FAMU-FSU COLLEGE OF ENGINEERING

PACU Patient Flow Optimization at Tallahassee Memorial HealthCare

A report submitted to Dr. Okenwa Okoli
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This report summarizes the technical progress made in the five phases of this project. Also included is a detailed business analysis.

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Abstract

Tallahassee Memorial HealthCare (TMH) has been experiencing growth in patient capacity and is adapting to meet the new demands. TMH serves the residents of North Florida and South Georgia. The Post-Anesthesia Care Unit (PACU) is an area in the hospital where patients receive care after undergoing surgery and are brought to the PACU from various operating rooms. The PACU has been experiencing backups that result in compounding negative effects throughout different areas of the hospital.

When the patient flow is slowed in the PACU on high-volume days, the operating schedule faces delays because they cannot move patients from the Operating Room (OR) to the PACU, and then to the patient's designated nursing unit. These delays can lead to cancellations in surgeries which cause the patients to become dissatisfied with their care at TMH. A concern for TMH is the cost incurred as a result of keeping patients in the PACU and/or OR for extended time since extended stays are not generally covered by insurance. The hospital has to use its own funds to pay for the extended stay of patients in the PACU and the nurses who are required to look after those patients.

The team obtained PACU data regarding patient length of stay in the PACU and the type of operations those patients underwent. The information derived from the data analysis, as well as PACU observations and staff interviews, allowed the Project Team to perform a Root Cause Analysis so as to determine which factors are hindering patient flow through the PACU. This analysis serves as the basis on which the Project Team created a Process Improvement Plan. This Improvement Plan was then evaluated in order to determine any potential risks once TMH implements the suggested solutions.

1. Introduction

Tallahassee Memorial HealthCare (TMH) is one of two hospitals located in Tallahassee, Florida. They are dedicated to transforming care, advancing health, and improving lives [1]. TMH contains the area's only state designated trauma center and accredited community hospital cancer program. The Tallahassee Memorial Orthopedic Center offers many services, and with over 20 orthopedic surgeons, they provide care for knees, hips, shoulders, elbows and more. With the exponential expansion occurring throughout the city of Tallahassee, TMH has expanded to meet the proportional increase in population demands. However, TMH has been unable to update its standard procedures in order to match the increased volume of patients.

TMH is currently having a problem moving patients efficiently and quickly through the main Post-Anesthesia Care Unit (PACU), which serves as the hospital's primary PACU. Within the PACU, the patient receives specialized post-operative care in order to ensure there are no medical complications due to the surgery or anesthesia. This room is staffed by nurses, anesthesiologists, and support staff who are trained to serve the needs of the patients. After arriving in the PACU, the patient receives a physical assessment and has their vital statistics monitored. During the patient's stay, their bandages will be checked, pain medicine will be administered as needed, and any questions the patient has will be addressed. Only upon total emergence and recovery from the anesthesia will a patient be moved out of the PACU.

In previous years, the main PACU would experience fluctuations in patient volume that was congruent with expected population patterns, such as a decrease in the number of patients during the summer or holidays due to students in Tallahassee traveling elsewhere, and the PACU performed efficiently during the majority of the year. However, the current patient volume level is consistently equivalent to what used to be the maximum level that was only occasionally experienced. It has become the new normal to exceed capacity or capability of the PACU on the

days when most elective surgeries are scheduled by surgeons, which can be three to four days each week. Not only has this over-capacity been a persistent issue throughout the past few years, but also it has continually grown worse. The PACU staff must allocate resources and staff based upon the expectation that they will experience significant delays on high-volume days. Due to the desire of TMH to provide the best care and experience for all patients, the TMH staff wishes to implement a new solution which will henceforth allow for patients to be efficiently moved through the PACU with as few delays as possible.

At Tallahassee Memorial, there are three PACUs, including the Main Operating Room PACU (which is the focus of this project), the Surgery Center PACU, and the Women's Pavilion PACU. The Main Operating Room PACU is currently the only PACU experiencing significant bottlenecking. One of the main reasons for the intense strain on the PACU is because this PACU receives patients from MRI, cardio-vascular, special-case, orthopedic, and the Emergency Room (ER). Thus, the bottleneck occurring within the Main Operating Room PACU cannot be rectified by modeling it after the other PACUs because the phenomenon occurring is unique to it. The current state must be critically evaluated in order to determine what process improvement solutions can be implemented so that there are no longer significant delays inside the PACU.

There are many other factors that contribute to the state of the PACU as well. Firstly, any patient who receives anesthesia must recover in a PACU, per TMH policy. Therefore, patients cannot be turned away, nor relocated to other holding areas of the hospital. Secondly, the PACU must be prepared to handle scheduled and unscheduled surgeries. The elective and planned surgeries are scheduled by the surgeons who use the TMH facilities, but there are often patients that must receive an unscheduled operation due to their entry into the Emergency Room. Thirdly, a patient cannot be moved until the bed to which he is assigned is available and clean. This can

cause the following surgeries to be delayed or even cancelled. It is the combination of all of these factors that impact and place constraints upon the PACU operating procedure.

The TMH senior design team has been tasked with improving patient flow through the PACU until TMH moves to a new facility in a few years. The senior design team will accomplish this through the implementation of the DMAIC process, where DMAIC is identified as Define, Measure, Analyze, Improve, and Control. Each section of the DMAIC process is referred to as a phase, with phase one corresponding to "Define," phase two corresponding to "Measure," and so on in this way. This report will include aspects of the Define, Measure, Analyze, Improve, and Control Phase. The Define Phase is used to determine if the problem is feasible in regards to DMAIC application, what the current state and problem of the process is, and the consequences of the problem. The Measure Phase is used to gather all data and measurements regarding the system and explain the relevance of that data. The Analyze Phase is used to identify root causes by analyzing the data collected in the Measure Phase. The Improve Phase is theoretically used to implement improvements to the system. For the purposes of this project, the Improve Phase will be used to construct an Improvement Plan. This is because the type of improvements necessary for this project are not ones that can be implemented by the Project Team; rather, TMH will be the ones to implement the improvements upon the completion of the project. The Control Phase is used to ensure whatever improvements have been made, are actually making discernable improvements to the system. For this project, the Control Phase will be used to perform various types of analysis on the Improvement Plan in order to prove the validity and effectiveness of the Improvement Plan. In accordance with the requirements for each phase, this report will discuss the project charter, customer and technical requirements, process measurements, a root cause analysis, a business analysis, and project progress.

2. Project Charter

2.1 Project Overview

Tallahassee Memorial HealthCare has been experiencing bottlenecking in the PACU, thus creating an increase in the length of stay in the PACU, an increase in patient transportation times, and overcapacity in the PACU. These issues are symptoms of a problem that is unique to the Main Operating Room PACU and is not being experienced in other areas of the hospital.

The PACU is an area in the operating room suite in which patients are held and monitored during anesthesia recovery. A patient enters the PACU upon the completion of surgery in the operating room, and is removed from the PACU upon total emergence from the general anesthesia [2]. During a patient's time in the PACU, clinicians will monitor vital signs, maintain the patient's airflow, provide pain management, and ensure there are no postoperative complications. The care a patient receives during this time is critical to not only ensuring a gradual and controlled emergence from the anesthesia, but also to ensure any complications that may arise can be treated swiftly and effectively. A patient can be expected to remain in the PACU anywhere from 60 to 120 minutes. If a patient must receive additional pain medication while in the PACU, it is TMH policy that the patient be held for an additional 30 minutes.

Currently, the TMH Organizational Improvement and Planning department is concerned with patient flow through the main operating room PACU because of the bottleneck that is occurring only within this specific PACU. The PACU only holds fourteen beds, arranged in two rows and seven columns. On days when the most surgical operations are scheduled, there are often patients waiting for a bed to become available in either the PACU or the specific nursing unit to which the patient will be taken. The overflow of patients can cause a patient to be held in the operating room until a bed is available in the PACU. The back-up in the operating room will then cause delays or even cancellations in scheduled surgeries.

There are two main concerns with the peaks in PACU capacity. The primary concern is for patient safety and experience. It is paramount that a patient's vitals be constantly monitored, and if there is an abundance of patients, the nursing staff may be overextended while attending to patients. TMH strives to ensure all patients have the best experience possible while receiving treatment, but overflow of the PACU is not conducive to an overall positive experience for the patient. The other important concern is the increased costs associated with extended patient stay in the PACU. The combination of patient experience, patient safety, and hospital costs creates a compelling need for the hospital to address the PACU issue.

In order to improve patient flow through the PACU, the team will adhere to the guidelines established by the Six Sigma DMAIC (Define-Measure-Analyze-Improve-Control) process. During the Define Phase, the team will seek to identify, understand, and report upon the objectives and scope of the project. The Define Phase is important to the success of the project because all subsequent tasks and goals will be based upon the concepts outlined in this report. All subsequent phases will use the outlined objectives and benefits in the subsequent section as a reference in order to remain on task and within scope.

2.1.1 Objectives and Expected Benefits

The following items are a comprehensive list of objectives for this project.

1. The team will become familiar with all aspects of the patient flow process through the main operating room PACU at TMH. This will be accomplished through data analysis and observation.
2. The team will identify any and all root causes found to negatively impact patient flow through the PACU.

3. The team will provide Project Sponsors Cynthia Blair, Dr. Abhishek Shrivastava, and Mr. Joseph Camps with process maps, PACU capacity analytics, and process improvement plans by the conclusion of the project.
4. Through the implementation of the DMAIC process, the team will provide a report and solution to patient flow bottlenecking in the PACU by the end of the project in Spring 2016.

The following list provides the expected benefits associated with each objective listed above, respectively.

1. By becoming familiar with the patient flow process, the team will be able to understand the inherent issues. If the process is not understood, the team may not be able to articulate the cause of the bottleneck. Once the issues are understood and evaluated, the team can then logically work backwards to identify the true root causes.
2. Identification of the root causes is critical to implementing the correct solution. Due to the various factors that affect the process, the team must identify and analyze each of these factors to determine which has the strongest impact on the process. The primary causes can then be studied in order to reach the optimal solution.
3. Completing the required maps and diagrams has two main benefits. The main benefit is that the project sponsors will be able to receive the data in the format most pertinent to them. The secondary benefit is that the team will better understand the patient flow process by completing the diagrams and maps, thus allowing the team to better implement the DMAIC process.
4. By completing the DMAIC process and submitting the required reports, the team will be able to present the most effective solution(s) to the TMH Organizational Improvement and

Planning Department. TMH will then be able to improve patient flow through the main OR PACU because of the application of a solution founded in data analytics.

2.1.2 Business Case

As the primary healthcare provider for 17 counties in the North Florida and South Georgia region, it is imperative that TMH operate at maximum efficiency and productivity [1]. Over the past several years, TMH leadership has worked tirelessly to increase the number of patients the hospital is able to treat during a given time interval. While TMH has successfully reached their goal of increasing patient volume, it is has been unable to appropriately upgrade procedures to match the increase in patient throughput. Therefore, the successful completion of this project will provide major relief to the bottlenecking that has been hindering post-operative care.

The two primary goals of TMH are to ensure patient safety and provide a quality patient experience while at the facilities. The bottlenecking in the PACU has been preventing TMH from providing a fully satisfactory patient experience because of the additional time patients are forced to spend in PACU rather than with the patient's loved-ones. In the PACU, there are 14 bays in which a patient can be brought on his or her stretcher. On peak days in the PACU, all 14 bays are occupied and any additional patients must be held in the operating room. The Project Team was informed that sometimes a patient can be held longer in the PACU because the bed assigned to the patient in the nursing unit has not yet been cleaned or made available. Delay in the nursing units causes delays in the PACU, which causes delays in moving patients out of the Operating Room, and then causes delays in scheduled operations. If the bottleneck can be eliminated, these issues will be predominantly resolved, and TMH will once again be able to completely reach their goals of patient safety and experience.

Another benefit to be expected from eliminating the PACU bottleneck is lowered costs for the hospital. When patients are held longer in the PACU, costs are primarily incurred two different

ways. If patients are being held longer in the PACU than expected, then there will be an increase in the number of hours when most nurses are on staff. Any overstaffing that is occurring is generating extra costs for the hospital. Additionally, since hospitals are receiving lump-sum payments from insurance companies rather than an itemized, task-based payment, the hospital must pay for any additional expenses incurred from longer stays in the PACU. These additional costs will be avoided upon the successful completion of this project.

Problems associated with the bottleneck will occur in both the short term and the long term. Likewise, there are various benefits to be realized over the short and long term. The Threats and Opportunities Matrix in Table 1 not only lists the problems and opportunities, but also shows the relationship between the long term and short term. The short term in this case is defined on a daily or weekly basis. The long term is defined as six months or longer. The threats are the problems that will occur if the project is not successfully completed, and the opportunities are the benefits realized if the project is successfully completed. It can be seen that many of the short term threats will lead to more threats in the long term, such as poor patient experience leading to potential future patients seeking treatment elsewhere. However, there are also compounding opportunities. Improved patient flow will allow more patients to be treated each day. Thus, the importance of this project can be understood from Table 1 because it lists the many effects associated with either the success or failure of the project.

Table 1: Threats and Opportunities Matrix

	THREATS	OPPORTUNITIES
SHORT TERM	Patients do not receive proper care	Patients receive better personal care
	Overstaffing of nurses	Patients spend less time in PACU
	Poor patient experience	Surgeons and nurses are able to perform their jobs more effectively
	Scheduling conflicts	Fewer scheduling conflicts
LONG TERM	Bottleneck worsens	Constant flow of patients through PACU and OR
	Patients seek treatment elsewhere	Patients continue to seek treatment at TMH
	TMH loses significant funds to nursing costs	TMH increases savings
	Decrease in number of surgeries scheduled	More patients can receive treatment

2.1.3 Project Stakeholders and Team Organization

The TMH PACU Senior Design Project consists of three main groups: the Project Team, the Project Sponsors, and the Project Stakeholders. Each of these three groups will remain in communication throughout the DMAIC process in order to successfully complete the project. Figure 1 provides an illustration of the organization of the project groups, with the Project Team in green, Project Sponsors in red, and Project Stakeholders in blue. The categorization of either TMH employees or Florida Agricultural & Mechanical University – Florida State University (FAMU-FSU) College of Engineering faculty and students can be seen in Figure 1 based upon the background colors of orange and purple, respectively.

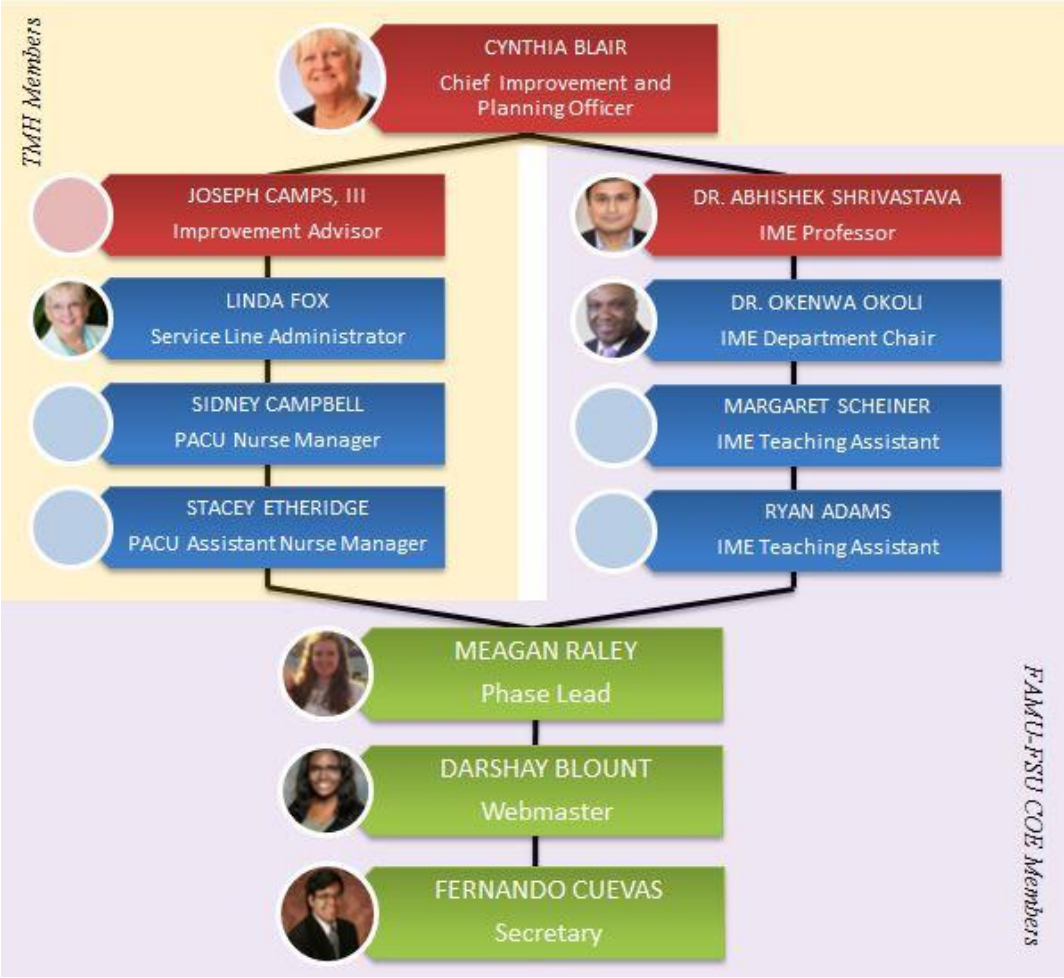

Figure 1: Team Organization

The Project Team is comprised of Meagan Raley, Darshay Blount, and Fernando Cuevas. The Phase Lead is responsible for project planning and project goal execution. The Webmaster will communicate with the College of Engineering's Communication and Multimedia Services (CMS) in order to establish and update the team website for all five phases of the report. The Secretary is responsible for recording and updating team meeting minutes, as well as ensuring the overall organization of the team. While the Phase Lead is responsible for delegating tasks, the Project Team will regularly meet in order to discuss and agree upon the various tasks necessary for the project. The Project Team as a whole is responsible for ensuring all Deliverables are completed on

time and with superior quality. Table 2 lists the team roles each Project Team Member will hold throughout the duration of the project.

Table 2: Project Team Member Roles

Project Team Member	Project Phases				
	Define	Measure	Analyze	Improve	Control
Darshay Blount	W	W	W, L	W	W
Fernando Cuevas	S	L	E	S	L
Meagan Raley	L	S	S	L	S

Key: L = Lead, S = Secretary, W = Webmaster, E = Industrial Engineering Specialist

The Project Sponsors consist of Ms. Cynthia Blair, Mr. Joseph Camps, and Dr. Abhishek Shrivastava. Ms. Blair is the Tallahassee Memorial HealthCare Chief Improvement and Planning Officer. Mr. Camps works as the Improvement Advisor, and will be the Project Team's main point-of-contact at TMH. Dr. Shrivastava is one of the Industrial and Manufacturing Engineering Professors at the FAMU-FSU College of Engineering. A project description was submitted to both the Project Team and Dr. Shrivastava at the beginning of the Design Phase by the TMH Project Sponsors. All three Project Sponsors have met with the Project Team on various occasions in order to discuss and clarify the project description.

The Project Stakeholders at the FAMU-FSU College of Engineering include Dr. Okenwa Okoli, Ms. Margaret Scheiner, and Mr. Ryan Adams. Dr. Okoli serves as the Industrial and Manufacturing Engineering (IME) Department Chair, as well as the Senior Design Course Professor. Both Ms. Scheiner and Mr. Adams are doctoral candidates in the IME Department and serve as the Teaching Assistants for the Senior Design Course. All three of these Stakeholders have provided information regarding the DMAIC process and report procedures, and will continue to do so throughout all phases of the project.

The Project Stakeholders at Tallahassee Memorial Healthcare are Ms. Linda Fox, Line Administrator for Surgical Services; Ms. Sidney Campbell, PACU Nurse Manager; and Ms. Stacey Etheridge, Assistant PACU Nurse Manager. Each of these stakeholders is directly involved with the scheduling and management of the PACU. These stakeholders have provided in-depth knowledge regarding PACU procedures that has been critical to the development of the Project Charter. These stakeholders will provide information regarding the PACU throughout the project, as well as be informed of major project updates by the Project Team.

2.1.4 Project Team Background Information

Darshay Blount is a senior Industrial Engineering student at Florida A&M University from Orlando, Florida. Darshay has previous intern experience with Johnson & Johnson and Northrop Grumman. At Johnson & Johnson, she worked in information technology ensuring that all of the resources throughout the company were being managed effectively. At Northrop Grumman, she worked in supply chain management and helped ensure that all orders were completed and fulfilled in a timely manner. On campus, she is involved in several organizations including Presidential Ambassadors, Alpha Kappa Psi Professional Business Fraternity, Inc., and Alpha Kappa Alpha Sorority, Inc. Darshay is very methodical and observant which allows her to easily find improvements within various processes.

Fernando Cuevas is a senior Industrial & Manufacturing Engineering student from Panama graduating in spring 2016. Fernando has previous experience working with Ingenieria y Explosivos, S.A. (INEXSA) and International Blasting Services, Inc. (INBLAST – Exsa Peru being the mother company). Both are Panamanian companies that work with blasting and explosives. At INEXSA, he worked as operation and management assistant, assuring that the company's goals were being achieved by having control of the amount of resources used in every blasting on the quarries. At INBLAST he worked as assistant of the General Manager, reporting

every action in the company. Fernando was in charge of the management, operations, and inventory in the Panama branch. In addition, Fernando is also a member of the Fundraising Committee in the organization of Panamanians at FSU called PTY@FSU. All of these roles allowed Fernando to obtain great management and leadership skills.

Meagan Raley is a fourth year Industrial Engineering student and will graduate in the spring of 2016. Meagan will complete and defend her Honors Thesis on Triboluminescent Fiber Optic Wires in Composites in the spring of 2016. Meagan has obtained research experience by working at the High-Performance Materials Institute as a Research Assistant since March of 2015. She is currently the Secretary for the FAMU-FSU chapter of the Institute of Industrial Engineers, and Vice President of the Alpha Pi Mu Industrial Engineering Honor Society. In addition to these roles, Meagan has obtained leadership and group skills in her previous roles as Phi Eta Sigma Fundraising Chair, Representative on the FSU Council of Honor Societies, Editor for the FSU Undergraduate Research Journal, and completing the Leadership Theory course at FSU.

2.2 Approach

2.2.1 Scope

The Project Team will examine the patient flow process through the main operating room's PACU at TMH in order to eliminate the bottleneck that consistently occurs during peak operating hours. For this project, the scope will include updating PACU layout, improving processes within the PACU, and analyzing patient time lapse throughout the system. Initially Environmental Services (EVS) was considered to be within the scope of this project, but after conducting staff interviews the Project Team determined EVS was not a major source of delay. The Project Team determined the following factors were beyond the scope of this project:

1. Nurse Staffing: not enough time to analyze complexities of staffing
2. Physical Facility Layout: cannot re-allocate rooms in the hospital

3. Surgical Scheduling: cannot alter the surgeon's schedule
4. Nursing Unit Room Assignment: beyond the constraints of this project
5. Patient Discharge Procedures: beyond the constraints of this project

The first priority of this project is to understand the process flow. In order to evaluate whether or not improvements can be made to the actual process, current information must be gathered. The team will make observations of the PACU in order to understand the physical layout of the PACU, the way in which patients are moved, and the way in which the process works. The observations will supplement the patient flow data provided by the TMH Project Sponsors. The data consists of such information as how many patients enter the PACU during the day and how long those patients remain in the PACU. It is critical that all data and observations be analyzed to the fullest extent so that all factors are determined and analyzed.

The PACU surgical schedule is created by the surgeons who will be performing the surgeries in the main PACU. It has been made clear to the Project Team that while distributing scheduled surgeries evenly throughout the week would be the most obvious solution, it is not feasible due to the political aspects of the relationship between the hospital and surgeons. Therefore, it has been determined that altering surgical schedules is beyond the scope of this project. Additionally, changing, altering, or re-assigning facility space is out of the scope of this project. TMH is currently utilizing all available space, so re-allocating various rooms will not be an option for handling patient overflow. While the current space may be analyzed for the purposes of improving efficiency, no additional space can be created or utilized. All project solutions must exist within the current physical space.

2.2.2 Assumptions & Constraints

The following list includes all assumptions made by the Project Team. This list may be updated in subsequent Phase Reports if new assumptions arise.

1. All electronic data and verbal information provided by the TMH Project Sponsors and Stakeholders is accurate, to the best of their knowledge.
2. The TMH Organizational Improvement and Planning Department will implement the process solutions found by the Project Team upon the completion of the project.
3. The new process system(s) will be utilized by the PACU nursing staff.
4. The only PACU that will implement any solution(s) presented by the Project Team will be the Main Operating Room PACU, and will only be implemented until the new TMH building is completed in a few years.
5. Any provided information that is strictly proprietary will be presented to the Project Team as such, and will only be included in reports upon the approval of the TMH Project Sponsors.

The following list includes all constraints realized by the Project Team. This list may be updated in subsequent Phase Reports if new constraints are found.

1. The patient schedule for the PACU is only made available to the PACU at most 24 hours prior to the scheduled operations.
2. No changes can be made to the surgical scheduling system.
3. Only the current facility areas are available. No additional areas of the hospital will be created or made available during the course of this project.
4. Observations will be constrained to brief, scheduled observation times, and will not be conducted over an extended time period, such as full shifts or full days.

2.2.3 Deliverables

Table 3 is a Deliverable Schedule for this project. The table includes due dates, recipients, and phase leads for the respective deliverables. The deliverables listed include all five phases,

explicitly. The deliverables listed in Table 3 will be completed by the listed date, and will be included in subsequent reports. Additionally, TMH Stakeholders, such as the PACU Nurse Manager, are not included in the list of recipients for Phase Reports, but will be included in the list of recipients for the Final Report.

Table 3: DMAIC Deliverable Schedule

DELIVERABLE	DUE DATE	RECIPIENT	PHASE LEAD
Team Contract	September 17, 2015	Senior Design Teaching Assistants	Meagan Raley
Define Phase Report	October 20, 2015	Project Sponsors	Meagan Raley
		Senior Design Teaching Assistants	
		Senior Design Instructor	
Define Phase Presentation	October 20, 2015	Senior Design Teaching Assistants	Meagan Raley
		Senior Design Instructor	
Senior Design Poster	November 24, 2015	Senior Design Teaching Assistants	Fernando Cuevas
Measure Phase Report	December 1, 2015	Senior Design Teaching Assistants	Fernando Cuevas
		Senior Design Instructor	
		Project Sponsors	
Measure Phase Presentation	December 1, 2015	Senior Design Teaching Assistants	Fernando Cuevas
		Senior Design Instructor	
PACU Capacity Analytics	December 1, 2015	Project Sponsors	Fernando Cuevas
Analyze Phase Report	January 29, 2016	Project Sponsors	Darshay Blount
		Senior Design Teaching Assistants	
		Senior Design Instructor	
Analyze Phase Presentation	January 29, 2016	Senior Design Teaching Assistants	Darshay Blount
		Senior Design Instructor	
Improve Phase Presentation	February 26, 2016	Senior Design Teaching Assistants	Meagan Raley
		Senior Design Instructor	
Control Phase Report	March 31, 2016	Project Sponsors	Fernando Cuevas
		Senior Design Teaching Assistants	
		Senior Design Instructor	
Senior Design Poster	March 18, 2016	Senior Design Teaching Assistants	Fernando Cuevas
Process Improvement Plan	April 14, 2016	Project Sponsors	Fernando Cuevas
Process Maps	April 14, 2016	Project Sponsors	Fernando Cuevas
Final Report	April 14, 2016	Senior Design Teaching Assistants	Fernando Cuevas
Final Presentation	April 14, 2016	Senior Design Teaching Assistants	Fernando Cuevas

Figure 2 is a SIPOC diagram for the project process, where SIPOC is defined as Supplier-Input-Process-Output-Customer. The "Suppliers" include the Project Sponsors and Project Stakeholders who have provided information to the Project Team. The information provided is listed, respectively, in the "Input" column of the diagram. The "Process" column includes Define,

Measure, Analyze, Improve, and Control, which are the five phases outlined by the Lean/Six Sigma DMAIC process. The "Outputs" will be the deliverables requested by the Project Sponsors, and all five phase reports required by the DMAIC process. The "Customers" are those peoples or groups who will benefit from the successful completion of this project. The three customers listed in the SIPOC diagram are TMH Improvement and Planning Department, PACU Nurses, and PACU Patients. Each of these customers will receive at least one of the outputs from the project process. The TMH Improvement Department will receive the Process Improvement Plan, Process Maps, and DMAIC Reports.

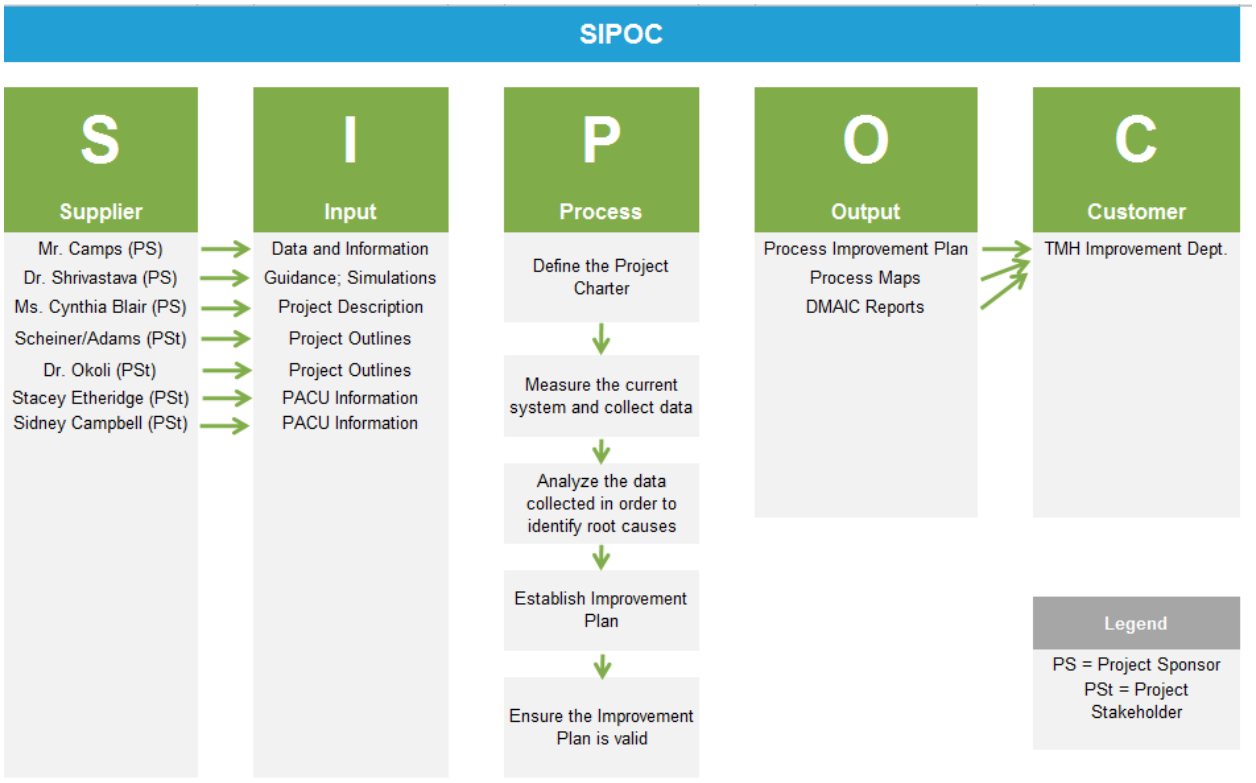

Figure 2: SIPOC Diagram

2.2.4 Milestones

Table 4 is a comprehensive list of all tasks required for each of the five phases of the DMAIC process. The Measure, Analyze, Improve, and Control Phases list the overall objective for the respective phase. These tasks have been updated with each phase report as information became

available. The tasks are representative of major milestones for each phase. The Project Team will be responsible as a whole for completing each milestone with efficiency and at a high caliber.

Table 4: Project Milestones

PHASES	TASK
Define	Identifying the team roles
	Team Contract
	Initial Project Sponsor meeting
	TMH Clearance
	Define Phase Report and Presentation
Measure	Collect electronic PACU data
	Perform initial data summary analysis
	Meetings with Project Sponsors
	Measure Phase Report and Presentation
	Analyze PACU and TeleTracking data
	Analyze nurse staff scheduling
	Observe PACU
	Create process maps
Analyze	Identify root causes and solutions
	Observe PACU
	Analyze Phase Report and Presentation
Improve	Perform Root Cause Analysis
	Suggest process solutions
	Observe PACU
	Improve Phase Presentation
Control	Create simulation to show the effects of the improvements
	Provide improvement plan to sponsor
	Control Phase Report

The Project Team made a network diagram in order to keep track of all the actions performed throughout the Define Phase. In Figure 3, all the tasks made by the Project Team with their specific

durations (days) and activity float are illustrated in order to determine which tasks need to be done at the time specified. The float numbers are represented in red, and the duration numbers are represented in black. A float number of zero means there is no flexibility in completing that task. Any integer value representing the float indicates the amount of flexibility, in days, associated with the task.

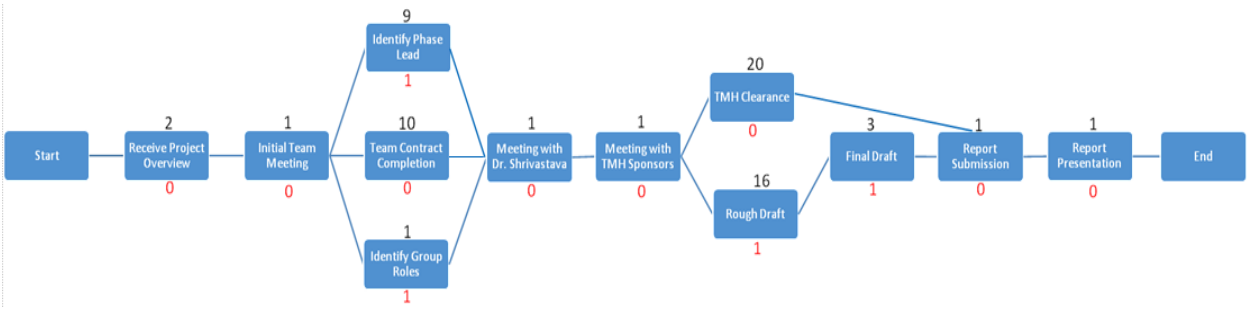

Figure 3: Network Diagram

In Figure 4, the critical path on the network diagram is identified by the yellow arrow across the various tasks. A critical path is the sequence of project activities that add up to the longest overall duration. It determines the shortest possible time to complete a project. Therefore, it is important to recognize the critical path in order to attribute importance to the various tasks in such a way as to ensure project completion.

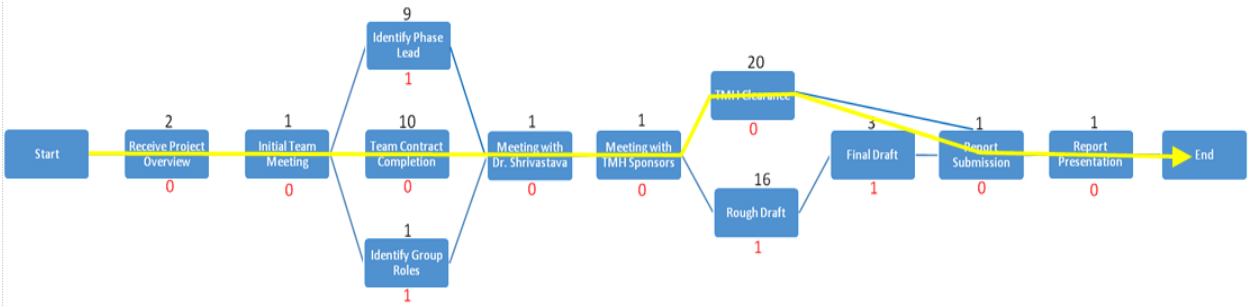

Figure 4: Network Diagram with Critical Path

Another way to keep track of all the tasks that need to be completed is a Gantt chart. The Gantt chart is a control tool that illustrates the project schedule with the start and finish dates of tasks needed to complete any project. The length of a task is represented graphically by a horizontal bar. In Figure 5 and Figure 6, the Gantt chart with all the elements needed to complete the DMAIC Phases of the Senior Design Project at Tallahassee Memorial HealthCare are shown for the Fall 2015 and the Spring 2016 semesters, respectively.

The group will use a Gantt chart for each phase to manage the tasks for that period, and relate it to the entire project. In the first level, the Define Phase, the initial tasks were taken into consideration. These tasks include receiving the project overview, completing the Team Contract, meeting with Project Sponsors, and completing the Define Phase Report and Presentation. In the second level, the Measure Phase, the main tasks associated with the phase are listed. Similarly, the third, fourth, and fifth levels of the Gantt chart outline the major tasks associated with the respective project phases. By analyzing the Gantt chart, the duration and order of tasks can be analyzed so as to appropriately schedule project tasks.

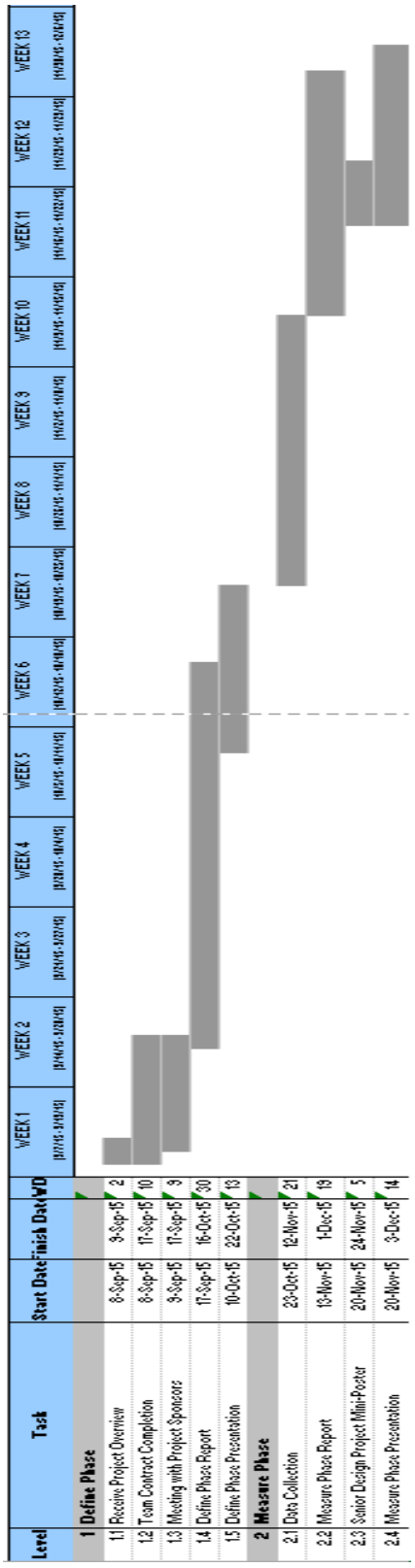

Figure 5: DMAIC Gantt Chart for Fall 2015

Level	Task	Start Date	Finish Date	VD
1	**Analyze Phase**			
1.1	Perform Root Cause Analysis	7-Jan-16	20-Jan-16	14
1.2	PACU Observations	12-Jan-16	27-Jan-16	16
1.3	Analyze Phase Report	22-Jan-16	29-Jan-16	8
1.4	Analyze Phase Presentation	25-Jan-16	29-Jan-16	5
2	**Improve Phase**			
2.1	Identify Solutions to Bottleneck	2-Feb-16	12-Feb-16	11
2.2	Create Improvement Plan	12-Feb-16	22-Feb-16	11
2.3	Meeting with Project Sponsors	2-Feb-16	26-Feb-16	25
2.4	PACU Observations	2-Feb-16	26-Feb-16	25
2.5	Improve Phase Presentation	22-Feb-16	26-Feb-16	5
3	**Control Phase**			
3.1	Provide Sponsor with Improvement Plan	1-Mar-16	3-Mar-16	3
3.2	PACU Observations	14-Mar-16	23-Mar-16	16
3.3	Analyze Possible Solutions	15-Mar-16	24-Mar-16	10
3.4	Create Process Simulation	28-Mar-16	30-Mar-16	3
3.5	Control Phase Report	28-Mar-16	31-Mar-16	4

Figure 6: DMAIC Gantt Chart for Spring 2016

2.2.5 Budget / Bill of Materials

The project sponsor specified a budget is not needed to complete the project. The team has to use the available resources in order to improve the patient flow. However, if a software solution is needed, such as updating the current software or buying new technology, then the Project Team will need to determine if the cost of the solution will be minimal compared to the revenue saved by the solution. If training will be required as part of the solution, then TMH will need to determine what funds it is willing to allocate towards new training. Then the team will justify to TMH that this solution would be worth their time and money.

The main concern the team needs to have is the increased cost of having patients in the PACU for an extended period of time. If a patient has to receive additional care, TMH has to use its own funds to cover those costs. Another major cost the team has to take into account is the nurse overstaffing cost. When there is an increase in the number of patients, the amount of nurses increases, creating an increase in staffing costs. By improving the patient flow from the operation room to PACU, the increased cost of overstaffing and additional patient care will be reduced, and TMH will save money.

3. Technical Achievements

3.1 Defining Customer & Technical Requirements

3.1.1 Customer Requirements

The customer of this project is Organizational Improvement and Planning Office of Tallahassee Memorial Healthcare. In order to explicitly identify the customer requirements, the team had two meetings at TMH. In attendance at the first meeting was Ms. Cynthia Blair, Mr. Joseph Camps, Dr. Abhishek Shrivastava, Darshay Blount, Fernando Cuevas, and Meagan Raley. The Project Team was informed about all the issues TMH is currently encountering in the main

PACU: patient flow between OR and PACU, surgeons' scheduling preferences, nurse staffing, reduced amount of beds in the PACU, and lack of communication between departments. Together, these problems create a bottleneck in the patient flow between the OR and PACU.

After meeting with the Project Sponsors and Project Stakeholders, it was determined the customer requirements are zero delays, eliminate bottlenecks, improve communication, increase availability of beds, and improve patient tracking. Addressing the customer requirements will be the main focus of this project.

3.1.2 Technical Requirements

After knowing all the customer requirements, the Project Team discussed different possible technical requirements that would allow the customer requirements to be met. These technical requirements include creating an appropriate schedule, categorizing patients, analyzing EVS scheduling, analyzing nurse staffing, and updating the computer system. The technical requirements were determined based upon what the team determined would be necessary to successfully meet all customer requirements. By incorporating these technical requirements, the process will improve in a significant way because the communication among departments will be improved.

3.1.3 Description of Process

The process to be improved is the bottlenecking experienced in the PACU. TMH is facing problems moving patients from the operating room to the PACU when patient overflow occurs, as well as moving patients to a nursing unit after they are ready to leave the PACU. It is apparent that this process needs to be improved due to the exorbitant amount of time patients are forced to wait in the PACU. The team will create a plan, using the resources available, to improve the patient flow through the PACU. These resources include industrial engineering improvement methods, such as operations research analysis, and simulation programs. The application of these techniques,

in congruence with the continued coordination of TMH Project Sponsors and Stakeholders, will allow the Project Team to accurately assess and improve the PACU patient flow. It is important to improve this process because TMH has to ensure patient safety and provide quality patient experience.

Figure 7 provides an illustration of the patient process flow. The diagram is simplified for the purposes of this report in order to illustrate the general flow a patient will follow during the course of his stay at TMH. In Figure 7, the first column of the process represents the type of procedure the patient receives, including MRI, special cases, Emergency Room cases, and surgeries performed in the operating rooms. The patient will undergo one of the aforementioned procedures, and will then be brought to the PACU. It should be noted that some patients may go directly to the Intensive Care Unit (ICU) after surgery. Once the PACU nurse determines a patient has successfully recovered from the anesthesia and all pain has been appropriately addressed, the patient is moved to his or her nursing unit. The type of nursing unit the patient is brought to is determined by what type of procedure the patient received. Another classification the patient will receive is whether the patient is "In-patient" or "Out-patient." In-patient classification indicates a patient will remain in the hospital for longer than 48 hours for observation and care, as is required by more invasive surgeries. Out-patient classification indicates the patient will stay less than 48 hours for observation, and are often sent home the same day as the procedure. If an out-patient must stay longer than 48 hours, then the patient must become an in-patient. Also illustrated in Figure 7 is the contingency of a patient being taken to the Intensive Care Unit (ICU) if he or she is deemed critical after surgery. It is important for this process to be understood because the bottleneck experienced in the PACU will influence the parts of the process before and after the PACU.

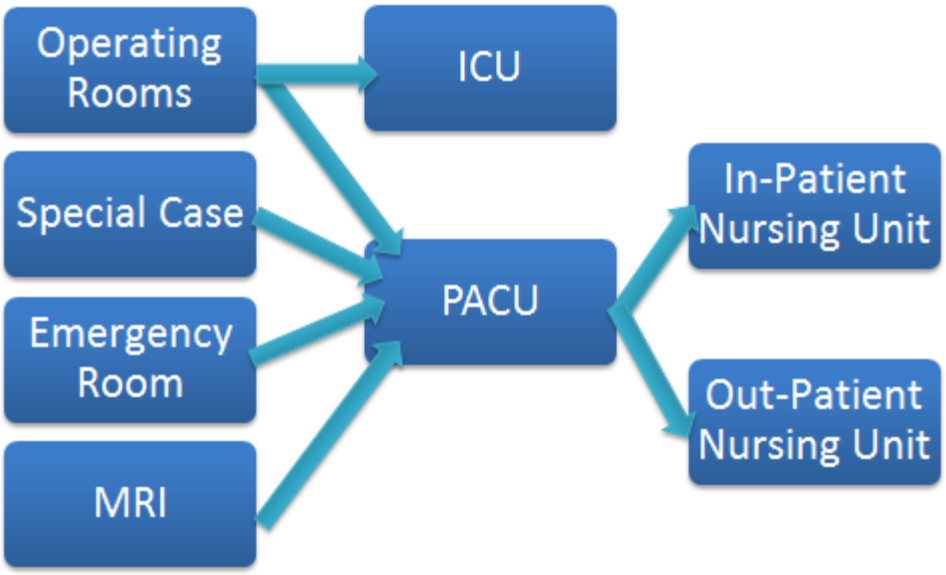

Figure 7: Process Flow Chart

In order to improve the process, TMH needs to have better communication among departments, nurse staffing, and EVS. In Figure 8, the Ishikawa diagram shows the main issues causing the bottleneck at the PACU as initially described to the Project Team by various TMH staff. The process encounters six main problems which are spatial, EVS, surgical scheduling, communication, staffing, and procedures. Along the line associated with each cause are details concerning that cause. Each of these causes contributes to the overall effect of decreased patient flow through the PACU. By identifying the causes of the bottleneck in the PACU, the Project Team and sponsors can holistically understand what is affecting the process through a visual aid.

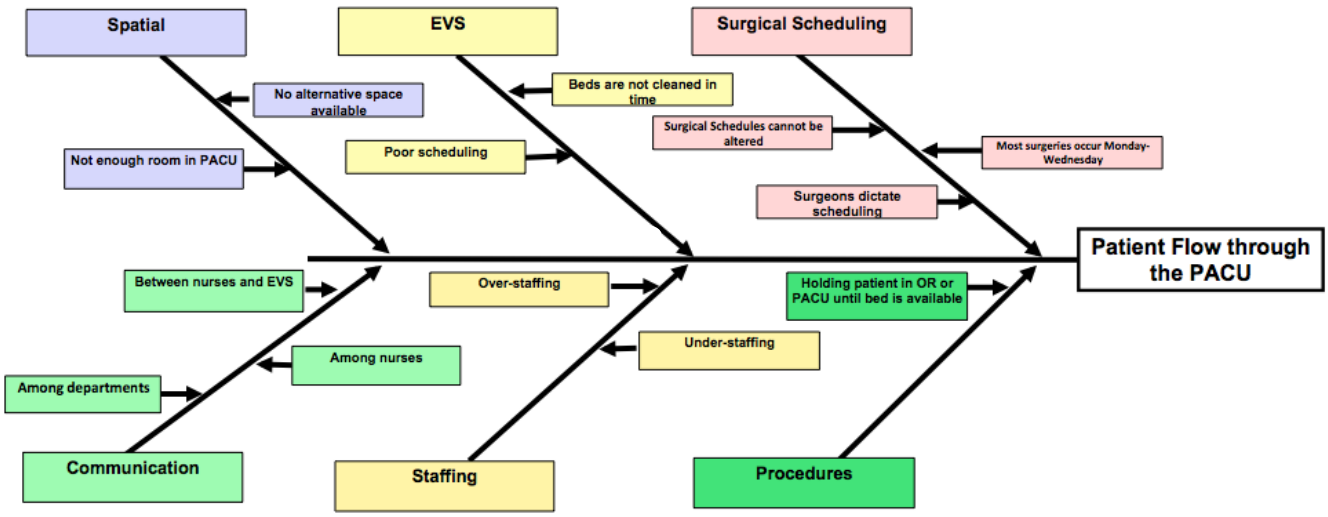

Figure 8: Ishikawa Diagram

The House of Quality (HOQ) is a diagram, resembling a house, used for defining the customer requirements and desires, together with the company's capabilities. It is a Six-Sigma tool that allows for correctly matching the customer's wants with how the company will deliver and meet them. In this project, the team used a HOQ diagram in order to identify the areas that need to be improved and the way in which those improvements can be implemented. The House of Quality matrix is shown in Appendix A. The conclusion from the House of Quality is that patient relocation is the most important technical requirement because it has the highest relative weight of 29.9. If the team is able to appropriately relocate a patient from the OR through the PACU and then to the nursing unit, the OR and PACU will not encounter a bottleneck and proper patient flow will be achieved. The technical requirement with the heaviest weight is Patient Relocation. The team investigated this factor to discover what was causing the most delays. Initially, the team believed that EVS was a major contributor to delays within the PACU. But, after observing the process and gaining a deeper understanding of patient flow the team discovered that EVS is doing their job to the best of their ability and providing clean beds in a timely manner.

A Work Breakdown Structure (WBS) is a project deliverable that organizes the tasks for each member or department working in the project. A WBS was created by the Project Team which will be referenced throughout all phases. Each WBS is divided into three main categories: Project Team, Project Sponsors, and Project Stakeholders. Each one of these categories has different tasks in order to complete the project efficiently and effectively. The WBS for this project is presented in Appendix B.

A Responsibility Assignment Matrix (RAM), in Appendix C, is a chart that describes the participation of each member in order to complete the project deliverables, goals, and tasks. To identify the type of responsibility associated with each team member, the letters R, A, C, and I will be used to represent responsible, accountable, consulted, and informed, respectively. All Project Team members, Project Sponsors, and Project Stakeholders are included.

3.2 Measuring the Baseline Performance / Design Process

The data analyzed in this report was collected using Discern Analytics, an application that enables end users to create custom data reports. The program queries and pulls data entered and stored in Cerner, TMH's Electronic Medical Record (EMR) system. In this project, two separate reports were created and merged to form a comprehensive data set. The data was pulled in this manner due to the way that Cerner organizes data in different domains. One domain contains the patients' surgical data, and the other contains data specific to the patients' stay in the PACU. The Project Team needed both surgical and PACU data for this project, so the data was collected separately and merged as described. The two data sets were joined based on the Surgery Case Number, a unique number given to each surgical encounter. The same number is linked to the patients' PACU stay.

Nurses in the OR enter data electronically in Surginet, which is an EMR module tailored for surgical areas. Both the OR and PACU contain computers that the nurses use for charting. Every time a patient receives services at TMH or its ambulatory centers for the first time, they are given a medical record number, a unique identifier for that patient for the rest of his life. Then, each time that patient has an encounter at a TMH facility, they are given a financial number (FIN), and all clinical documentation completed during that specific visit is linked to the FIN. In this way, there is both, one record for each patient and specific clinical data for each visit. Data is stored on internal databases.

TMH has software called "TeleTracking" that is used by hospitals to bring real-time enterprise visibility to patient care demand and to optimize the discharge planning process. The software also keeps track of EVS operations such as bed assigned to clean, bed ready to clean, bed being cleaned, and bed cleaned.

There is another software program called Surginet that is used by OR nurses to record surgery start, surgery end, and OR exit time, but PACU nurses do not use this system. The PACU nurses use TeleTracking to enter when the patient is ready to move (RTM) that is ready to leave the PACU. When the PACU nurse hit the RTM button, it alerts patient placement that this patient needs a nursing unit bed assigned. TeleTracking only provides visibility for patients who are assigned a bed after surgery; if the patient had a nursing unit bed before surgery, their data will not show up in TeleTracking.

The Project Team analyzed patient volume, transportation times, and time lapse in the PACU. This was done by generating histograms, box and whisker plots, and various tables, which are displayed in Appendix D. The Project Team analyzed the data in order to determine the current

state of the PACU, and potentially determine any attributable causes for the delays experienced in the PACU. The following conclusions were made based on this data analysis:

1. Patient volume is distributed relatively well between Monday and Friday, with the weekends showing a significant drop in patient volume. This is in contrast to the original hypothesis presented to the Project Team that the surgeons were scheduling the majority of surgeries on Monday, Tuesday, and Wednesday.
2. Patient volume is evenly distributed throughout the year.
3. There are more out-patients than in-patients at the end of the week because patients will be discharged by the weekend (due to the fact that out-patients will only stay in the hospital less than 48 hours). There are more in-patients than out-patients on Monday and Tuesday, as well as on Saturday and Sunday. Having more in-patients on the weekend may contribute to delays on Monday and Tuesday because in-patients must stay longer than 48 hours.
4. The three surgery types that experience the highest patient volume are General Surgery (2,302 patients), Neurological Surgery (1,625 patients), and Orthopedic Surgery (2,445 patients). This may lead to back-ups in the Nursing Units designated for these surgery types. However, the various surgery types are generally well distributed throughout the week.
5. The three Nursing Units that experience the highest patient volume are 3A: PostOpCare, 4A: Outpatient, and 6A: Orthopedic.
6. The PACU Length of Stay (LOS) and the Surgery Type are not correlated.
7. The PACU LOS and the Nursing Unit have a positive correlation. This is because a main source of delay is not having a room available for the patient.

8. Transportation from the OR to the PACU is not a source of delay.
9. The average PACU LOS tends to be between 60 minutes and 90 minutes. There are a significant number of outliers that experience much longer LOS times, with the longest PACU LOS at approximately 9 hours.
10. The average PACU LOS is generally the same throughout the week, but all days experience a surplus of outliers.
11. Many errors were found throughout the data. The data collection system must be improved in order to more accurately determine attributable causes in the system.

3.3 Identifying the Root Causes / Component Testing

The observations, staff interviews, and data analysis were the basis for the Project Team's Root Cause Analysis. In order to accurately depict the various factors that contribute to the bottleneck of patients not leaving the PACU, the Project Team made an Ishikawa Diagram, displayed in Figure 9. The Ishikawa diagram includes seven major factors that cause patients to not leave the PACU: the PACU layout, communication, BedBoard, capacity, discharges, errors in system use, and surgical scheduling. Each of these factors will be discussed in the following subsections. The discussion will include a description of the factor, whether or not the team is able to improve it, and if so, how the team will improve it.

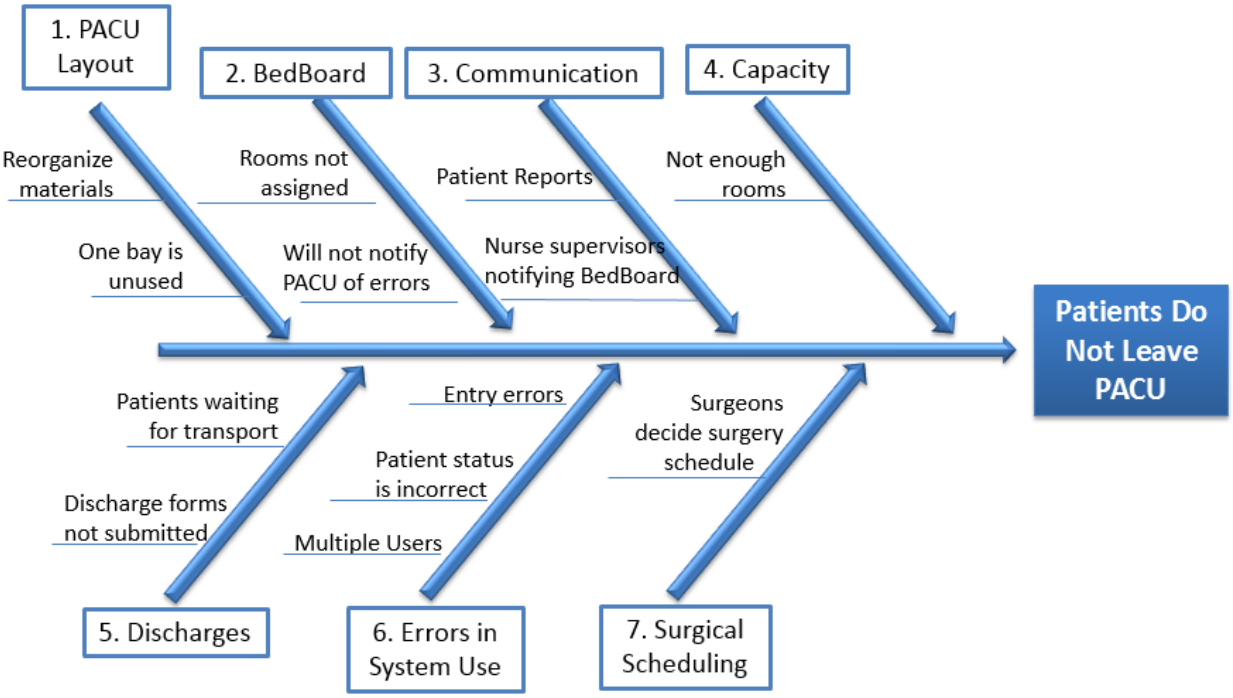

Figure 9: Ishikawa Diagram of Factors Causing Patients to Not Leave PACU

3.3.1 PACU Layout

In the main Operating Room PACU, there are 14 "bays" in which a patient's stretcher can be placed while the patient receives treatment in the PACU. Each PACU nurse is charged with caring for two patients, simultaneously. The PACU nurse uses one computer that is placed between the two bays. There is one bay in the PACU that is currently being used as a storage area for various supplies. The Project Team believes that reorganizing the PACU so that this bay can be utilized will help to alleviate the bottleneck. This is because an additional patient would then be able to stay in the PACU.

3.3.2 BedBoard

BedBoard is a department at TMH that is responsible for assigning patients to a bed in the various nursing units throughout the hospital. During staff interviews, the Project Team found that room assignments is a major issue for all nursing units. The PACU nurses often hold patients for

one to two hours while waiting for a room assignment. Additionally, the Project Team was told that BedBoard will not assign a room if the patient's transfer information was not submitted correctly, which leaves the PACU nurses waiting indefinitely until they call BedBoard to ask about the room. Thus, the Project Team has determined room assignment to be a significant factor in the PACU bottleneck. However, the Project Team and project sponsors have determined that room assignments are out of the scope of this project. While analyzing the way in which rooms are assigned may be significant for future work, it will not be analyzed for this project.

3.3.3 Communication

During the Project Team's observations of the PACU, there were various communication problems throughout the process. The two main communication problems are patient reports and room status updates.

When a patient is brought to the PACU, one of the operating room nurses verbally gives a report to the PACU nurse regarding the patient's medical history and status, including such things as allergies. When the patient is ready to leave the PACU, the PACU nurse then calls the nursing unit to which the patient is assigned and verbally relays the patient's medical information. Upon conducting staff interviews, the Project Team found that the PACU nurses are often placed on hold by the nursing unit for upwards of 30 or 45 minutes before the PACU nurse can give the patient's medical information. The Project Team believes this system of communicating patient information could be improved and would assist in moving patients out of the PACU more efficiently. The Project Team suggest automating this system by sending medical information over a secure server. Automating the transfer of medical information would not only reduce waiting time, but also reduce the risk of errors in the report.

The other main communication issue occurs during the room assignment process. When a bed in the nursing unit is being cleaned and when it is ready to be occupied, the nurse supervisor

of the nursing unit calls BedBoard to tell them the status of the room. This is a potential source of delay because a nurse supervisor may not immediately recognize that a room is available. The Project Team suggests having one nurse assigned to regularly check the status of all rooms and notify BedBoard of those statuses. Another option would be to have an integrated system so that BedBoard would have automatic updates on the status of a room, which would eliminate the need for a nurse to make a phone call to BedBoard.

3.3.4 Capacity

The nursing units that receive the highest patient volume are 3A, 4A, 4N, and 6A (as indicated by the data). From interviews with TMH staff, the team learned that these nursing units often run at capacity, or close to capacity. However, the Project Team does not have the ability to alter the layout of the hospital, therefore will not focus on this factor.

3.3.5 Discharges

During staff interviews, the Project Team learned that getting a patient discharged is often a long process. This is because of the various release forms which must be signed and submitted by the doctor, and other factors such as patients waiting for their transportation to arrive. The amount of time it takes for a patient to be discharged from the hospital affects PACU length of stay because the patient remains in the room before they leave. The patient is no longer receiving any care so the room could be able to be used for another patient, but cannot because the first patient is still there. The various facets of getting a patient discharged are beyond the scope of this project as they are out of the control of the Project Team.

3.3.6 Errors in System Use

TeleTracking is the software system used by the PACU nurses, EVS, and floor nurses to track the transportation and status of patients. Since the system is used by various people throughout the hospital, different people have access to information and may understand it

differently. The user interface, as noticed by the Project Team during observations, is not user friendly and is difficult to navigate. As discussed in section 4.3 of this report, many errors were found in the data, such as a patient arriving in the PACU before he left the OR. The Project Team has determined that some of these errors are most likely accidental errors due to the multi-tasking a nurse must perform constantly. Additionally, the Project Team learned the nurses will sometimes enter into the system that a patient is "ready to move" as soon a patient enters the PACU in order to expedite the process of getting the patient a room. Since the nurses are not always using the system appropriately, some of the data has been diluted. In order to address all these system usage errors, the Project Team proposes for PACU nurses and floor nurses to receive more training in the use of the computer system. Ideally, TMH could utilize a new, updated program. The program should be user-friendly so as to accommodate all levels of computer-literacy. However, implementing a new program may be costly, so training may be a more feasible solution.

3.3.7 Surgical Scheduling

Currently all surgeries are scheduled by the surgeons. The current schedule effects the PACU length of stay because when there are more surgeries, there are more patients going through the PACU. Due to various factors in the hospital, the high volume of patients corresponds to the bottleneck in the PACU. The surgical schedule could be re-designed so as to promote more efficient patient flow. However, surgeons are granted permission by TMH to schedule surgeries according to their preference, and the Project Team has no way of influencing the way in which surgeries are scheduled. Thus, surgical scheduling is beyond the scope of this project.

3.4 The Improvement Plan

During the course of this project, the Project Team realized that the data provided by TMH is limited because it only provides time stamps. Essentially, the Project Team can only identify the length of delay, and not the attributable causes. This has led the Project Team to estimate the largest factors of delay in the PACU based on observations and staff interviews. From the root cause analysis the Project Team identified three causes to the PACU bottleneck within the scope of the project: PACU layout, communication, and errors in computer system use. To mitigate these issues, the Project Team proposes an improvement plan that will include a redesign of the PACU bed bay, training PACU nurses, automating patient reports. The Project Team is also suggesting a future senior design project to further improve the process due to the room assignment methodology being beyond the scope of this project. To obtain optimal results, TMH should implement all four solutions.

3.4.1 PACU Layout

The current PACU layout consists of eight columns that house the materials needed to care for a patient; yet only seven of these columns (which allows for two patients each) are being used for patient care. There is space for 16 bays, or spaces for beds, within the PACU. One is blocked off and the other is by the unused column. In Figure 10, two pictures show the current state of the two unused bed bays. While there are various supplies being stored in these areas, it can be seen in Figure 10 (b) how there the current shelving is not being fully utilized. This suggests there is opportunity for re-evaluating the way in which supplies are being stored. By redesigning the PACU, one to two additional bays can be made available for use within the PACU, enabling the treatment and care for more individuals. To implement this improvement, TMH can reorganize the storage from one unused bay to the other, or create shelving on an unused wall in the PACU and organize the materials needed there. The first solution would only open up one bay and is easier

to implement. The second solution would release both bays, but would cost more regarding time and money. TMH will need to evaluate which solution is feasible based upon the resources they are willing to allocate for the solution.

(a) (b)

Figure 10: (a) Picture of Bed Bay 6 in PACU, and (b) Picture of Bed Bay 9 in PACU

3.4.2 Training PACU Nurses

Post-Anesthesia Care Unit nurses need additional training on the computer systems in use within the hospital. Having all of the nurse staff receive adequate training on the computer software would eliminate data entry errors and reduce wait time. The data entry errors would be virtually eliminated because nurses will know how to input and understand the information they are receiving. Wait time will be reduced because nurses waste time inputting information they receive into the computer because they do not know how to efficiently use the system. To retrain the nurses on the computers, TMH would have to pay nurses for their time spent in training instead of caring for patients. Limited training modules can be found online [3] but an in-depth training package

can be purchased from TeleTracking. TMH could have their PACU nurse staff complete the training on days they were not scheduled to work in order to ensure patient needs are still met. This solution may be met with some contention from the nurse staff to have to give up one of their off days for training.

3.4.3 Automate Patient Reports

Currently, the OR nurses are verbally giving the patient reports to the PACU nurses. After the PACU nurse receives the information from the OR nurse, they relay the information to the various nursing units via telephone. This method not only wastes time but also has a large margin of error. While multitasking at a hospital, nurses are not actively listening to the information they are receiving on the phone. This causes them to not relay all of the information to the nursing unit. By having the patient reports sent electronically wait time will decrease as will the possibility of patient report errors.

To implement this solution TMH would need to obtain a secure server and multiple printers. The printers would need to be able to access the secure server and having scanning capabilities. TMH would need to purchase one printer for the PACU and a printer for each of the various Nursing Units located throughout the hospital. In order to ensure security, the printers would need to be connected to an external scanning device. This scanning device would operate by only allowing access to the printer once the nurse has scanned his/her badge. The scanner would be similar in function to the scanners placed at doorways throughout TMH, and would be activated by the badges which are already carried by the nursing staff. The new reporting system would operate as follows:

1. The OR Nurse would bring the hardcopy of the patient report to the PACU when the patient is brought to the PACU

2. Once the patient has received treatment and is ready to be transferred to his/her assigned Nursing Unit, the PACU Nurse will scan in the patient report.
3. The patient report will be digitally sent to the appropriate Nursing Unit.
4. The hardcopy will be kept with the patient until the patient is brought to his/her assigned Nursing Unit room.

3.4.4 Analyze Room Assignment Methodology

During the course of this project, the Project Team realized that the data provided by TMH is limited because it only provides time stamps. Essentially, the Project Team can only identify the length of delay, and not the attributable causes. This has led the Project Team to estimate the largest factor of delay in the PACU based on observations and staff interviews. The Project Team has determined the largest source of delay currently affecting the PACU is the room assignment methodology. The room assignments are made by "Bed Board," and serve to assign a patient to a particular room in a Nursing Unit, based on the type of procedure the patient underwent. The team suggests that the room assignment methodology should be its own project in the future. This would enable a future senior design team to develop a lasting solution to the PACU bottleneck instead of a temporary one. Creating a new method to assign rooms will prevent bottlenecking from happening in the current PACU and the new building being planned by TMH. This project would act as a supplement to this one by addressing the main issue causing the delays.

3.5 Controlling Process Improvement

For the purposes of this project, the Project Team was unable to implement the Improvement Plan because the types of improvements that need to be made are beyond the immediate ability of the team. For example, one improvement suggestion is to provide better/more training for PACU Nurses in order to facilitate more efficient usage of the current computer system. However, the Project Team does not have the authorization or the training to provide

instruction for the nurses. Therefore, TMH will be responsible for implementing the improvement suggestions outlined in the Improvement Plan (Chapter 6). The Project Team is unable to compile a Standard Operating Procedure or Operations Manual because the Project Team is unfamiliar with the various procedures already in place which the staff must adhere to. It will be the responsibility of the TMH managers to develop and incorporate a Standard Operating Procedure or Operations Manual once they have implemented the improvement suggestions.

If the improvements to the process are expected to become a permanent part of the daily operating procedure at TMH, then the PACU Nurse Managers must take the lead in not only implementing the changes, but also ensuring the other PACU Nurses are committed to the improvements. The PACU Nurse Managers will be responsible for the cultural change in the PACU because they are the most senior level staff members who are almost constantly in, or near, the PACU. While the improvement suggestions made by the Project Team will not significantly alter the daily functional habits of the PACU Nurses, it will still require adjustment and commitment so as to ensure the improvements become the standard. Possible problems that may arise upon the implementation of the Improvement Plan are outlined as follows:

1. PACU Layout: A risk for this improvement suggestion would be if the storage adjustments are not done correctly, the nurses may experience difficulty in finding/reaching various supplies. This is most likely a low-probability risk since TMH has performed "5S" projects, or workplace organizational improvement projects, in various parts of the hospital. A potential barrier to this improvement is the reluctance by TMH executives to allocate funds for the possible purchase of storage/shelving. Another potential barrier is the resistance by management to provide nurse staffing for the bed bay(s) which would become available.

2. Training PACU Nurses: There is no apparent risk in providing training for the PACU Nurses. By providing training for nurses, TMH only increases the likelihood of the nurses being able to successfully and efficiently utilize the computer software. A potential barrier for this solution is the reluctance of managers to provide the necessary training due to funding or time constraints.
3. Automate Patient Reports: A risk for this improvement suggestion is the potential for personal patient information to be accessed by those without clearance or permission. However, the Project Team has attempted to diminish the probability of this happening by incorporating into the Improvement Plan various security measures, such as a scanning device for access to the printers. A potential barrier to this improvement suggestion is unavailable funding to purchase the necessary technology.
4. Analyze Room Assignment Methodology: The potential risk for this improvement suggestion is if another senior design team is unable to perform a DMAIC project on room assignment methodology, then the problem may continue to persist, if not worsen. It is imperative that TMH take the necessary steps to improve the room assignment methodology; otherwise the problems in the current system will only transfer to the next system once the new building is completed. A potential barrier is the FAMU-FSU College of Engineering Industrial and Manufacturing Engineering Department and TMH being unable to coordinate the future project.

If TMH provides appropriate training for the PACU Nurses, as the Project Team suggests, then there will be a reduced risk of data entry errors, and an increased likelihood of consistent data records being entered. By ensuring the nurses are able to operate the software, the data recorded by the system will inherently be more accurate and comprehensive. Having accurate data will

allow TMH to better understand and analyze the current process state. Until TMH improves the way in which data is entered into the system, TMH will continue to be unable to appropriately identify the factors hindering patient flow through the hospital.

4. Business Analysis

4.1 Economic Analysis

The bottlenecking occurring within the PACU causes TMH to incur extra costs. Holding patients in the room while waiting for them to be discharged or moved to another room cost the hospital money. When the backup of the PACU causes the operating rooms to be held up, scheduled surgeries have to be rescheduled. Surgeries and operations are how TMH makes most of its money, if patients start cancelling their operations and going to a different hospital to receive care, the hospital will have a decrease in profits. Studies show that PACU expenses "may be 35% or more of OR costs" [4] . When patients spend more time in the PACU, the hospital has to pay for those extra costs. Improving efficiency can reduce the required PACU staffing ratios and the need for supplies. The average salary for a PACU Registered Nurse is $89,000 in Florida [4]. By reducing the number of patients remaining in high level PACU care, the hospital can employ fewer PACU Registered Nurses and save money.

4.2 Environmental Impact

Improving the patient flow through the PACU does not have a positive or negative effect on the environment. This is because the process involves reorganizing people and the way they perform a task instead of utilizing materials that may impact the environment.

4.3 Ethical Considerations

The staff at TMH may not comply with the new process. They have a culture of completing processes in the way that the individual considers best. By creating a standard process for the main PACU, older employees may resent the changes and use their own methods instead. This would cause issues within in the hospital if something were to go wrong when the employee deviates from the standard process. For example, if a lawsuit were to arise from an incident in the hospital, the hospital could say that their employees were using a standard process, but if the employee just does as they see fit, the hospital will not be able to support them in the courts. This would cause the hospital to lose money, by having to pay the lawsuit.

4.4 Health and Safety

According to the Occupational Safety & Health Administration (OSHA), hospitals are one of the most dangerous places to work. In 2013, hospitals in the United States recorded "6.4 work-related injuries and illnesses for every 100 full time employees" [5]. To ensure that health issues are not a problem, the Safe Patient Handling policies will have to be followed. If workers are injured during work, it cost the hospital directly and indirectly. Indirect effects of workplace injuries include an increase in "employee turnover, training, overtime, incident investigation time, productivity, and morale." Studies show that the cost of replacing a nurse can cost between "$27,000 to $103,000 per nurse" [6]. To avoid these extra costs, when transporting patients to different areas, nurses need to be using the safest techniques for handling patients. At TMH, patients have to be transported from the PACU to different areas of the hospital based on their conditions. Minimizing the delays in the PACU will cause the staff to not be rushed when transporting patients, resulting in safer patient handling techniques.

4.5 Social and Political Considerations

The culture at Tallahassee Memorial affects the day to day operations of the hospital. The senior design team plans to improve the computer system used in the hospital. Currently, nurses call each other on the phone to discuss patient details; having an up-to-date system will help eliminate time and ensure that all patient details are accurately recorded. The TMH culture has a lot of verbal communication, but updating the computer system will eliminate the need for some of this. Therefore, the team has to be able to convince staff that communication will be more effective nonverbally. As a result of the improvements, relationships between different parts of the hospital, such as EVS, PACU nurses, and managers, will remain the same if not improve. This is because by having an electronic system, there will be less miscommunications so problems that arise from those situations will occur less frequently.

4.6 Sustainability

The solution to the bottleneck occurring within the main PACU is not meant to be a long term solution. The results of this project are meant to be a temporary solution until the new tower for the hospital is completed. The new tower will hopefully be fully completed in 2020, so the project results are meant to last for the next five years. To ensure that the results will last until then, the senior design team will plan the project results for the hospital's projected growth. Instead of designing the problem to meet current demand, the team will design the process improvement plan to meet future demand.

5. Project Success

The project with Tallahassee Memorial HealthCare was successful because all deliverables (Improvement Plan, Process Flow Chart, and Patient Flow Chart) for the Project Sponsors were completed and four solutions were obtained. While the Project Team did not implement the

solution suggestions, the Project Team was able to determine the exact steps TMH would need to implement, should they choose to. The Project Team determined the primary cause of delays in the PACU are not caused by the process within the PACU, but rather because of the current room assignment methodology implemented by Bed Board. This is a major finding because prior to this project, the root cause of the delays was unknown. All assumptions and conclusions are believed to be valid because they were derived explicitly from the data, observations, and staff interviews. One assumption the Project Team made while detailing the Improvement Plan was that TMH would be able to afford the suggested improvements. If this were found to not be true, then the Improvement Plan would need to be refined in order to accommodate the new budget. In order to accurately determine the validity of the improvement made by the Project Team prior to implementation, a simulation of the process in the Arena software would need to be created. While the Project Team was unable to simulate the complexities of the current process, the Project Team was able to determine that Arena is a viable software package for simulating the system. A major future suggestion made by the Project Team is for TMH to sponsor a Senior Design Project in which students would analyze the room assignment methodology. This future project is essential to decreasing the amount of time a patient must spend in the PACU.

6. Conclusion

The main Operating Room PACU at TMH is currently exceeding capacity throughout the week. Once the PACU is at capacity, there is a backup throughout different areas of the hospital. The team was tasked with analyzing the bottleneck and finding the root causes and possible solutions to the issue. The issue presented to the team was determined to be one that can be improved through the use of the DMAIC Process.

During the Define Phase, the team worked to understand the goals and deliverables required by the Project Sponsors and Project Stakeholders. The team brainstormed different causes and solutions to the issue facing the PACU. The team decided to speak with EVS employees to discover a way to alter their bed cleaning schedule, so patients will not have to wait hours for a clean bed. The team determined a need to obtain electronic data for patient tracking to understand PACU length of stay, where the patients are going after leaving the PACU, and how long each step in the process takes. The Ishikawa Diagram shows the main issues causing the bottlenecks at the PACU, and the House of Quality showed that analyzing EVS scheduling and moving the patients through the hospital are the most important factors to consider.

Throughout the Measure Phase, the team analyzed data provided by the Project Sponsor. The team was able to gain an understanding of the different variables that affect patient throughput in the PACU. During this phase, the team was able to meet with EVS managers and gain exposure to the TeleTracking system. This meeting showed that TMH has a way to track and manage the amount of time patients are spending in different locations. The data shows that the majority of patients come from Orthopedic, General, and Neurological surgeries. Observing the histograms and boxplots of PACU length of stay for patients from these surgeries, shows the data is skewed to the right. The majority of time spent in the PACU is normal, but there is an exceedingly large number of outliers which increase the average length of stay. This pattern is evident in all of the data analyzed in this report. Despite initial statements made by the project sponsors, patient volume is distributed relatively well throughout the week days. This led the Project Team to investigate other correlations among the data. The team also noticed while performing basic analysis of the data that there were many errors and discrepancies that showed that the employees may not be using the current system correctly or efficiently.

In the Analyze Phase, the team performed further analysis on the PACU data. This allowed the team to discover the root causes of the PACU delays. The team investigated the causes of the large number of outliers observed and discovered that many were due to user error, meaning most of the large time variables were due to incorrect information being input into the system. On several occasions, the team visited TMH, observed the PACU, and spoke with PACU nurses about the current process. Through these visits, the team learned that the EVS cleaning schedule is not a factor to the delays in the PACU.

During the Improve Phase, the Project Team produced a solution to deliver to the project sponsors. Based on the root cause analysis on the PACU process, the Project Team identified seven main contributors to the PACU bottleneck, but acknowledged that only three are in the scope of this project. Therefore the team considered options to improve communication by automating the patient reports, redesign the PACU layout, and train nurses on the current software. In this phase, the team created the process improvement plans, system flowchart and patient flowchart to present to the sponsors and stakeholders.

The Control Phase is the final phase of the DMAIC process of improvement. In this phase, the Project Team continually corresponded with the project sponsor, Mr. Camps, to understand what he needed from the project. Using information provided by Mr. Camps, the team was able to complete a simulation that shows the effects of adding additional bays to the PACU. Throughout the project, the team observed that the current method of assigning patients to rooms is flawed. For a future project, the room assignment methodology should be analyzed and changed so TMH will not incur the same issues after moving to the new facility.

7. References

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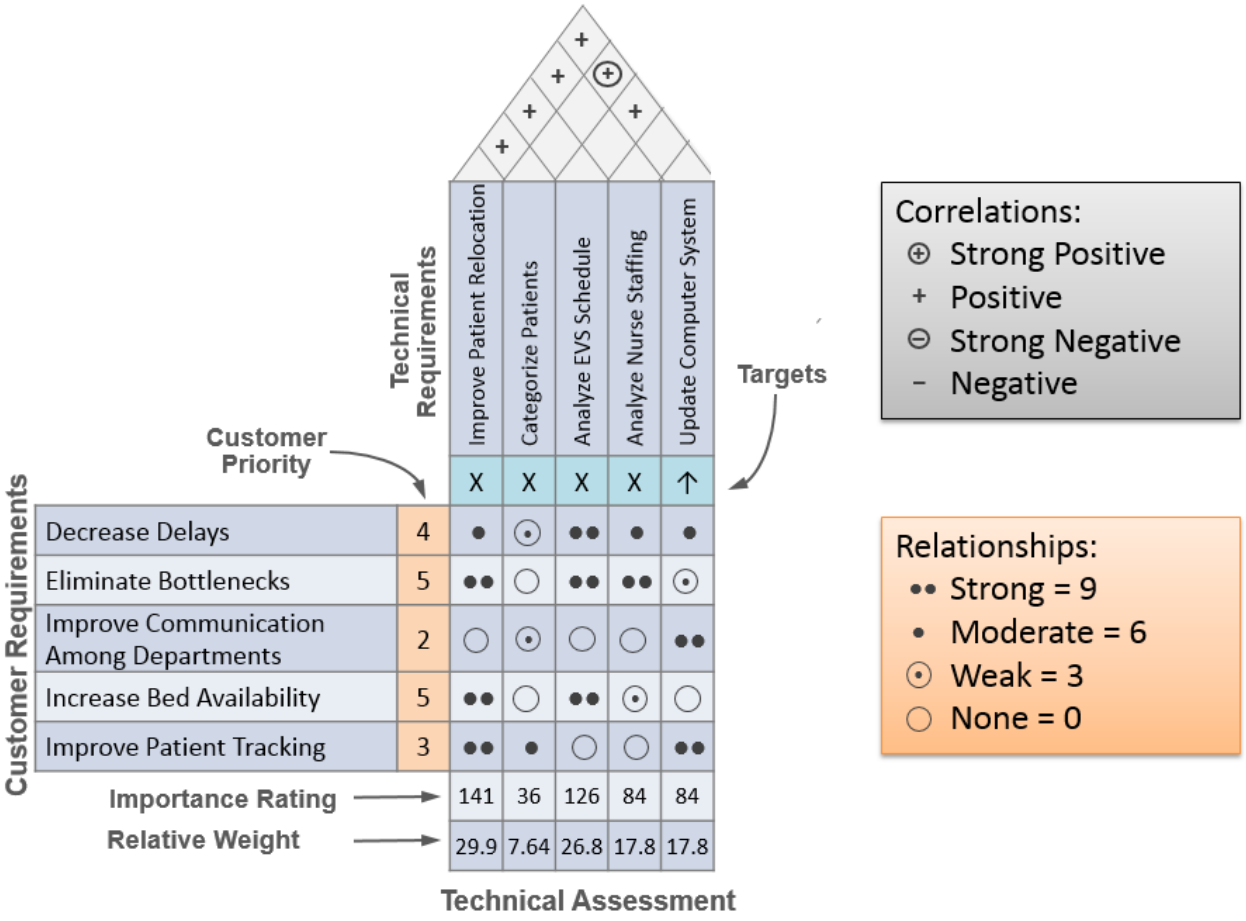
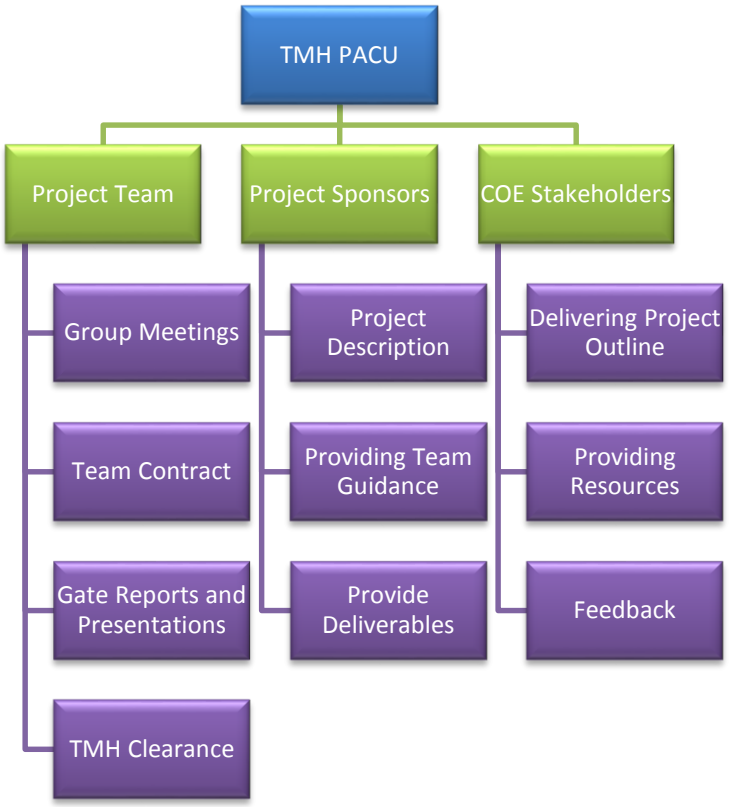
Appendix A: House of Quality Matrix



Appendix B: Work Breakdown Structure



Appendix C: Responsibility Assignment Matrix

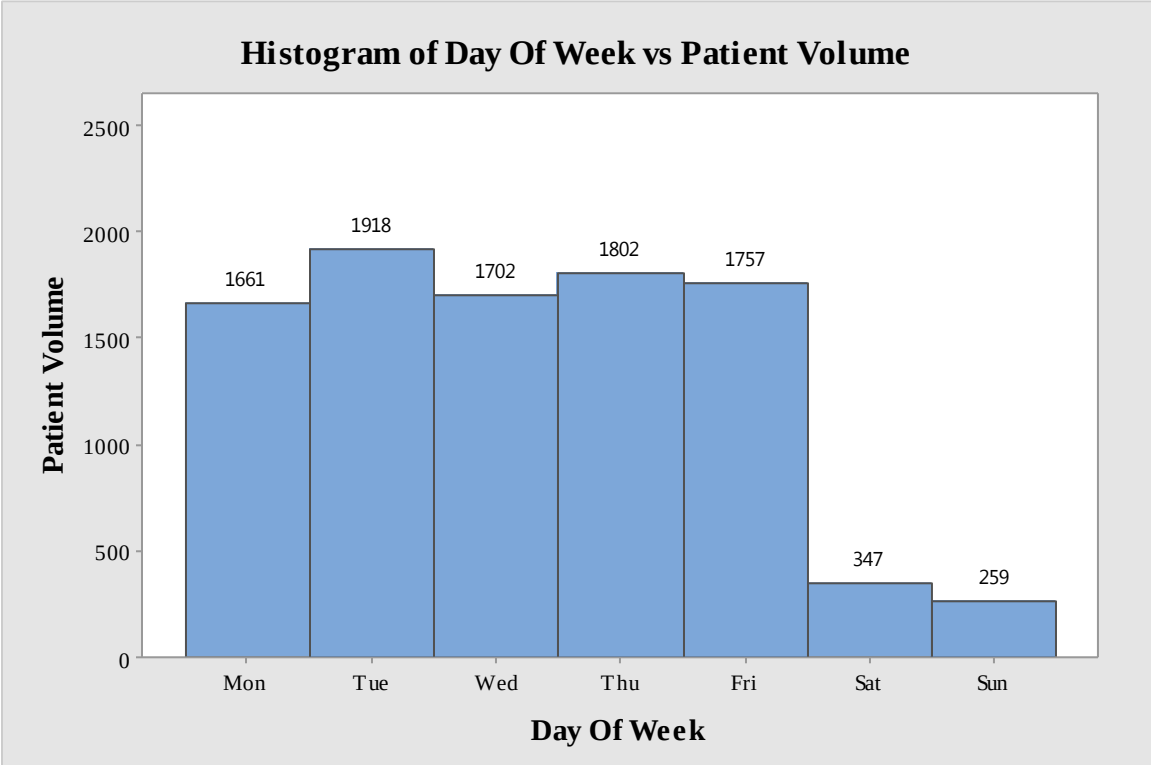
Project Member	Darshay Blount	Fernando Cuevas	Meagan Raley	Joseph Camps	Cynthia Blair	Abhishek Shrivastava	Okenwa Okoli	Ryan Adams	Margaret Scheiner
Title	Project Team	Project Team	Project Team	Project Sponsor	Project Sponsor	Project Sponsor	Stakeholder	Stakeholder	Stakeholder
Group Meetings	A	A	R			C		I	I
Team Contract	A	A	R				I	C	C
Define Phase Report	R	R	R	C	C	C	I	C	C
TMH Clearance	R	R	R	C	I				
Data Collection	R	R	R	A		C	I	I	I
Initial Data Analysis	A	R	A	C		C	I	I	I
Measure Phase Report and Presentation	R	R	R	I	I	C	I	C	C
Poster Presentation	A	R	A			I		C	C
Providing PACU Data	C	C	C	R	A	I			
Project Description	I	I	I	R	R	I	I	A	A
Providing Team Guidance	I	I	I	C		R	R	R	R
Provide Deliverables	I	I	I	R	R	C	I	A	A
Delivering Project Outline	I	I	I				C	R	R
Providing Resources	I	I	I	R	C	R	R	R	R
Feedback	I	I	I	C	C	C	C	R	R

Appendix D: Data Analysis

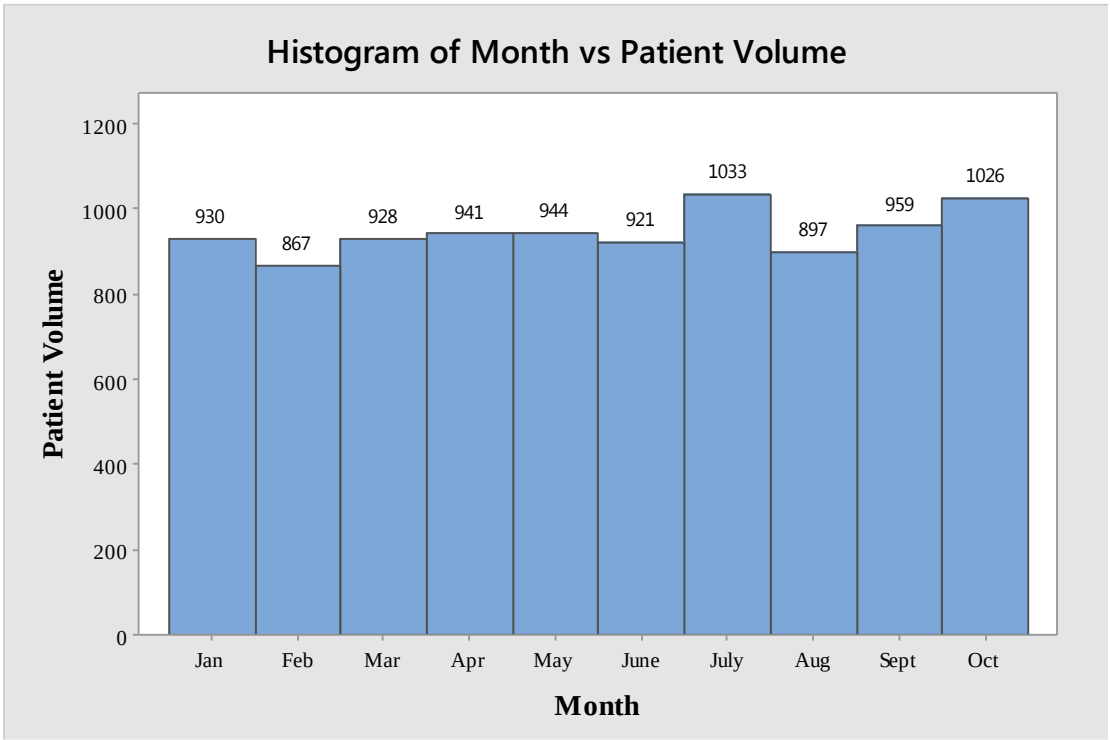
Data Field Descriptions

Data Field	Data Field Description
Surgery Stop Time	Time at which surgery was finished/incision closed
OR Exit Time	Time at which patient exits the OR (in route to PACU)
Time Lapse - Surgery Stop to OR Exit	Time patient spent in the OR after the surgery ended prior to exiting the OR (OR Exit minus Surgery Stop)
PACU Time In	Time patient entered the PACU
PACU Time Out	Time patient left the PACU
Time Lapse - PACU Length of Stay (LOS)	Total time patient spent in the PACU (PACU Out minus PACU In)
Time Distribution - PACU LOS	Range of time spent in PACU in 1 hour increments.
Day of Week	Day of week patient entered the PACU
Month	Month patient entered the PACU
Year	Year patient entered the PACU
Surgical Specialty	Type of surgical case that was performed
Nursing Unit	Hospital unit that patient stayed in after exiting PACU (i.e. 4A, 6A, etc.)

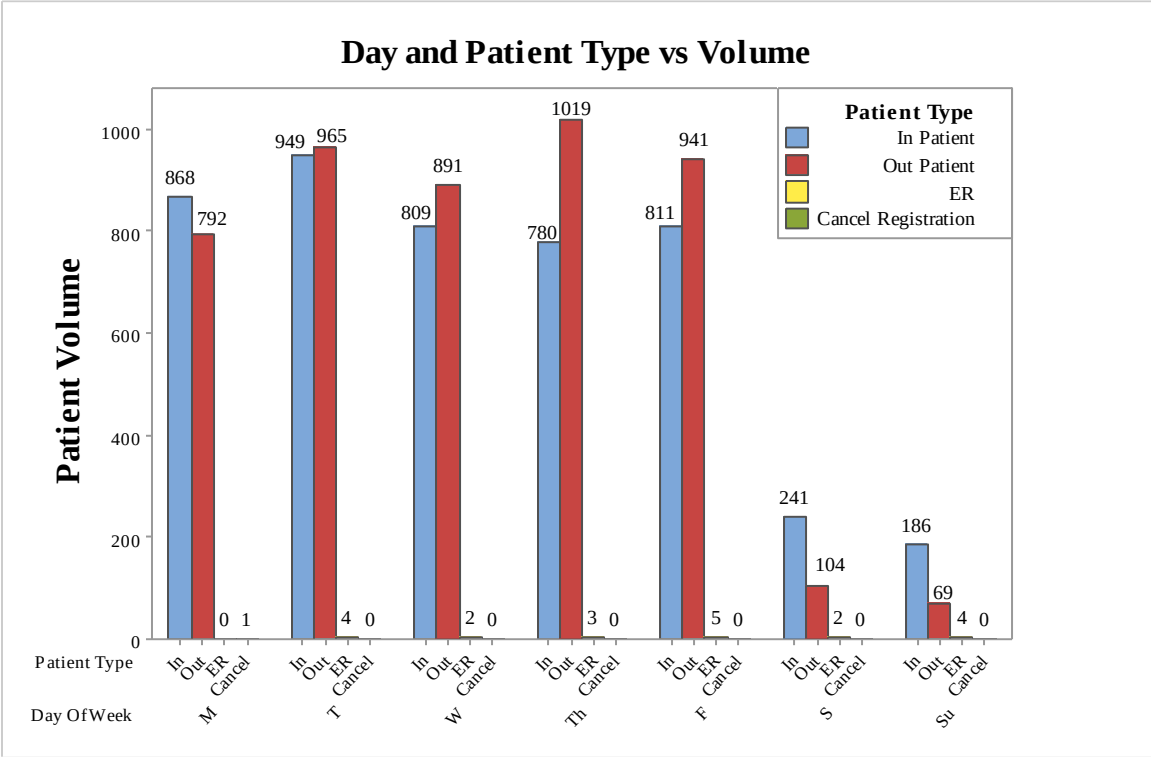
Patient Volume by Day of the Week



Patient Volume by Month



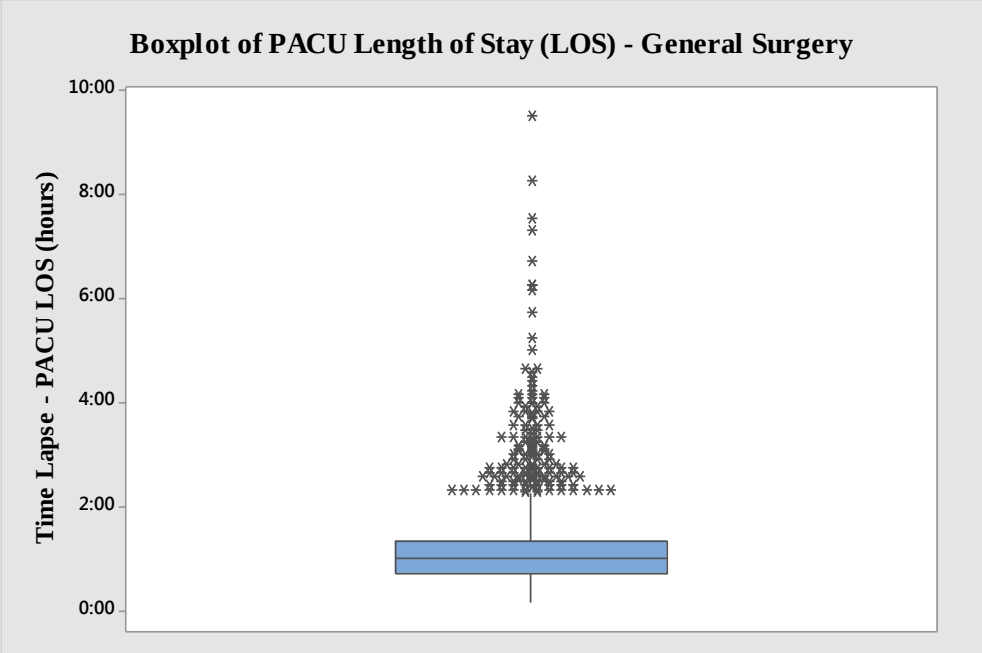
Patient Volume by Type and Day



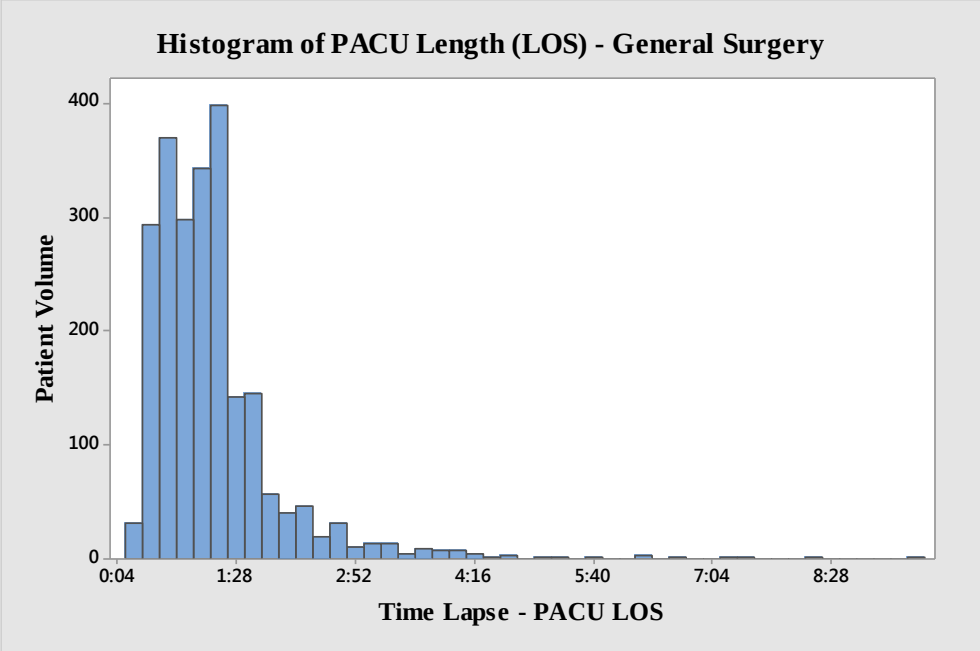
Patient Volume by Surgery Type and Day

	Days							
	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total
Cardiovascular Surgery	39	54	46	64	43	11	6	263
Gastroenterology				2				2
General Surgery	442	291	423	410	535	122	79	2,302
Neurological Surgery	308	375	337	303	257	26	19	1,625
Obstetrics/Gynecology	101	57	176	125	45	16	8	528
GYN ONC				3	1			4
Ophthalmology	3	1	3	151	69	7	4	238
Oral Surgery	2	113	2	8	4	13	11	153
Orthopedic Surgery	532	671	418	258	402	91	73	2,445
Otolaryngology	6	8	8	5	6	5	8	46
Plastic Surgery	82	94	37	147	75	20	13	468
Podiatry	1			1		2		4
Urology	127	67	128	71	73	20	21	507
Vascular Surgery	18	187	124	254	247	14	17	861
Total	1,661	1,918	1,702	1,802	1,757	347	259	9,446

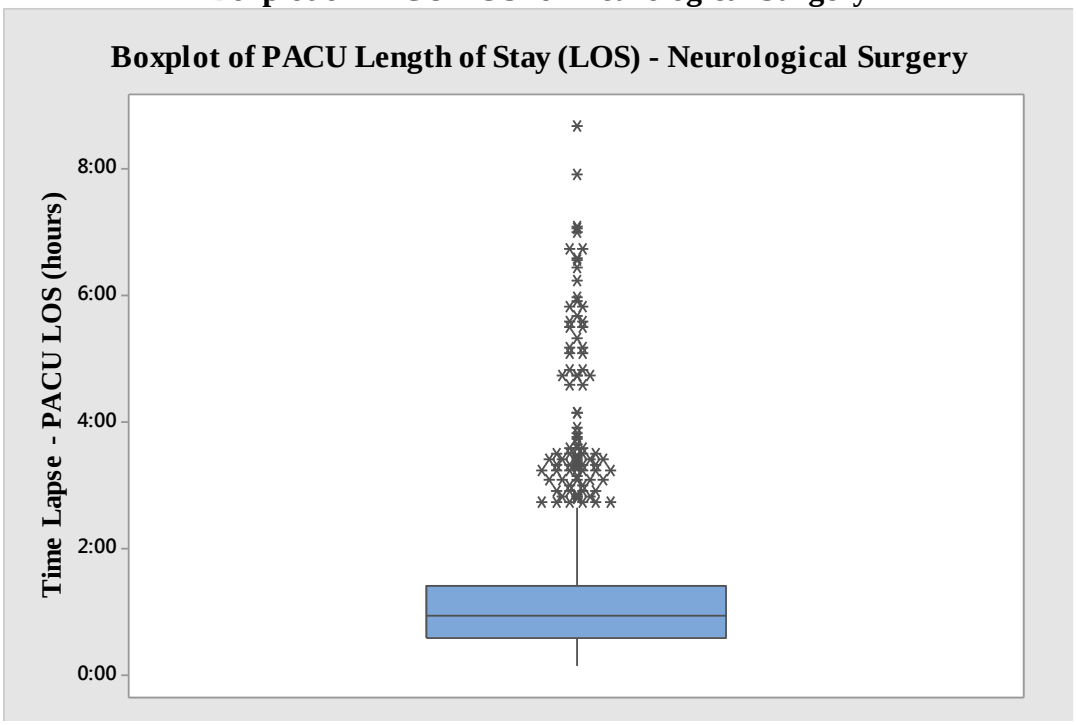
Boxplot of Length of Stay in PACU for General Surgery



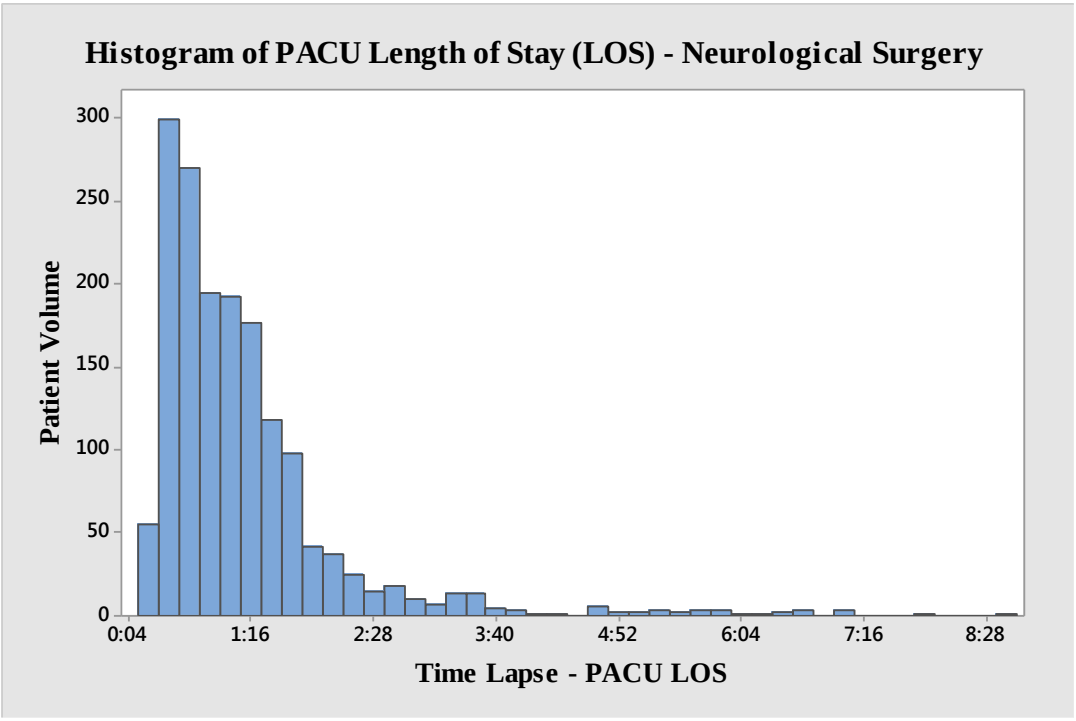
Histogram of PACU LOS for General Surgery



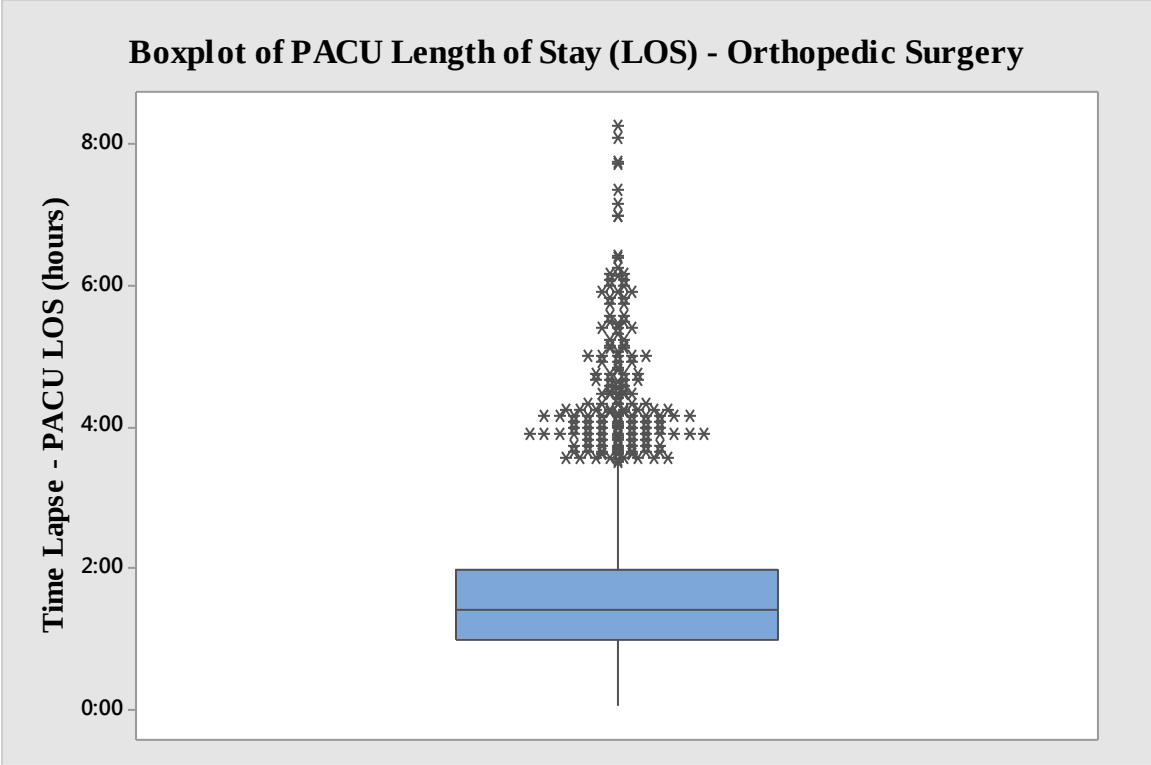
Boxplot of PACU LOS for Neurological Surgery



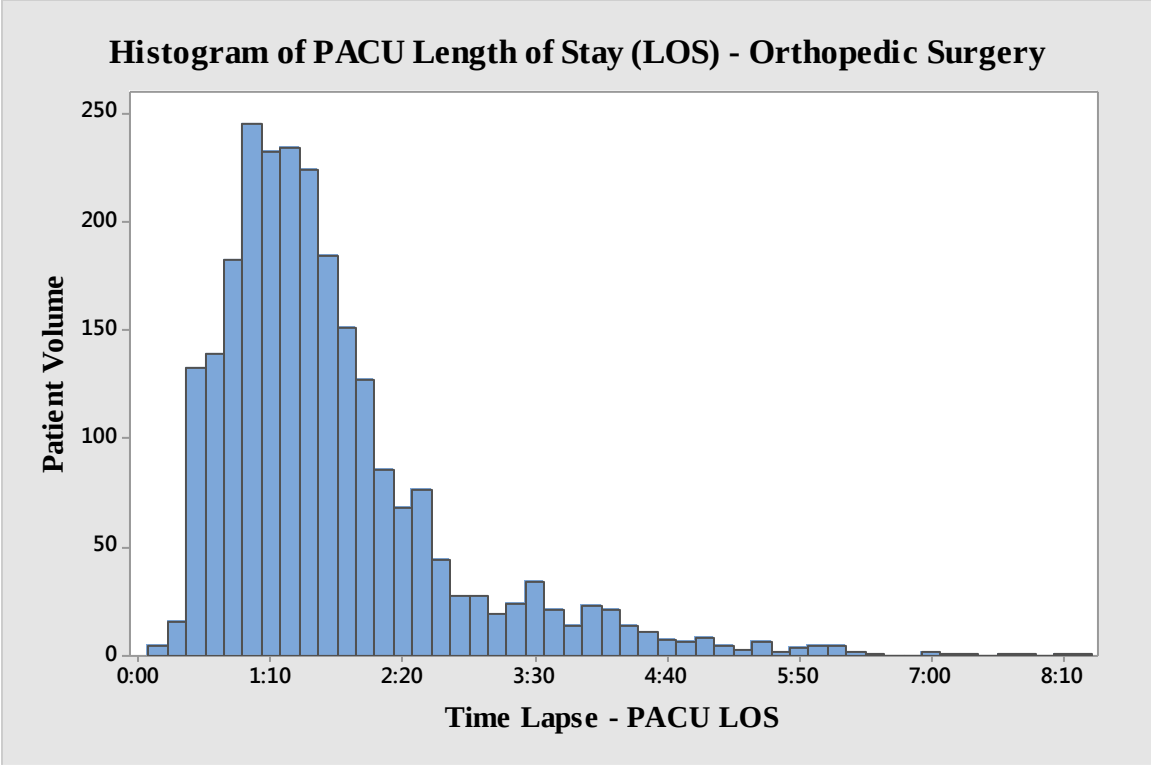
Histogram for PACU LOS for Neurological Surgery



Boxplot of PACU LOS for Orthopedic Surgery



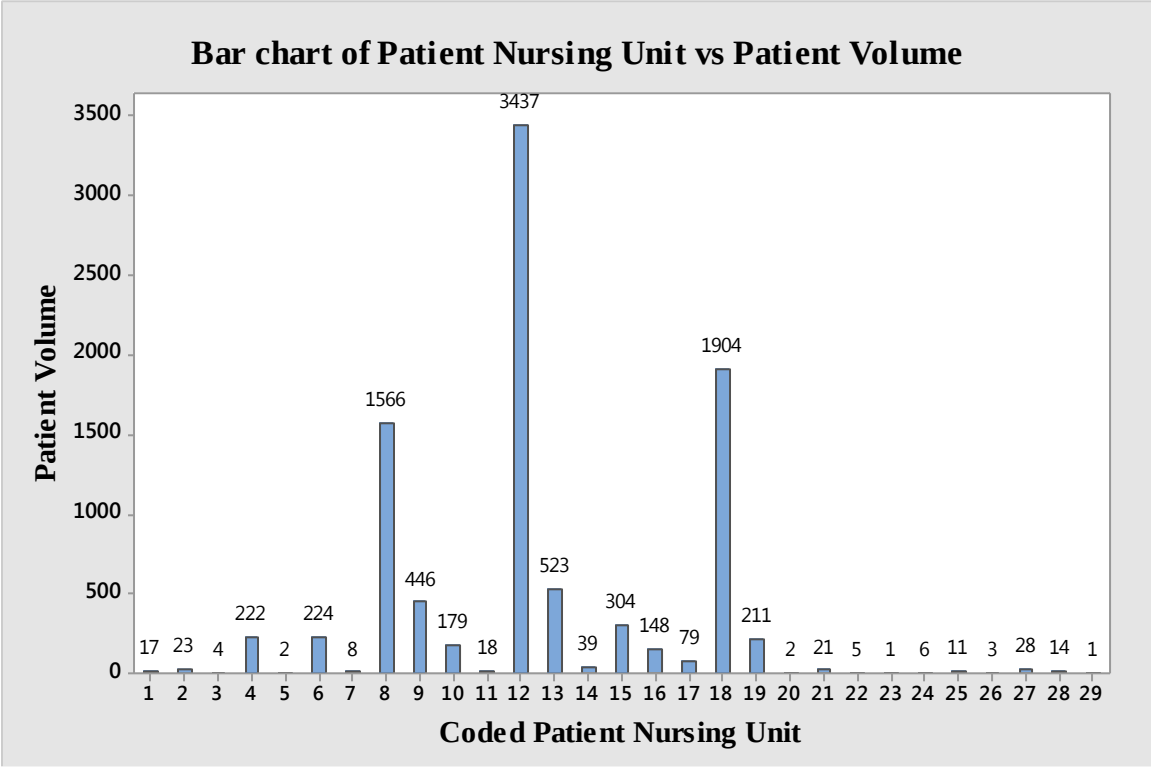
Histogram for PACU LOS for Orthopedic Surgery



Patient Volume by Nursing Unit and Day

Patient Nursing Unit		Days						
	Codes	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1-CVSICU	1	1	5	4	2	3	1	1
1-MSICU	2	2	6	4	6	4		1
2-PICU	3	2		1		1		
2A-CDU	4	35	31	43	38	38	27	10
2B-Heart/Vasc OP	5			1		1		
2N	6	38	31	31	36	40	23	25
3-CICU	7	3		2	3			
3A-PostopCare	8	237	238	261	340	325	90	75
3C-PostopCare	9	94	95	106	92	36	15	8
3N-CPCU	10	18	30	26	41	37	17	10
4-VNICU	11	3	5	3	2	2	1	2
4A-Outpatient	12	542	737	635	783	740		
4N-NeuroCtr	13	88	111	112	91	75	25	21
4N-NIMCU	14	7	8	6	7	5	4	2
5A-InternalMed	15	36	52	52	66	59	20	19
5B-DiabetesMedUnit	16	17	30	23	28	29	12	9
5C-IMCU	17	13	12	17	14	16	5	2
6A-Ortho	18	473	466	323	219	287	79	57
7A-ADCU	19	37	46	39	22	38	21	8
Antenatal CU	20			1	1			
Bixler1-2	21	1	4	1	3	6	3	3
Cent Reg	22	1	1			2	1	
LD B	23						1	
MomBaby East	24		2		1		1	2
MomBaby West	25	4	1	2	1			3
NEE	26		1	1				1
OP Peds	27	6	3	4	6	9		
Pre-adm testing	28	3	3	4		4		
UNIT 3	29						1	
Total		1661	1918	1702	1802	1757	347	259

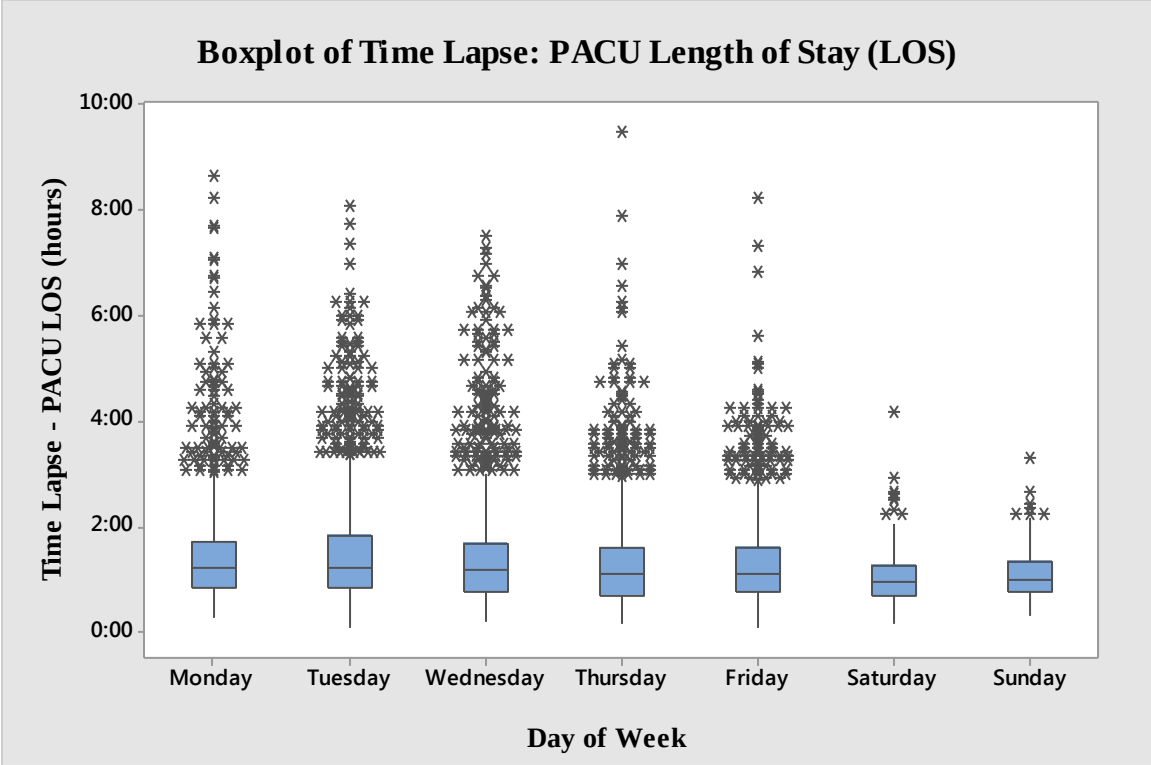
Bar Chart of Patient Volume by Nursing Unit



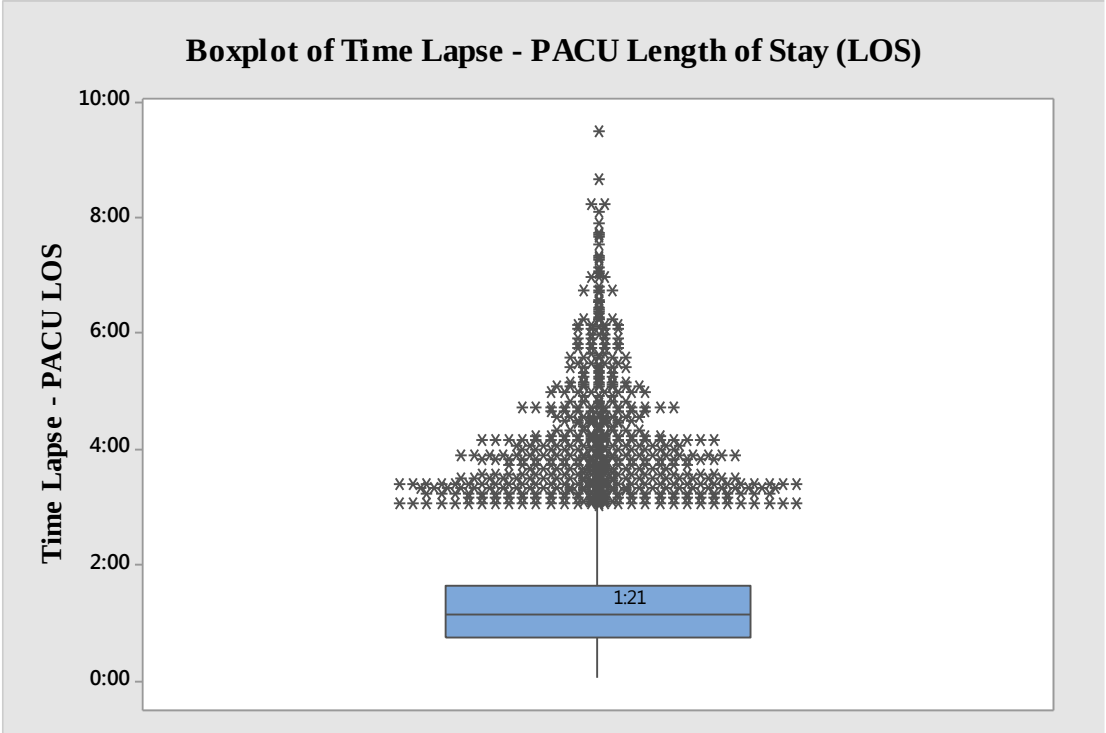
PACU LOS by Surgery Type

Surgery Type	Surgery Stop -> OR Exit		OR Exit -> PACU In		In -> Out PACU		Surgery Stop -> PACU In	
	Ave	Std. Dev.	Ave	Std. Dev.	Ave	Std. Dev.	Ave	Std. Dev.
Cardiovascular Surgery	0:13	0:08	0:04	0:20	1:42	0:59	0:17	0:24
Gastroenterology	0:15	0:21	0:09	0:07	0:35	0:02	0:25	0:14
General Surgery	0:09	0:05	0:04	0:32	1:10	0:45	0:12	0:12
Neurological Surgery	0:08	0:06	0:03	0:04	1:10	0:56	0:11	0:07
Obstetrics/Gynecology	0:10	0:06	0:03	0:03	1:29	0:52	0:13	0:05
GYN ONC	0:08	0:02	0:05	0:01	1:45	0:17	0:09	0:04
Ophthalmology	0:03	0:03	0:02	0:01	0:34	0:16	0:06	0:03
Oral Surgery	0:12	0:06	0:03	0:02	1:08	0:45	0:15	0:07
Orthopedic Surgery	0:08	0:05	0:03	0:03	1:40	1:03	0:11	0:06
Otolaryngology	0:14	0:09	0:02	0:01	1:03	0:36	0:17	0:10
Plastic Surgery	0:09	0:05	0:03	0:03	1:11	0:45	0:12	0:05
Podiatry	0:04	0:02	0:03	0:02	0:48	0:07	0:07	0:00
Urology	0:09	0:05	0:03	0:05	1:15	0:51	0:12	0:07
Vascular Surgery	0:10	0:05	0:02	0:04	1:31	0:55	0:13	0:06
Total	0:09	0:05	0:03	0:10	1:21	0:56	0:12	0:09

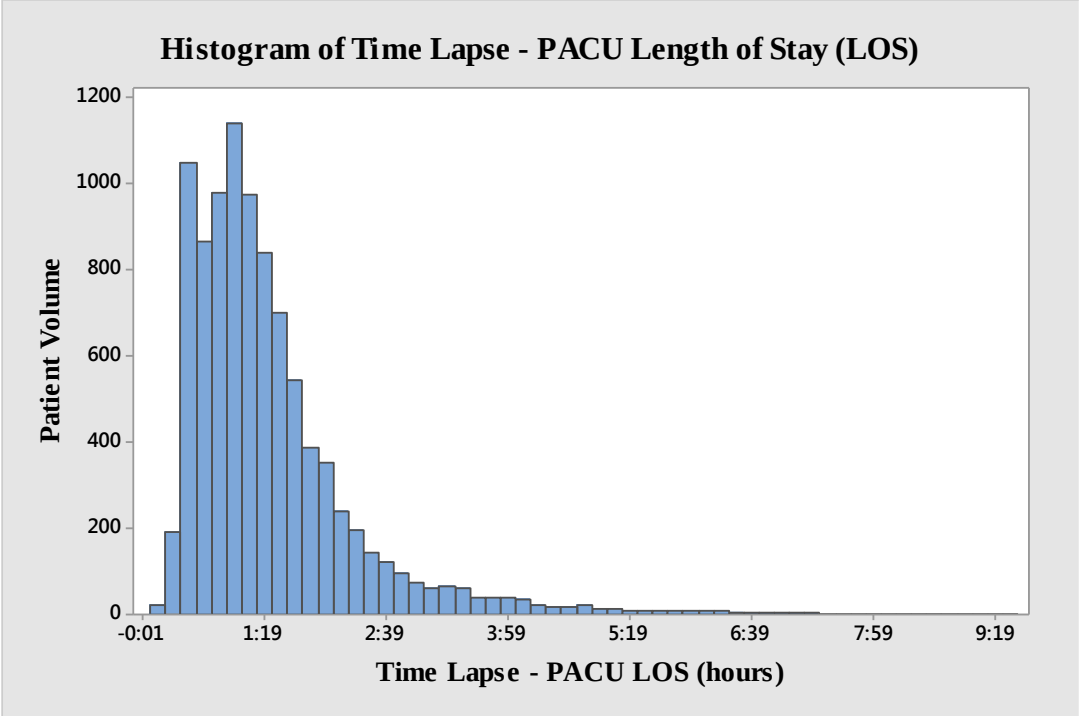
Boxplot of PACU LOS by Day



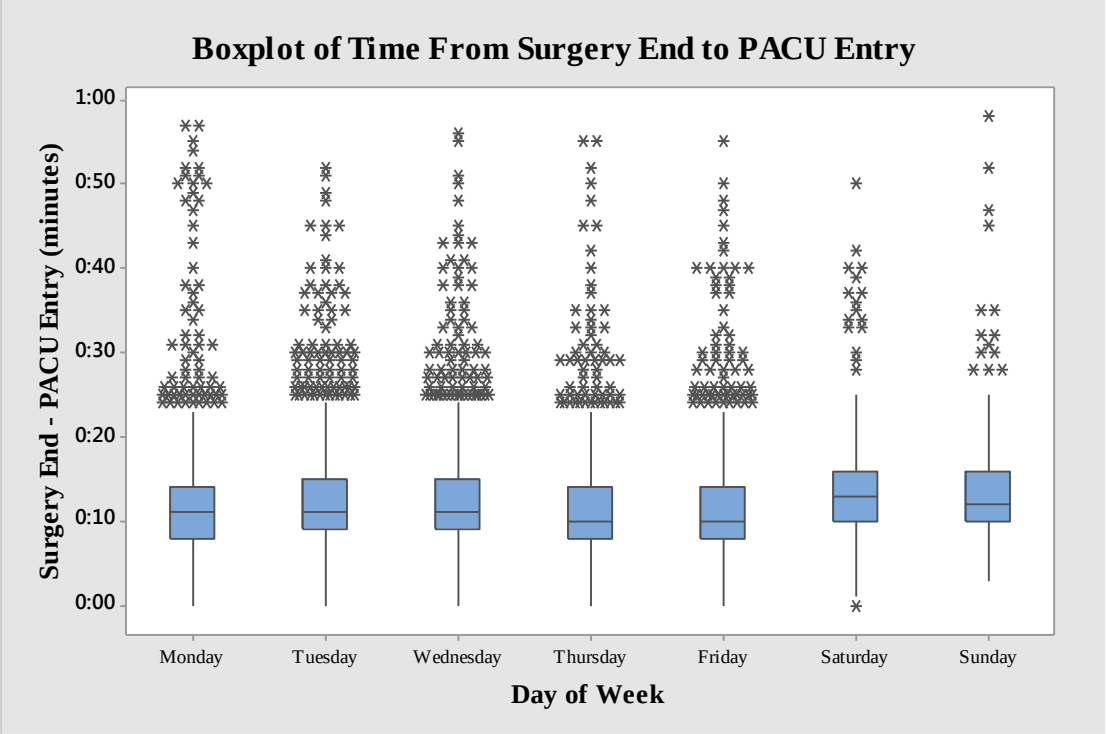
Boxplot of PACU LOS



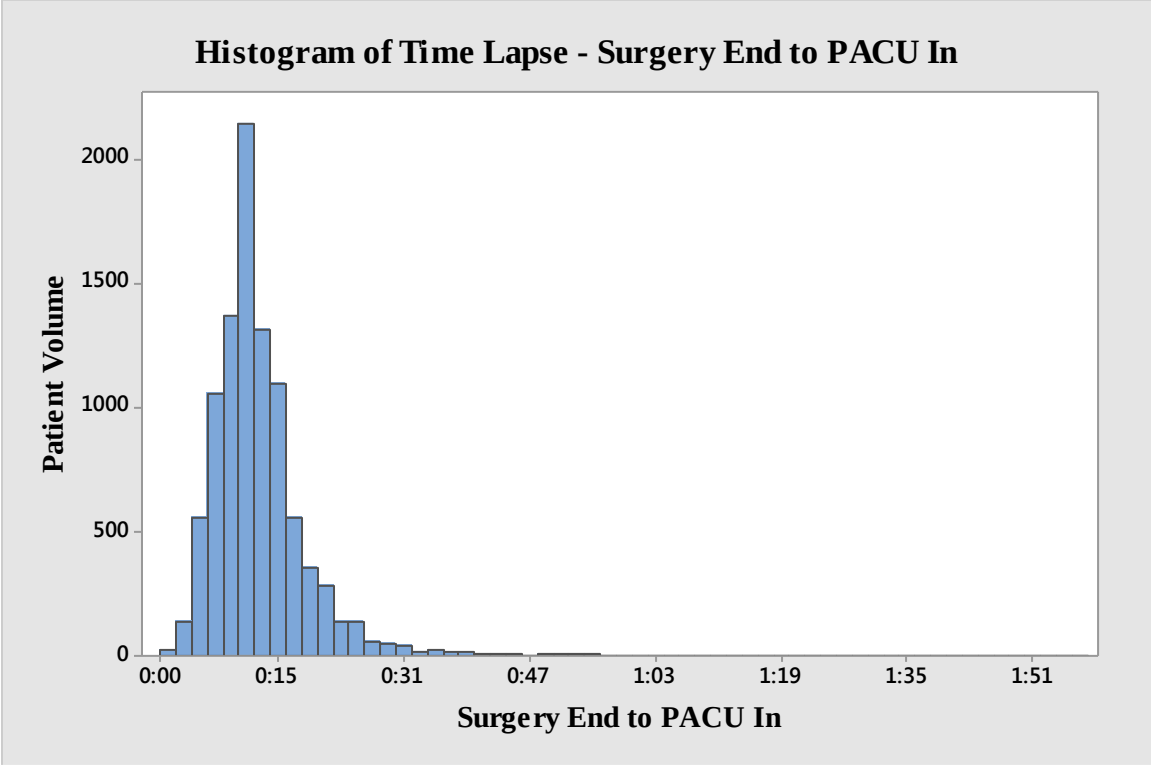
Histogram for PACU LOS



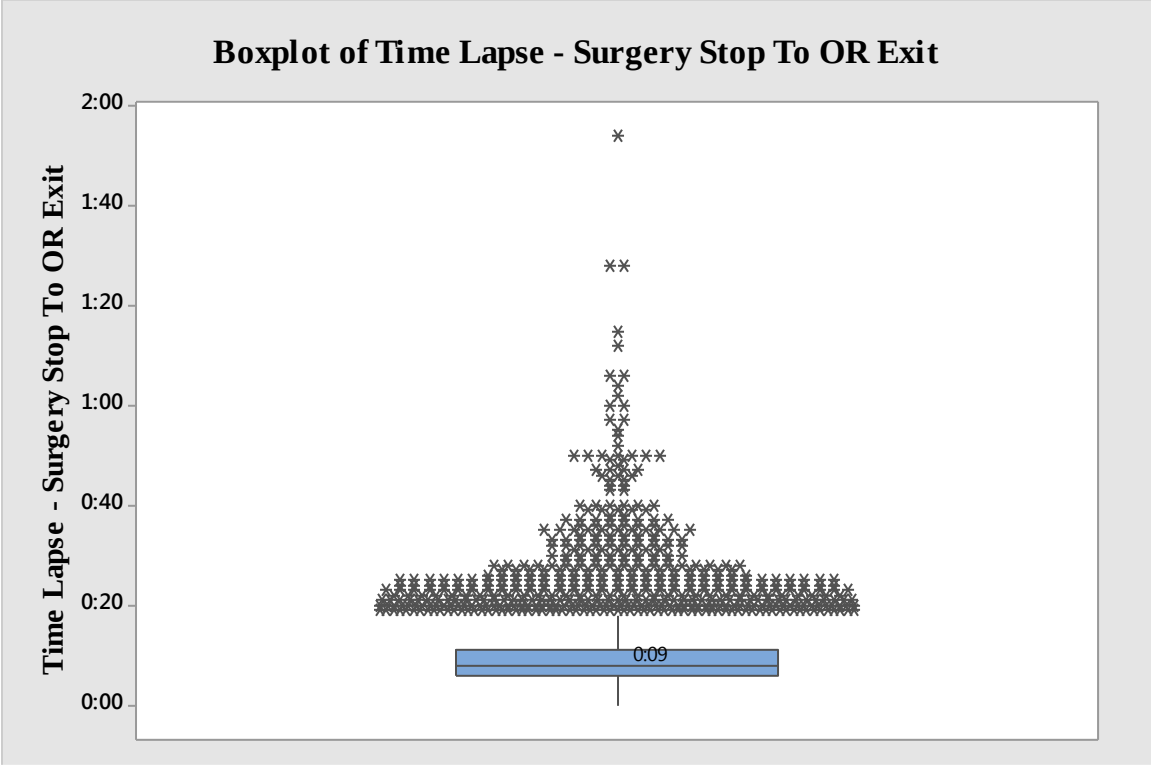
Boxplot of Time Lapse from Surgery End to PACU Entry



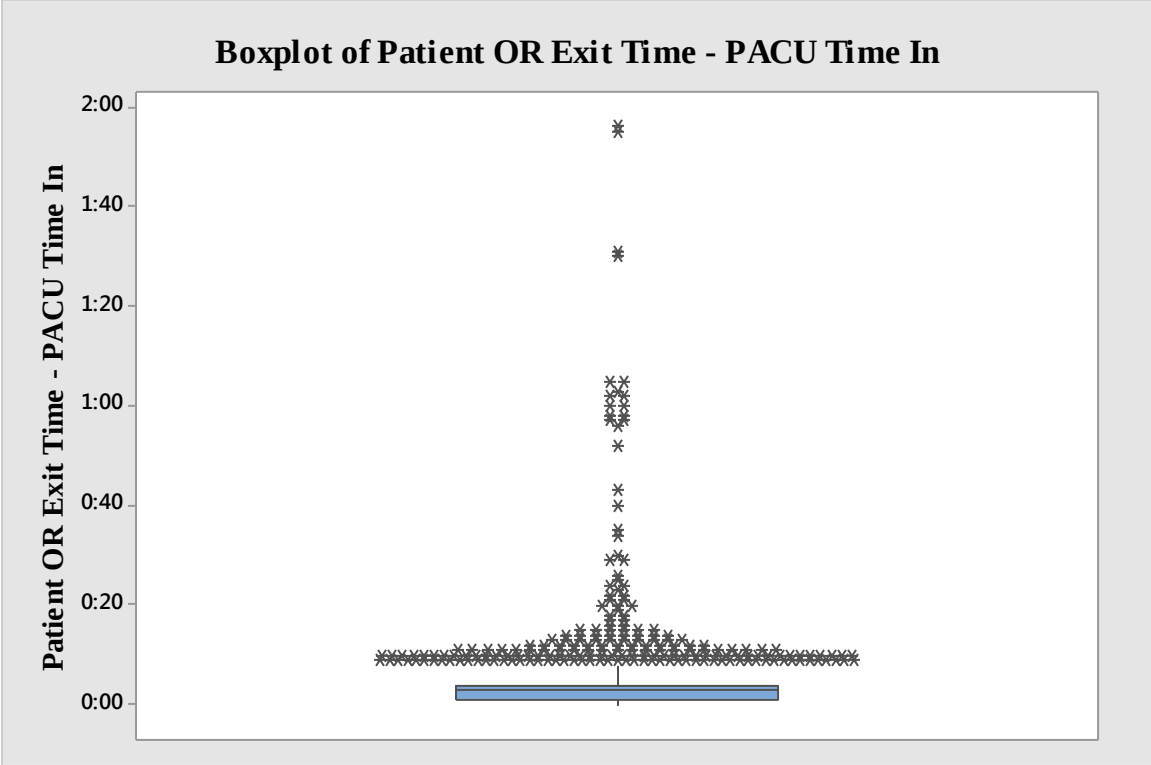
Histogram of Time Lapse from Surgery End to PACU Entry



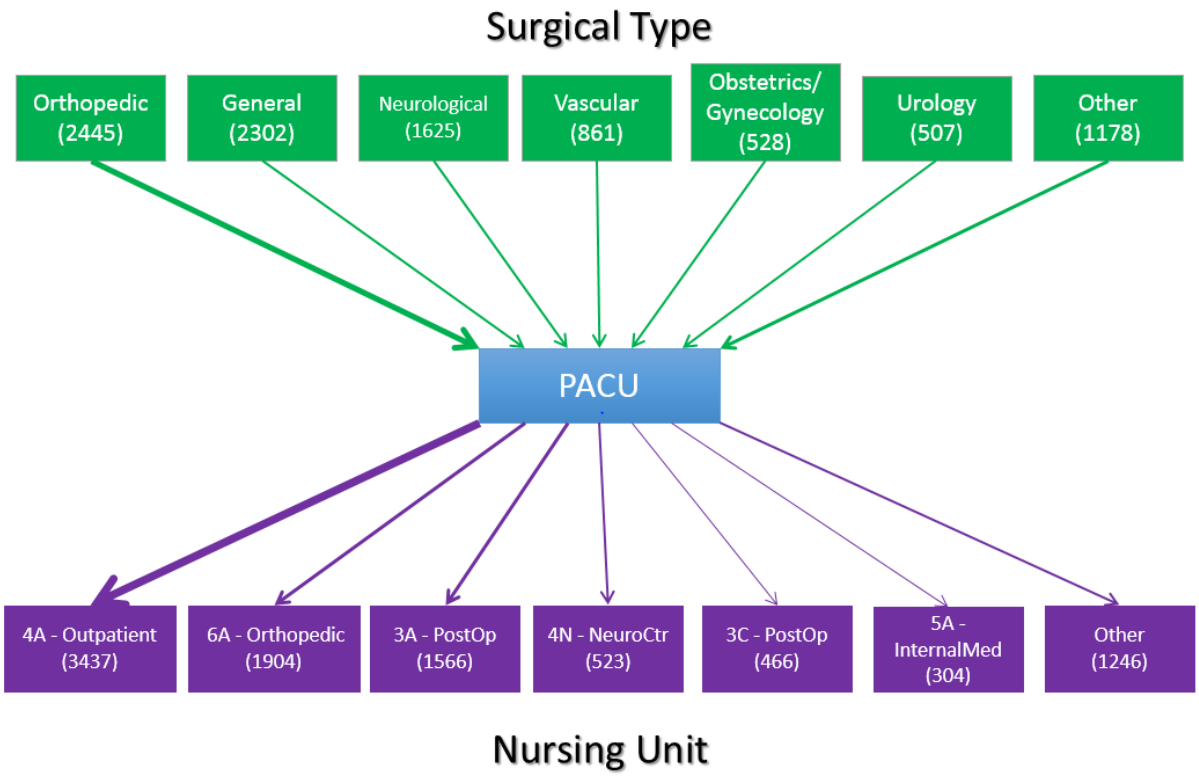
Boxplot of Time Lapse from Surgery Stop to OR Exit



Boxplot of Time Lapse from OR Exit to PACU Entry



Appendix E: The Process Flow Chart



Scaling of Arrows by Patient Volume:
4.50 pt. arrow = 3001-4000 patients
3.00 pt. arrow = 2001-3000 patients
2.25 pt. arrow = 1001-2000 patients
1.00 pt. arrow = 501-1000 patients
0.50 pt. arrow = 1-500 patients

Appendix F: The Patient Flow Chart