4 hours. Admission to ICU time decreased by the greatest margin, decreasing by 75% from 53 hours to 13.2 hours. There were also notable reductions in hospital stay (from 3.68 to 2.03 days) and ICU length of stay (from 3.45 to 1.93 days). Total lead time fell from 88.4 hours to 62.91 hours, a 28.8% improvement.

These enhancements answered directly stakeholder questions raised throughout the Define Phase and confirmed the strategic importance of the introduced alterations. The confluence of technological systems, rational decision-making, and real-time monitoring was able to cut profoundly process delays as well as increase patient flow.

3.4.5 Alignment with Lean Six Sigma Goals

The interventions carried out during the Improve Phase indicate the underlying core principles of Lean Six Sigma to improve efficiency and remove non-value-added steps in the patient admission process. The unnecessary data entry and waiting times were eliminated systematically, whereas process variability and unpredictability were reduced using automation and wise resource allocation. The use of data-driven decision-making, in combination with ongoing testing, feedback incorporation, and iterative optimization, guaranteed that changes were aligned with operational requirements and ensured long-term viability.

Through the emphasis on high-impact, evidence-based interventions, the Improve Phase effectively re-engineered patient admission processes, leading to a quicker, more stable, and responsive system. These optimizations not only streamlined hospital operations but also improved patient throughput and overall healthcare provision

4. Results & Discussion

The implementation of Lean Six Sigma (LSS) through the DMAIC methodology yielded significant improvements across multiple stages of the patient admission process. Initial examinations involved collecting Voice of the Customer (VoC) data to reveal patients experienced long waiting periods at registration locations and Emergency Department queues and slow ICU processing times and patient release cycles. The qualitative information revealed essential points for deciding the key intervention areas. Patient stakeholders with hospital staff members and healthcare administration personnel kept emphasizing issues with coordination effectiveness and communication shortcomings along with resource-related challenges. The healthcare providers translated their quality-related issues into Critical to Quality (CTQ) metrics which provided quantitative tools to assess current conditions and define target improvement areas.

Table 7: Critical to Quality (CTQ) Metrics

CTQ Metric	**Before (Current State)**	**After (Future State)**	**Improvement**
Overall Lead Time	88.40 hours	62.91 hours	↓ 28.8%
Registration Time	21.50 hours	4.30 hours	↓ 80.0%
ED to Discharge Time	55.60 hours	33.40 hours	↓ 39.9%
Admission to ICU Time	53.00 hours	13.20 hours	↓ 75.1%
Hospital Stay Duration	3.68 days	2.03 days	↓ 44.8%
ICU Length of Stay	3.45 days	1.93 days	↓ 44.1%

A set of visual comparisons was created to display duration improvements between the present state and future state across the entire process. The bar chart presented in Figure R1 shows time reductions that span from patient registration through the ICU stage into total procedure times. Visual data in given below verifies the CTQ table's numerical findings to demonstrate how every performance enhancement method yielded specific time-saving outcomes.

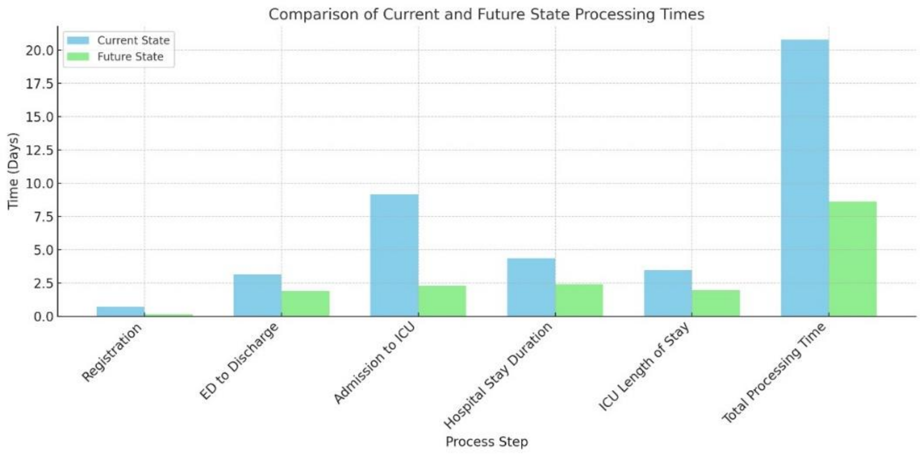

Figure 4: Bar chart – Comparison of Current and Future State Processing Times

The bar chart displays the time performance contrast between the existing state and projected state stages.

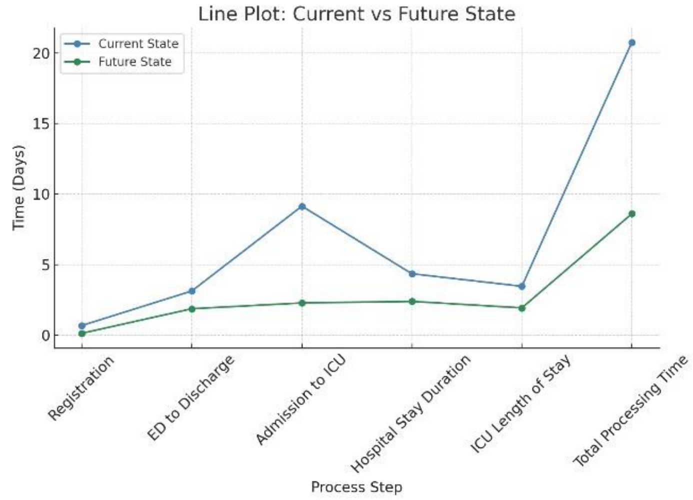

Figure 5: Line chart – Comparison of Current and Future State Performance

The line graph shows how post-intervention hospital stages became more efficient by displaying downward slopes.
The visual representations validate how Lean Six Sigma interventions achieved better patient flow performance while maximizing resource efficiency and shortening overall healthcare duration.

Six Critical to Quality indicators including overall lead time, registration duration and ED to discharge duration, admission to ICU time, hospital stay length and ICU stay duration were measured during the project. At the beginning these performance indicators demonstrated severe problems because lead time presented 88.4 hours of duration while registration required 21.5 hours to complete and patients experiencing 53 hours of delayed ICU admission. The average hospital stay amounted to 3.68 days and ICU occupancy reached 3.45 days which indicates weak discharge planning and underused resources. The numbers experienced substantial reductions following the deployment of strategic process development initiatives. The implementation reduced registration duration to 4.3 hours which formed an 80% performance gain from the original process. Healthcare professionals reduced ICU admission delays by 75% which resulted in 13.2 hours as the new average admission duration. The patient hospital duration decreased to 2.03 days and patients spent 1.93 days in ICU. The total period from registration to outcome decreased to 62.91 hours. The implemented interventions proved effective and strategic optimization of these vital stages improved patient processing while enhancing healthcare service delivery.

During the Measure phase DPMO allowed researchers to standardize delay quantification through the Defects Per Million Opportunities method. The study used specific thresholds which established what constituted defects when patients spent longer than 60 minutes in the registration queue or more than four hours in the ICU. The DPMO defect measurement system exposed additional inefficiencies beyond time-based observations by providing defect data at each patient hospital stage in addition to improving the overall process quality by 16.4 percent after the intervention. The implementation of Lean Six Sigma produced meaningful decreases in the defect measurement rates, thus demonstrating its success in healthcare institutions.

Table 8: DPMO Metrics

Metric	Before Implementation	After Implementation
Total Defects	1,158,146	968,682
Total Patients	431,088	431,088
Total Opportunities	2,155,440	2,155,440
DPMO	537,313.03	449,412.65

The Fishbone Diagram served as a tool to detect fundamental causes of operational inefficiencies. The analysis diagram demonstrated widespread issues in the healthcare system caused by poor department coordination and limited staff training and outdated medical equipment shortages as well as outdated manual filing practices and deficient bed management systems. The identified factors demonstrated exceptional influence in ICU and ED operations because real-time decision-making is essential there. Pareto Analysis helped identify the stages that were responsible for most delays in the process. Research findings indicated ICU admissions along with hospital stays and ED to discharge transfers generated around 80% of total delays thus requiring heightened attention from

the improvement team. By focusing on these essential contributors to inefficiencies the team achieved the most beneficial outcomes while requiring minimal additional resources.
Value Stream Mapping (VSM) created a clear visual presentation of how patients experienced their healthcare pathway. The existing VSM revealed an inefficient and disintegrated process that took 29,000 minutes and 20.76 days to complete. The implementation of Lean interventions resulted in a major improvement to processing times because the future state VSM revealed total lead time reduced to 8.6 days coupled with a processing time reduction to approximately 12,422 minutes. The registration duration fell dramatically from 985.48 minutes to 197.10 minutes. The implementation of AI alongside automation systems served as essential factors that resulted in valuable improvements. Hospital registration operations became more efficient through digital check-ins and patient data pre-population systems and AI tools created enhanced ED coordination along with real-time ICU bed tracking for better patient transfers. The digital solutions minimized waiting time along with administrative workloads so healthcare resources benefited from better usage and staff members operated with greater efficiency.

Table 8: Current vs Future VSM values

Process Step	Current State (Days)	Future State (Days)	Improvement Observed
Registration	0.68	0.13	Reduced by 80%
ED to Discharge	3.13	1.87	Reduced by 40%
Admission to ICU	9.14	2.28	Reduced by 75%
Hospital Stay Duration	4.35	2.39	Reduced by 45%
ICU Length of Stay	3.46	1.93	Reduced by 44%
Total Processing Time	20.76	8.6	Reduced by 58%

The maintenance of these improved outcomes needed a reliable control system in place. Standard Operating Procedures (SOPs) implemented standardized workflows that received support through control charts which continuously monitored essential performance indicators for ongoing compliance purposes. Kaizen practices enabled organizations to sustain continuous improvement through ongoing participation of frontline staff who provided feedback and improvement input. The monitoring of DPMO trends helped prevent new errors while upholding the benefits obtained from project implementation.
Lean Six Sigma applications allowed the healthcare institution to deliver momentous delays reduction combined with better coordination practices and superior patient experience. Structural analysis and targeted procedures together with monitoring activities produced 58% improvement in total lead time and 75% increased ICU admission speed and an 80% shorter registration period. Data-driven process improvement transformations advance hospital operations and generate tangible results for patient care quality together with system performance improvement.

5. Conclusion

This study highlights the practical and successful application of Lean Six Sigma methodologies in improving hospital admissions through the DMAIC process. After identifying sources of inefficiency and root causes of the problems with tools such as Value Stream Mapping, Fishbone Diagrams, and Pareto Analysis, we were able to reengineer essential stages of the admissions workflow (registration, ED to discharge, ICU admissions) to achieve a 58% reduction in total lead-time. The project actively used automation, AI-based coordination, and real-time ICU tracking to facilitate a decrease in registration time of 80% and ICU admissions time of 75%.

The benefits of these improvements were in increased efficiency of the hospital and better patient experiences with more time-efficient clinical services. Additionally, there were tangible improvements in clinical delays and the optimization of how we used the hospital's resources. Importantly, the implementation of Standard Operating Procedures (SOPs), control charts and Kaizen ensured the improvements were sustained and continuously improved upon over time. This case study also serves to reinforce the idea that we need to take a data and process-based approach to reduce systemic inefficiencies that exist in our healthcare systems and provide a framework to apply in other institutions to improve both admissions workflows, as well as delivery of patient care

5.1 Limitations

Although the implementation of Lean Six Sigma improved the hospital admission process, this study does have limitations. This project was undertaken from the context of modeling from the ABC hospital dataset, which was valuable. Data from an electronic health record, or any quantitative modeling efforts, can never be able to ascertain all the time sequences, dynamics and complexities of all healthcare entities over time . The simulated environment, while necessary for this project, did not take into account the human element nor the competitive and emergent nature of healthcare systems. For example, staff resistance to the implementation of these changes, patient response variability and surges of emergencies perhaps in regions recovering from Covid-19, and the resultant interruptions to expected operational workflow. Similarly, the interventions, on largely theoretical grounds, presumed access to electronic or digital infrastructure and automation systems as well as artificial intelligence systems that could ultimately take place in hospitals - but these systems may be limited in their availability and viability to every hospital or situation. Understandably, there may be many arguments made to again counteract the generalizability of the outcomes of proposed interventions to other hospitals given differing operational constraints and operational resources .

5.2 Future Scope

The success of this project provides gaps within which Lean Six Sigma (LSS) could grow from the admissions process to other areas of a hospital like surgical scheduling, discharge planning, outpatient services, pharmacy workflow, and so on. Each of these areas can be optimized with quicker cycle times and enhanced value for patients' experiences. Additionally, possible improvements through real-time clinical data from wearables and electronic health records (EHR) may be able to further improve clinical decision-making, early intervention, and collaborative, complementary care delivery in the future.

Further research could examine the use of predictive analytics and machine learning to anticipate patient volumes, and need for ICU beds and staff. Identifying patient flows and seasonal/unscheduled variations could help hospitals to anticipate healthcare before they just respond to peaks in demand, shared, by overcrowding in the emergency department; and or as a result of an emergency (natural disaster) (infectious disease). Additionally, pilots involved urban-rural, private-public facilities and could provide clarity into how flexible this model can be and validate how mechanisms of change and/or collaboratives could operate in diverse settings. Lastly, other dashboards powered by real-time data, make it possible for staff to continually submit feedback on areas for continued process improvements, offer assurance for stakeholder engagement and, focus on continued quality improvement accountability. All of these items ultimately lead towards a more efficient, data-driven, and patient-centric health care system.

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