

## **ABSTRACT**

BENNETT, PORSCHE PRISCILLA. Optimizing Operating Room First Case Start Times: A Systems Improvement Approach. (Under the direction of Dr. Julie Ivy).

The need for engineering in healthcare is a continuously growing phenomenon. Many hospitals and medical centers struggle with patient and staff scheduling, process efficiency, and resource utilization and optimization, which are classical engineering problems. The Veterans Health Administration (VA) has recently been a trending topic in the media as they work to resolve such issues. While no system will ever be perfect, it is imperative for medical centers to perform at their optimal potential. The goal of this thesis is to assist the Durham VA Medical Center with improving surgery start times of first cases. The DMAIC (Define, Measure, Analyze, Improve, and Control) process was used as a lean six sigma, systems improvement strategy to optimize a veteran's surgical preparation and processing the day of his or her operation. The objective is to increase in-house capacity that results in fewer cases being sent out to non-VA providers, reduce surgical backlogs, and increase major surgery operating room capacity. Fulfilling the objective would inevitably improve the patient's experience, and offer scheduling availability to increase surgical cases in a day.

Veterans must go through an eight step process to be admitted to their operating room. Delays and inefficiencies within some of the processes results in veterans being admitted to their operating room later than the scheduled time of 8:00am (9:00am). The delay in a patient's start time not only affects first cases, but potentially subsequent cases. A simulation model was designed to analyze the performance of the current system. An array of recommendations and solutions were provided for each substantial processing delay within a

patient's pre-surgical process. Updated models were designed to implement the recommendations. Each model's processing times and percent of on-time starts were statistically analyzed and compared to the current system. The simulation with the most improved processing results and on-time starts was considered the optimal solution. The optimal solution increased on-time starts by 73.48% and reduced the overall time that a patient spent in the system by 31%.

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Optimizing Operating Room First Case Start Times: A Systems Improvement Approach

by  
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## **DEDICATION**

I would like to dedicate my thesis to my best friend Michelle Lynn Wallace who gained her angel wings in June of 2014 after ending her battle against breast cancer. She inspired me to push through every obstacle, no matter what life threw at me. She was truly one of my biggest fans and supporters. Her passion for education, innovation, and health care continues to inspire me to never be complacent, always stand for something, and continue to gain knowledge and be present. I would not be the person I am today without her! She was more than a friend, but my sister, that is truly missed.

## **BIOGRAPHY**

Porsche Bennett was born July 10, 1990 to Franklin and Adrienne Bennett. She was born and raised in Baltimore, Maryland where she attended a prestigious STEM based high school, Baltimore Polytechnic Institute. Porsche went on to enhance her engineering background at Rochester Institute of Technology (RIT) where she majored in Mechanical Engineering Technology. At RIT she began to research additive manufacturing and green materials. Her developed passion for research and innovation lead her to aspire to graduate studies. While she hadn't had any prior advanced knowledge in health care, she always had a passion to study and work in the field. As a result of illustrious health care research opportunities, distinguished faculty, and its renowned engineering program, Porsche began her graduate studies at North Carolina State University (NCSU) in the field of Industrial and Systems Engineering. She interned at the Durham Veterans Affairs Medical Center in ambulatory care and surgical services. Porsche wanted to apply the course work she had learned at NC State to assist in efficiency, and improved patient experience at the VA. As a result, she decided to volunteer and began research in "Operating Room First Case On-time Starts" in surgical services, under the guidance of her chair Dr. Julie Ivy and committee member, Dr. Javad Taheri. Porsche is expected to receive her Masters of Science degree in Industrial Engineering, May 2016.

## ACKNOWLEDGMENTS

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It has been with great privilege to attend North Carolina State's Edward P. Fitts Department of Industrial and Systems Engineering and learn from some of the most knowledgeable and distinguished professors.

Lastly, thank you to my wonderful parents, 4 siblings, 11 nieces and nephews, and amazing close friends for your incredible love and support; without you all, I would not be where I am today!

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## LIST OF SYMBOLS AND ABBREVIATIONS

Admin	Administrative
Anesthesia	Anesthesiologist
IV	Intravenous therapy
OR	Operating Room
Pre-op	Pre operation
Prep	Preparation
RN	Registered Nurse
VA	Veterans Affairs
Q3	Quarter 3
Q4	Quarter 4

Abbreviations are in alphabetical order.

# Chapter 1 Introduction

## 1.1 Background

The United States Department of Veterans Affairs (VA) is a benefit system for veterans and their families. The VA provides benefits of financial support, education, and healthcare ("History - VA History - About VA", 2016). Within the last few years the VA has been criticized in the news as it was reported that veterans were not able to see a doctor and receive diagnosis and treatment in a timely manner due to backlogs and documentation (Devine, 2015). On April 23, 2014, CNN reported that 40 veterans died waiting for patient care at the Phoenix VA (Pearson, 2014). Furthermore, on September 3, 2015, it was reported that a total of "307,000 veterans may have died awaiting Veterans Affairs health care," due in part to the lack of procedures to oversee records (Devine, 2015). More specifically, Bob Wombolt, a Korean War veteran, spoke out in 2011 about his two year wait for hip replacement surgery at the VA hospital in Fort Harrison (Uken, 2011).

Since 1953, the Durham Veterans Affairs Medical Center has been striving to improve the health and well-being of United States Veterans (US Department of Veterans Affairs, 2015). The Durham VA provides services to more than 200,000 veterans who live within 26 counties in North Carolina (US Department of Veterans Affairs, 2015). The VA has been working to stand true to its vision, by taking a hands-on approach to continuous improvement in efficiency and patient care. The VA's vision is as follows:

“VHA will continue to be the benchmark of excellence and value in health care and benefits by providing exemplary services that are both patient-centered and evidence-based. This care will be delivered by engaged, collaborative teams in an integrated environment that supports learning, discovery and continuous improvement. It will emphasize prevention and population health and contribute to the nation's well-being through education, research and service in National emergencies” (US Department of Veterans Affairs, 2015).

The VA strives to fulfil their vision by following their core values of Integrity, Commitment, Advocacy, Respect, and Excellence (“ICARE”) (US Department of Veterans Affairs, 2015).

The Durham VA provides surgical services within 14 categories, provided by an array of surgeons from Duke, surrounding hospitals, and surgeons whose practice is solely dedicated to the VA. The 14 categories include plastics, cardiac, dental, podiatry, psychology, orthology, vascular, gastro intestinal, ophthalmology, gynecology, neurology, thoracic, urology, and general surgery. While the VA’s surgical services unit aims to provide exceptional health care, like many medical centers and hospitals, they encounter several roadblocks. These roadblocks affect their ability to accommodate an increase in demand, improve their patient experience, and surpass their current efficiency.

The focus of this research is to assist the Durham VA Medical Center with improving surgery start times of first cases. Reducing processing queue times would improve the start

time of first cases and would result in the increase of in-house capacity and fewer cases being sent out to non-VA providers. In addition, surgical backlogs can be reduced, providing earlier surgical appointments. Moreover, the refinement would not only affect first cases, but could potentially allot for more surgeries to be added in a day.

## **1.2 Clinical System Overview**

The Durham VA hospital takes eight non cardiac/non special case surgery patients every Monday through Friday. On Monday, Tuesday, Thursday, and Friday all first cases are scheduled to start at 8:00am. On Wednesdays, all first cases are scheduled to start at 9:00am. On Wednesdays the delay in start time is attributed to a 7:30am to 8:15am surgical staff meeting. The systematic flow of a patient, paperwork, and staff attribute to a patient's ability to arrive to his or her operating room by 8:00am (9:00am). A patient's flow throughout the system entails each process from the time the patient arrives to check-in to the time he or she arrive to his or her designated operating room. The paperwork flow requires the completion of seven documents, signatures, orders, or evaluations that are nationally mandated to be completed prior to a patient's start of surgery. Lastly, there are eight staff members that are needed for a patient to progress throughout different stages in the system.

### **1.2.1 Patient Flow**

A patient goes through an eight step process and in some cases nine steps from the time he or she checks in to the time he or she enter the operating room. These processes will also be referred to as subprocesses. Patients complete the eight subprocesses in two different

locations, which are 4B short stay/4B and pre-op. Pre-op and 4B short stay/4B are referred to as major processes. The “4B short stay” subprocess is where patients who arrive before 6:00am wait until 4B is open. The “4B” subprocess is where patients are placed after 6:00am to begin their pre-surgical process. The “4B short stay/4B” is a major process that encompasses the subprocesses 4B short stay and 4B.

Figure 1 shows a veteran’s pre-surgical process at the Durham VA. When a patient arrives to the VA for surgery the patient must go to 4B short stay and check in. The 4B short stay subprocess is a waiting area for patients who arrive before 6:00am. At 4B short stay, a patient must sign in, providing his or her personal information and his or her arrival time is documented. A nurse will indicate in the system that the patient has arrived. While 4B is 24 hours, 4B nurses tend to patients who are there from the previous night’s surgery first. After surgery, some patients will need to be observed for a period not to exceed 24 hours. The patients that require observation are placed in 4B. Thus, a patient may have to sit in 4B short stay until nurses are finished with patients from the previous day and have prepped a bed and surgery attire for the patient that has just checked in. As a result, 4B is considered to be closed for new surgery patients until 6:00am.



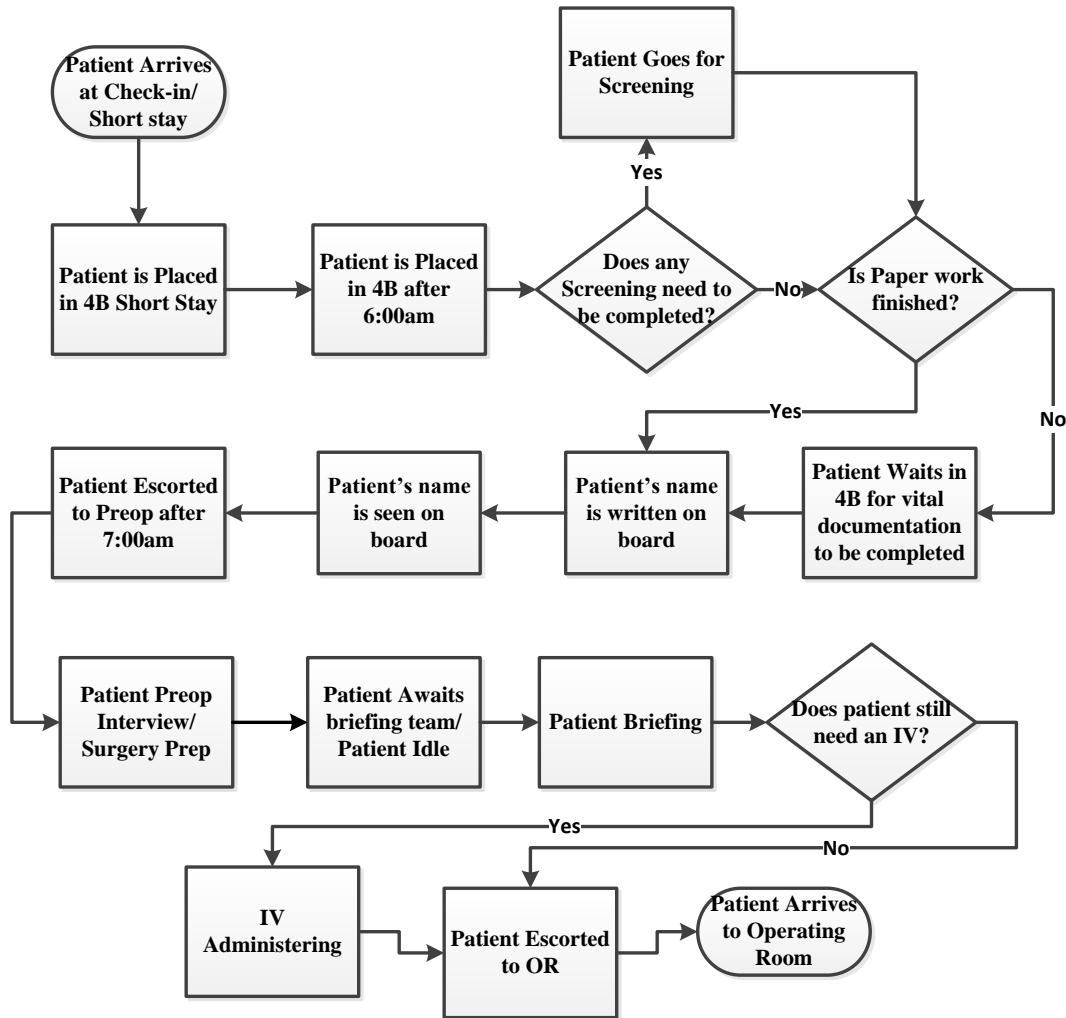


Figure 1: Patient Pre-surgical Process

At 6:00am all patients in 4B short stay will be dressed and placed in 4B. In some cases, patients will need additional testing completed the day of their surgery. Patients may need testing such as blood work, scans, x-rays, etc. in which case, they will be escorted to have the testing completed prior to being admitted to pre-op. Otherwise, a patient will wait in 4B until his or her paperwork is completed or 7:00am, whichever is later. Pre-op does not open until 7:00am, so a patient whose paperwork is completed prior to 7:00am will be held in 4B until pre-op opens. In special cases, such as cardiac surgery, a patient will be admitted to pre-op

prior to 7:00am. For the purposes of this study, cardiac surgery will be excluded, as cardiac has an efficient on-time start due to the rigor and length of surgery. The OR administrative nurse that is in charge of verifying the completion of paperwork will write each patient's name on a dry erase board that is located near 4B when a patient is ready to be escorted to pre-op. A nurse in 4B will periodically check to see when a new patient's name has been added. Once he or she sees that a new patient's name is added, the 4B nurse will send for an escort. An escort will transport the patient from 4B to his or her assigned pre-op bay.

When a patient arrives to pre-op, an interview is conducted. After a patient finishes his or her pre-op interview, he or she is prepped for surgery. Patient prep typically consists of having the surgical site cleaned and shaved, and in 59% of cases, a patient will be given an IV during this time. After a patient is interviewed and prepped, the patient will be briefed by his or her assigned surgical team. If the surgical team has not arrived yet, the patient will wait idly. Once the briefing team arrives, the team will review the procedure with the patient and answer any final questions or concerns. When the briefing is complete, if the patient does not have his or her IV, it will be administered at that time. Lastly, anesthesia will escort the patient to the OR.

### **1.2.2 Staffing**

Eight staff members are utilized per patient throughout a patient's process prior to arriving to the operating room. A 4B nurse is responsible for assisting a patient during his or her check-in process and for periodically checking to see if a new patient's name is written on the

board. The 4B nurse's station operates 24 hours a day. The OR administrative nurse is responsible for ensuring that each patient's vital paperwork is fully completed and his or her name thereafter is written on the board. The OR administrative nurse arrives to begin checking paperwork at 5:30am Monday through Friday. An escort transports patients from 4B to pre-op. A pre-op nurse ensures that a patient is prepped and interviewed upon entering pre-op. Pre-op nurse shifts begin at 7:00am Monday through Friday. Lastly, an anesthesiologist, resident, attending, and operating room nurse are assigned to a patient and are required to brief the patient in pre-op and care for the patient during surgery. The doctors and operating room nurse arrive at different times prior to the briefing.

### **1.2.3 Paperwork**

There are four key documents, one evaluation, and two signatures that are required before a patient can be admitted to pre-op. A resident/attending note (RES-ATT NOTE) is a document that a resident completes stating that he or she has assessed the patient and indicates what the surgical procedure will be for his or her patient. The document must be completed within 30 days of a patient's surgery. An attending must sign the resident/attending note indicating agreement with the resident's assessment and conclusion. A 24-hour attending update finalizes the details of a patient's surgery. A history and physical (H&P) is a document that must be completed within 30 days of a patient's surgery that summarizes the history of the patient's illness. This document also provides the physical assessment of the patient's current state. The physical assessment includes blood work, urinalysis, and a complete physical analysis of the patient's current condition. A resident

physician, a nurse practitioner, a physician assistant or an attending in a given specific service can complete the H&P. The H&P signature must be cosigned by the attending that will be conducting that patient's surgery.

An informed consent is a document that each surgical patient will sign allowing the specified surgeon to operate on him or her. A resident or an attending can complete the informed consent, but only the attending can sign off on the consent. An informed consent is only good for 30 days and must be resigned if it exceeds 30 days from the time it was initialized.

An antibiotic order is nationally mandated in which all patients must have antibiotics completely infused an hour before incision, unless otherwise indicated. An antibiotic order is also contingent upon the procedure. In procedures such as cataract or skin tag removal surgery, a patient will not need an indication for an antibiotic.

Lastly, a pre-op anesthesia evaluation is a nationally mandated evaluation conducted by anesthesia. Patients are seen within 30 days and this assessment assures that the patient's condition is stable enough to have the procedure. In addition, the patients are informed about the risks of surgery, types of anesthesia, and the risk factors associated with anesthesia. All patients are evaluated even if their procedure is as simple as a skin tag.

An OR administrative nurse references the VA's software system throughout the day prior to a patient's surgery as well as the morning of surgery, to check and document completion.

Once the OR administrative nurse has seen and documented that all paperwork, orders, and evaluations have been completed, he or she deems a patient ready to be escorted to pre-op. Currently, the monitoring of the completion of vital patient paperwork is collected manually and stored in a folder for legal and future reference.

### **1.3 Problem Statement**

While fulfilling all daily cases within the current scheduling demand, the OR has roadblocks prohibiting first case on-time starts. Ensuring an on-time start allots for more cases in a day, optimizing the utilization of employees, work space, and resources. First case on-time starts can also reduce a patient's overall time in the OR and increasing patient satisfaction. A "First Case On-time Start" project was developed to study all critical steps in the process to understand where the bottleneck occurs and to conclude what was the greatest cause of that delay/bottleneck. Upon studying the Durham VA surgical unit, a clear, consistent, and standardized OR first case on-time start model will be needed. In addition, new plans are needed that will sustain efficiency by using creative solutions to meet surgical demand. The OR workflow project supports the Durham VAMC Objective C: "To increase in-house capacity that results in fewer cases being sent out to non-VA providers, reduce surgical backlogs, and increase major surgery OR capacity."

## 1. 4 Goals & Objectives

The overall goal of this research is to fulfil four main objectives in an effort to assist the VA in finding viable solutions to improve pre-operation efficiency within budget. Each objective was separated into specific aims, which are as follows:

**Objective 1:** Provide the distribution of a patient’s time spent throughout the system and the attributes to the current efficiency rate of on-time starts by identifying: (i) the average time that a patient spends completing each process prior to surgery; (ii) the percent of on-time starts observed with a comparison to the quarterly VA reports; (iii) the main causes of a patient’s delay in starting surgery; (iv) the bottleneck in the system.

**Objective 2:** Develop an improvement strategy to increase the percent of on-time starts by: (i) recommending solutions to common delays in the system; (ii) developing a roadmap for standardizing the schedule for staff.

**Objective 3:** Develop a model to simulate the current and improved system by providing: (i) the current patient flow through the system, using time study data; (ii) a projected patient’s flow through the system when the proposed solution to the bottleneck is implemented; (iii) a patient’s flow through the system that encompasses all recommended improvements.

**Objective 4:** Improve the efficiency of paperwork documentation by: (i) developing a tool to replace the current “OR documentation monitoring” that will make data collection more efficient and secure; (ii) providing a method to improve communication of documentation status within the surgical teams.

## **Chapter 2 Literature Review**

Researchers have used an array of techniques to understand leading causes for delays in the start of first cases in the operating room. Both doctors and engineers have been focusing on improvements as the reform can be beneficial to cases thereafter. There are additional costs associated with late first cases to accommodate overtime of staffing that is needed for cases that extend longer than the scheduled shift. Starting first cases on time will assist with the on-time starts of subsequent cases. This will inevitably improve patient and physician satisfaction. This chapter gives a comprehensive review of literature that focuses on first case on-time starts and the simulation of patient flow and their ranges of application. The chapter will also discuss methodologies used, as well as similarities and limitations as it pertains to this thesis.

### **2.1 Simulation Modeling**

Hung, Whitehouse, O'Neill, Gray, and Kissoon (2007) and Rohleder, Lewkonia, Bischak, Duffy, and Hendijani (2011) considered simulation in efforts to model patient flow in a health care system. Hung et al. (2007) used discrete event simulation in Arena to model the patient flow of a pediatric emergency department (PED). The Arena model was designed based on expert opinion, historical patient arrival data, and observed patient flow. The observation included 517 patients, PED staff, and resources. The model was validated by comparing the simulated results and observed patient flow data. Similarly to this thesis, the model was validated on two levels that include specific processes and the overall process.

The Hung et al. (2007) processes entailed the length of patient stay for high acuity patients, triage, and registration. Wait times were observed and recommendations were simulated to reduce the time a patient spent in triage. The Hung et al. (2007) model can be used to simulate different scenarios and to test the effects on a patient's flow. Like Hung et al. (2007) and Benneyan (1997), this thesis evaluates patient wait times and identifies the primary reasons for a patient's delay in a process using simulation. Rohleder, Lewkonja, Bischak, Duffy, and Hendijani (2011) considered resource utilization, scheduling, and staffing arrival times to understand the effects on patient wait times in an orthopedic outpatient clinic. Rohleder et al. (2011) statistically analyzed the simulated data before and after implemented improvements to observe the reduction in total patient time in the clinic. This thesis focuses on optimizing patient processing times utilizing the current resources to eliminate costs of additional resources.

Ashby, Ferrin, Miller, and Shahi (2008) not only focused on using discrete event simulation to model patient volumes and improvements to current processes within a medical facility, but to simulate a new process as well. The Department of Health Services in Los Angeles (LA) constructed a new hospital to replace the LA County's largest health care facility.

Ashby et al. (2008) focused on the hospital's goal to place patients in a unit that best suited their acuity. In doing so, they simulated the effects of the transition, process redesigning, and improvements to their current processes. A process map from patient arrival to patient discharge was designed to describe each step in patient processing. Since the inpatient unit was affected by other units in the hospital, Ashby et al. (2008) also observed and simulated



the impact that the operating room, support services, and the emergency department had on the inpatient unit. While this thesis will not use simulation for testing the design of a new facility, it will entail process mapping and simulation of process improvement of a system that does not perform at an optimal level.

Jacobson, Hall, and Swisher (2006) and Sobolev, Sanchez, and Vasilakis (2011) discussed techniques used in health care simulation, and reviews research comparable to that of Hung et al. (2007), Rohleder et al. (2010), Benneyan (1997) and Ashby et al. (2008). They researched historical simulation methods that focused on identifying new approaches to efficiency in health care operations and understanding patient flow in health care facilities. Specifically, Jacobson et al. (2006) focused on optimizing the allocation of scarce resources, while Sobolev et al. (2009) compared research that utilized simulation modeling of patient flow in surgical care. In the Sobolev et al. (2009) study, the authors concluded that only half of the published simulated models considered policy makers and included involvement from health system managers during their study. Sobolev et al. (2009) noted that modelers made several assumptions with regards to system requirements and input data. The efforts made in this thesis to include the experts and management at the Durham VA Medical Center, address the concerns identified by Sobolev et al. (2009) with simulation models in health care. In addition, this thesis used very few assumptions to design a simulation and analyze a system that most resembled the actual process at the Durham VA.

Similar to Benneyan (1997), Hung et al. (2007), Ashby et al. (2008), and Rohleder et al. (2011), this thesis provides a simulation model that can be used as a decision making tool. Their focuses of observing the current system, process mapping of patient flow, and simulating multiple scenarios for process improvements is expanded in this thesis. This thesis bridges the gap between process improvements tackled by doctors and simulation techniques used by engineers. This thesis presents a time study, a pre-surgical patient flow model of first cases in the operating room, as well as an analysis of recommended improvements and its effect on patient flow. This thesis simulates patient flow by utilizing data that directly comes from time studies. The data is applied in the distributions fitted for the simulation model. The model provides an analysis that compares recommended solutions, while allowing the Durham VA to have a base model that can be manipulated to test additional changes the VA may later suggest. Furthermore, this thesis provides ready to use solutions for identified causes of bottlenecks and delays in the system.

## **2.2 Operating Room First Cases**

Truong, Tessler, Kleiman, and Bensimon (1996) explored if first case start times would be improved by reducing causes of delay. Truong et al. (1996) analyzed data collected at Sir Mortimer B. Davis (SMBD) - Jewish General Hospital that consisted of 90 surgical cases that were studied over 10 days. The data documented the time the first case patient arrived at his or her operating room. A late start at the SMBD- Jewish General Hospital was considered to be any time after 7:45am. Truong et al. (1996) found that 77.8% of patients were late to the OR. An assessment was conducted to determine the causes for patients having a late start.

Changes were then made in efforts to improve the number of late starts. A second audit was completed to determine if the solutions that were implemented, improved on-time starts. This thesis also utilizes data that captures the percent of late first cases and a study that identifies primary causes. While Truong et al. (1996) studied the effect of the solutions by changing the actual system; this thesis uses simulation to study the effects.

Wright, Roche, and Khoury (2010) evaluated operating room start time improvement efforts at an academic pediatric hospital. Similar to Truong et al. (1996), Wright et al. (2010) identified the primary reasons for delays and observed changes in on-time starts when implementing solutions to delays. Wright et al. (2010) concluded the primary causes of delay were patient preparedness the day of surgery and the availability of resources (anesthesia and surgeons). This thesis also observes resources, how processes are completed, and scheduling to conclude primary causes in delayed patient flow that affect their start time. In addition, Wright et al. (2010) also considered quarterly reports and the amount of time a patient was late beyond the on-time start time. This thesis verifies and validates the simulated data by comparing the observed data, simulated data, and the Durham VA quarterly reports.

### **2.3 Utilizing Six Sigma Methodologies**

It is important to utilize an effective methodology and technique for data-driven process improvements. Bent, Sherrier, and Peters (2010), Warner et al. (2013), and Glover, Van Aken, and Creehan (2009) used process engineering techniques to improve first case on-time starts. Similar to the methods used in this thesis, Bent et al. (2012) conducted a time study

that focused on the time spent from admission to preoperative processes to surgery. The data was collected using multiple observers. Bent et al. (2012) observed 73% of on-time starts and data determined that 66.5% of patients arrived late the day of their surgery. This thesis utilizes a similar approach. Major processes as well as their subprocesses have been observed and data have been collected using multiple observers to help eliminate a bias or error in the data to determine the percent of on-time starts and primary causes for late starts.

Warner et al. (2013) evaluated the effect of utilizing a lean process improvement technique, the DMAIC (Define, Measure, Analyze, Improve, and Control) process, on first case operating room on-time starts. Warner et al. (2013) found lean processing offered the ability to efficiently identify causes of delays for first cases and for quickly implementing process improvements. Warner et al.'s (2013) utilization of the process improved resident efficiency and decreased staff work hours. The Warner et al. (2013) assessment provided insight when deciding which lean six sigma processes to apply to this thesis and supporting its effectiveness.

Glover et al. (2009) focused on first cases of the day beginning at their scheduled time as well as the turnover time in between each case throughout the day. Glover et al. (2009) accomplished this by implementing a Kaizen event to improve space utilization, workflow, and processes. A kaizen event is “a focused and structured improvement project, using a dedicated cross-functional team to improve a targeted work area, with specific goals, in an accelerated timeframe” (Farris, 2008). The technique improved first case start times by 25%

compared to baseline performance. This thesis also incorporates a six sigma tool and process (DMAIC process) as anesthesia, surgeons, nursing, management, and engineering work together to collect data and improve processes. The DMAIC process offers the ability to more effectively and accurately (1) define the problem provided by the customer, (2) measure performance, (3) analyze observed data, (4) implement improvements to the system through simulation, and (5) determine what solutions will be implemented based on the effects of improvements simulated.

## **Chapter 3 Methodology**

The DMAIC and DMADV (Define, Measure, Analyze, Design, and Verify) processes were both considered. The DMAIC process is a methodology well used for existing processes that does not meet specifications or do not perform adequately ("DMAIC Versus DMADV", 2016). The DMADV process is suited for processes that are not currently in existence or a system that performs optimally, but still do not meet customer expectations or a six sigma level ("DMAIC Versus DMADV", 2016). We concluded the DMAIC process is the best methodology for this situation. The DMAIC process was chosen because the VA has a process in place that does not perform optimally. Thus, using the DMAIC process, the current system can be assessed and improved.

### **3.1 DMAIC Methodology**

The OR first case on-time start process was Defined, Measured, Analyzed, Improved, and Controlled. Figure 2 defines each step in the DMAIC process and how it corresponds to thesis chapters. The problem was defined by the customer, the Durham VA Medical Center's surgical Chief of Staff. The performance of the current system was measured to statically analyze the system. This also provided a baseline for identifying targets for improvement and possible solutions. A thorough analysis of the data was completed to accurately depict bottlenecks within the pre-surgical patient flow. Then, a solution that was within budget was recommended for every problem found. Lastly, the recommendations were simulated in an Arena model to provide projected possible efficiencies.

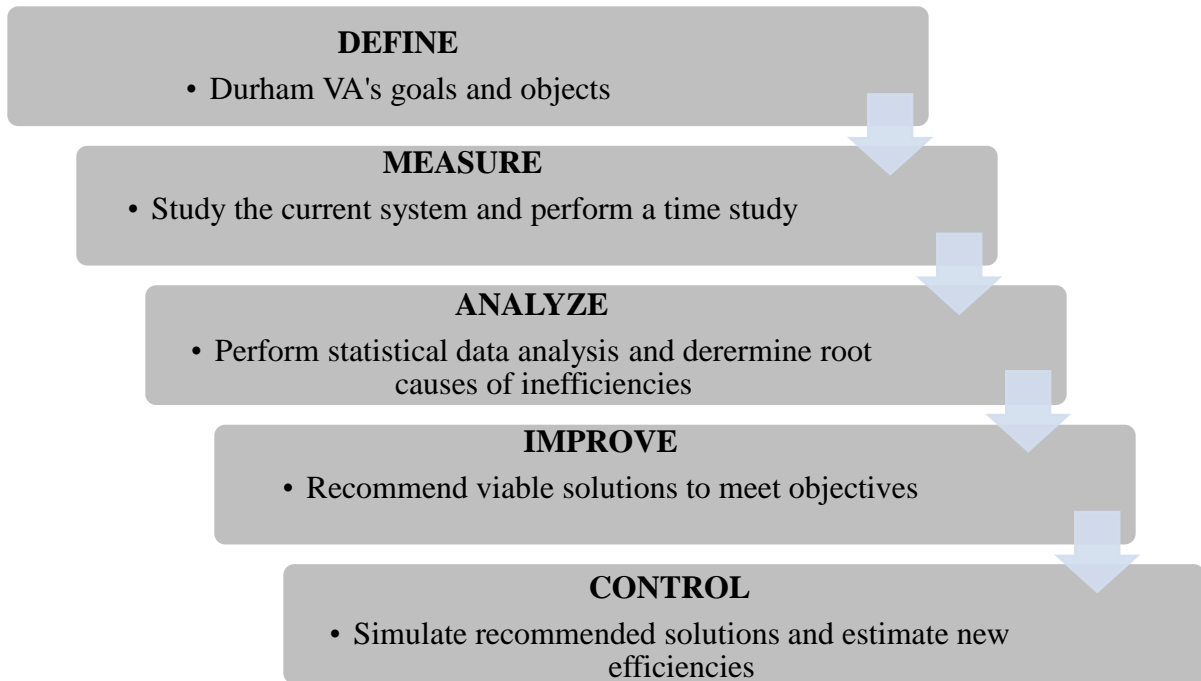


Figure 2: The DMAIC Process

### 3.2 Defining the Objectives

As discussed in Section 1.3, the Durham VA identified problems with first case on-time starts. The VA has concerns with major delays in surgery start time and increased patient waiting time prior to surgery. In addition, the Durham VA's current methods for communicating a patient's paperwork completion status prohibit VA staff from utilizing their time optimally. In Section 1.4, the project goals and objectives were defined in partnership with the VA. The four objects are to (1) determine the distribution of patient's time spent in the system and identify factors that contribute to the current efficiency rate of on-time starts, (2) develop a strategy to increase the percent of on-time starts, (3) develop a model to

simulate the current and recommended process, and (4) improve the efficiency of paperwork documentation.

### **3.3 Measuring the Current Process Performance**

A detailed plan was created to measure the process performance. To accurately describe how a patient's time is spent in the system and to identify the attributes of the current efficiency rate of on-time starts, the system was studied to understand the requirements for a patient to be admitted to the OR. The requirements encompass each process, the staff members, and documentation required. A detailed time study plan was created to capture the process. The staff members and the role of the OR administrative nurse were studied for one week each. The two-week study offered insight and data was collected about the current flow. A time study was conducted for 2.5 months to collect time stamps on the completion time of each process that a patient encountered prior to surgery for 39 patients. Studies were conducted to identify where roadblocks were throughout the process a patient goes through prior to surgery.

Five types of performance measures were obtained. The first performance measure was the time each patient spent completing each process. The processing times include (1) patient arrival to registration, (2) patient dressed and placed in 4B, (3) paperwork completion, (4) patient's name written on board, (5) patient's name seen on board, (6) patient escorted to pre-op, (7) patient arrival to pre-op, (8) patient pre-op interview, (9-12) individual team members arrival to pre-op (Anesthesiologist, Operating room Nurse, Attending, and Resident), (13)



briefing completion, (14) intravenous therapy (IV) administering, (15) patient escorted to the OR, and (16) patient arrival to the operating room. The second performance measure was the percent of on-time starts. The third performance measure was the step in the overall process that each patient was administered his or her IV. The fourth performance measure was rather or not the surgical team performed a block in pre-op. Lastly, the fifth performance measure was a summary of primary reasons for delay.

### **3.4 Analyzing the Data**

The data collected from the time study was analyzed to determine the root causes of inefficiencies within the system. The data was used to calculate the amount of time in minutes that each patient took to complete each process. The averages were calculated and statistically analyzed to show how the time that it takes to complete each individual process impacted the total time that it took to complete the overall process. The statistical analysis included the calculation of (1) the mean, standard error, median, mode, standard deviation, sample variance, and half widths for each subprocess and major process, (2) the 95% confidence intervals for each process, (3) the percent of on-time starts, (4) the percent of average patient time allocation per process, (5) the percent of paperwork completed before and after 7:00am, (6) the average time a patient spent idle, (6) the average time a patient spent obtaining pre-surgical care, and (7) fitted distributions for each process.

The simulation model was designed to imitate the current patient flow from the time the patient checks-in for his or her surgery to the time he or she is admitted to the operating

room. The simulation provided an analysis of the current system and additional performance measures.

### **3.5 Improvement Recommendations**

An array of potential solutions was recommended to improve the efficiency of the patient's process. The solutions aim to address the VA's concerns, and satisfy the goals and objectives defined by the VA. For any recommendation which required a significant change to a specific process, a tool was designed to replace the current process or layout. All recommendations were within the budget, utilized the current resources, and maintained the current staff shift hours. As a result, the VA would not have to increase resources or spend additional money to increase staffing time.

### **3.6 Controlling Future Process Performance**

It is difficult to test recommendations on the current operational system. The recommendations were implemented through a simulation model. This allows the VA to visually and statistically estimate the impact that the improvements would have on the pre-surgical process. New efficiencies were reported and compared to the current efficiency. This gives the VA an opportunity to evaluate which recommendations they will implement and which ones have the greatest impact on the overall goal of the project.

## Chapter 4 Data Collection

A four week analysis was conducted to study and learn the system. Monday, Tuesdays, Thursdays, and Fridays the first surgeries in an operating room starts at 8:00am, while the first cases for surgeries on Wednesdays begin at 9:00am due to a morning OR staff meeting. Furthermore, critical staff members, the process a patient completes from the time he or she enters the VA until the time he or she enters the operating room, as well as the vital paperwork that is needed were all studied in order to characterize and evaluate the system. It was imperative to understand every resource, location, and activity that goes into a patient's day of surgery process.

A data collection tool was formulated that noted the time a patient arrived at a location and completed every activity and the time each surgical team member arrived. The tool also noted which surgical team member completed each task and the time the patient arrived to his or her operating room. After a thorough assessment of the process, it was concluded that there were 15 important data points that were necessary to encompass all of the information needed to formulate a model and provide an accurate assessment of the efficiency of the system. In addition to collecting the 16 time stamps, the data collector noted the date and surgery type that corresponded to the case that was studied that day. The 15 time stamps collected were the time that (1) a patient arrived to registration, (2) a patient was dressed and placed in 4B, (3) paperwork was completed, (4) a patient's name was written on the board, (5) a patient's name was seen on the board, (6) a patient was escorted to pre-op (7) a patient

arrived to pre-op, (8) a patient obtained a pre-op interview, (9-12) individual team members arrived to pre-op (Anesthesiologist, Operating room Nurse, Attending, and Resident), (13) briefing was complete, (14) intravenous therapy (IV) was administered, (15) a patient was escorted to the OR, and (16) a patient arrived to the operating room.

Data was collected for 39 randomly selected business days, over a two and a half month time period. Two data collectors were needed to capture all the times each activity took throughout the process. One data collector followed the patient from the time the patient arrived to check-in until the time the patient arrived at the operating room. The other data collector simultaneously took notes and time stamped when the patient's paperwork was complete and documented the reason for any delays. The second data collector also monitored the staff flow from the time each individual surgical team member arrived to the OR until the time the team went to the operating room. In addition to time stamps, notes were taken regarding the reasons each patient had a delay in his or her processing. Each reason was placed into a specific category to determine the primary reasons for patient delays prior to surgery.

# Chapter 5 Data Analysis

## 5.1 Variable Definitions & Calculations

As defined in Table 1, 16 time stamps for each of the 39 patients observed represent the specific time noted during the time study that a patient begin that task. Subprocesses are the individual eight processes that a patient completes prior to surgery. The major processes are “4B short stay/4B” and “pre-op.” The subprocesses occur in one of the two major processes. Last, the total system refers to the summation of every process.

Table 1: Definition of Time Stamp Variables

1= Patient arrival in registration	9= Anesthesia arrival in pre-op
2= Patient dressed and placed in 4B	10= RN arrival in pre-op
3= All paperwork completed	11= Resident arrival in pre-op
4= Patient name written on board	12=Attending arrival in pre-op
5= Patient name seen on board	13= Briefing
6= Patient escorted to pre-op	14= IV administering
7= Patient arrival in pre-op	15= Patient escorted to operating room
8= Pre-op interview	16= Patient arrival to OR/Start of surgery

The time study data was divided into three levels, defined in Table 2, to specifically identify where a patient spent most of his or her time at the VA prior to arriving to the OR. All of the time stamps were utilized to calculate the outcome for each of the three levels. Level 1 is the time a patient took to complete each individual process. Level 2 is the time that a patient spent in each location. The two locations are 4B short stay/4B, and pre operation. Level 3 is the total time a patient spent in the system. The total time in the system is the time a patient checked-in to the time a patient arrived to the OR.

Table 2: Definition of the 3 Levels

Level	Description	
Level 1	The average processing times for each of the 10 calculated subprocess	
	1.	T <sub>j</sub> (shortstay)
	2.	T <sub>j</sub> (paperwork)
	3.	T <sub>j</sub> (wroteonboard)
	4.	T <sub>j</sub> (readonboard)
	5.	T <sub>j</sub> (escortpreop)
	6.	T <sub>j</sub> (ptprep)
	7.	T <sub>j</sub> (awaitbriefing)
	8.	T <sub>j</sub> (briefing)
	9.	T <sub>j</sub> (adminIV)
	10.	T <sub>j</sub> (escortOR)
Level 2	The average processing times for each of the two major processes	
	1.	T <sub>avg_4B</sub> short stay/4B
	2.	T <sub>avg_preop</sub>
Level 3	The average total time a patient spent prior to surgery	
	1.	T <sub>avg_system</sub>

The first level was to identify the amount of time that each patient spent completing each individual task, as defined in Table 3. Patient arrival in registration is the time in which a patient checked into the VA the day of his or her scheduled surgery. The time in which a patient was dressed and placed in 4B is the time during which a patient is given surgical clothes and assigned a bed to lay on while he or she waits to progress in the surgical process. Location “4B” refers to a specific area in the Durham VA that resides on the 4<sup>th</sup> floor in “wing B” where patient processing occurs. The “4B” area is considered a subprocess of the

major process “4B short stay/4B.” The time a patient’s paperwork is complete is the time stamp that all required paperwork is completed and signed off in the VA computer system. The time a patient’s name is written on the board indicates that the OR administrative nurse wrote the patient’s name on a board located near the 4B nursing station to indicate that a patient is ready to be escorted to pre-op. The time a patient’s name is seen is the time that the patient’s name is read by a 4B nurse to be assigned an escort to be taken to pre-op. Those five time stamps represent the overall time a patient spent in 4B short stay/4B. The “4B short stay/4B” is a major process that encompasses the subprocesses 4B short stay and 4B.

There are nine time stamps that encompass the total time a patient spends in pre-op. There is a one minute escort time to travel from 4B to pre-op. Thus, in all cases, the patient arrival to the pre-op holding area time will be exactly one minute after the time in which a patient’s name is seen on the board and the patient is escorted to pre-op. The pre-op interview time is when a nurse meets with the patient to inform him or her of his or her rights and responsibilities when he or she first arrives to pre operation.

Anesthesia, resident, attending, and operating room nurse arrival to pre-op is the time they individually arrive at their patient’s bay in pre-op. The briefing time is the time frame in which the surgical team’s key players (Attending, resident, anesthesiologist, and registered operating room nurse) meet with the patient to (1) introduce the surgical team and their roles, (2) ensure they have the correct patient, (3) confirm antibiotics have been given, (4) review the critical steps of the procedure, and (5) address potential problems in the case

("What's New in The Patient Safety World", 2012). The IV administering time is the time it took to administer a successful IV. The time in which a patient was escorted to the OR is the time the patient completed all routine pre-op tasks and was taken to his or her designated operating room. Lastly, the start of surgery is the time that a patient arrives to the operating room. All the time stamps were specific points in time during the day the data was collected.

Table 3: Definition of Outcome Variables for Level 1

<b>Variable</b>	<b>Definition</b>
Tj(shortstay)	Time patient j spends in 4B short stay/Check in
Tj(paperwork)	Time patient J spends in 4B/ Awaits paper work
Tj(wroteonboard)	Time it takes administrative RN to write patient j name on board
Tj(readonboard)	Time it takes 4B RN to read patient j name on board
Tj(escortpreop)	Patient j escort time to pre-op
Tj(ptprep)	Patient j prep time & pre-op interview
Tj(awaitbriefing)	Time patient j awaits briefing team/Idle time
Tj(adminIV)	Time patient j is administered an IV after briefing
Tj(escortOR)	Patient j escort time to OR
For j	Patient 1 to 39

The time for each subprocess was derived from the difference between the start of one process and the start of another. For data analysis purposes, Wednesdays were treated the same as any other day of the week. The difference in the start times of processes would still be that of the times of an 8:00am start. For example, if a patient completed a task on Wednesday from 8:20am to 8:40am, that time was changed to 7:20am to 7:40am. This allows all time stamps to be placed on the same scale. When the data is analyzed, any time after 8:00am is considered a late start. It is inaccurate to consider a patient entering the OR on



Wednesday at 8:55am a late start because Wednesday cases are scheduled to start at 9:00am. This adjustment will allow all the data to be analyzed together without penalizing Wednesday starts for starting after 8:00am. This conversion also makes it more accurate to simulate.

Due to the variability in the order that each briefing team member arrives, the time that the patient waited for the briefing team to arrive was calculated based upon the time the first team member arrived to the time the last team member arrived. Each difference was multiplied by 1440, which is the number of minutes in a 24 hour day, to convert the time stamp into minutes. The time that it takes a patient to have a complete briefing was provided by nurse and doctors as expert opinion.

The derivations are as follows:

$$T_j(l) = \begin{cases} 1440(t_{t+1} - t_i), & \text{for } i = 1, \dots, 7 \\ 1440[\max(t_{i+2}, t_{i+1}, t_i) - \min(t_{i+2}, t_{i+1}, t_i)], & \text{for } i = 9 \\ 1440(t_{t+1} - t_i), & \text{for } i = 12, \dots, 16. \end{cases}$$

Where t is a given time stamp 1,.....,16.

The first level is the average time a patient spent in each subprocess. Level 1 was calculated to determine where patients spent most of their time.  $T_{avg_k}$  is the average time a patient spends in a subprocess, for any given process k, where n= 39.

$$T_{avg}(k) = \frac{\sum_{j=1}^n T(k)}{n}, \quad k = 1, \dots, 8.$$

The second level is the amount of time a patient spends in either of the two pre-operation locations within the hospital, as defined in Table 4. Each subprocess or task is completed in 4B short stay/4B or pre-op, excluding patient escorting.

Table 4: Definition of Outcome Variables for Levels 2 and 3

<b>Variable</b>	<b>Definition</b>
Tavg_4B short stay/4B	Average time patients spend in 4B short stay and 4B
Tavg_preop	Average time patients spend in pre-op
Tavg_system	Average patients spend throughout system

The average time that patients spend in 4B short stay/4B is equal to the combined average time that patients spend in short stay, waiting for their paperwork to be complete, and waiting for their name to be written and seen on the board.

The calculations for each of the outcomes for Level 2 are as follows:

$$Tavg_{4B\ short\ stay/4B} = Tavg_{shortstay} + Tavg_{paperwork} +$$

$$Tavg_{wroteonboard} + Tavg_{readonboard}$$

$$Tavg_{preop} = Tavg_{ptprep} + Tavg_{awaitbriefing} + Tavg_{briefing} + Tavg_{adminIV}$$

The third level, also defined in Table 4, is the total time a patient spends in the system. The third level is comprised of the average time a patient spends in 4B short stay/4B, pre-op, as well as the escort time to pre-op and the OR.

The calculations for each of the outcomes for Level 3 are as follows:

$$Tavg_{system} = Tavg_{AB\ Shortstay/AB} + Tavg_{preop} + Tavg_{escortpreop} + Tavg_{escortOR}$$

## 5.2 Processing Time

The average time that a patient spends in each individual subprocess ( $Tavg_k$ ) is shown in Table 5. In the discussion that follows, the standard deviation will appear in (parenthesis) with the average. The data shows that a patient spends most of his or her time waiting for paperwork. A patient spends an average of 67.54 (37.04) minutes of his or her time waiting for his or her paperwork to be completed. That time accounts for 49% of the total time a patient spends in the system. Many veterans drive a long distance, at a very early time in the morning to arrive at the suggested time. Part of a patient's experience is attributed to his or her waiting time upon arriving to his or her appointment. The data suggests that there is an opportunity to drastically decrease the amount of time that a patient spends at the VA. In addition, veterans spend on average 7.92 (11.40) minutes for his or her name to be written on the board and on average, 12.79 (12.94) minutes for his or her name to be seen. Thus, 20.72 minutes is attributed to communication. However, there is a lot of variability in the process which suggests an opportunity for improvement. The current form of communication can be improved so that team members do not walk back and forth to a location to check the status of a patient. An improvement in communication in turn, can potentially decrease the time a patient waits to be escorted to pre-op.

Table 5: Time Study Processing Times Summary Statistics in minutes

<b>Processes</b>	<b>Average Time (Std. deviation)</b>	<b>Half width</b>	<b>Minimum</b>	<b>Maximum</b>
Tavg_system	137.90 (27.85)	9.03	39.00	194.00
Tavg_4B/shortstay	101.05 (31.01)	10.05	16.00	159.00
Tavg_shortstay	12.03 (9.83)	3.19	0.00	34.00
Tavg_paperwork	67.54 (37.04)	12.01	0.00	138.00
Tavg_wroteonboard	7.92 (11.40)	3.70	0.00	51.00
Tavg_readonboard	12.80 (12.94)	4.20	0.00	49.00
Tavg_escortpreop	1.00	-	-	-
Tavg_preop	34.79 (19.47)	6.31	7.00	88.00
Tavg_ptprep	17.59 (15.60)	5.06	1.00	61.00
Tavg_awaitbriefing	5.28 (7.48)	2.42	0.00	38.00
Tavg_adminIV	4.59 (4.19)	1.36	1.00	17.00
Tavg_briefing	*	*	*2.00	*11.00
Tavg_escortOR	1.00	-	-	-

\*Briefing time was utilized from expert opinion  
 -The time is exact and does not deviate

It is also important to assess each subprocessing time to determine where a patient spends the majority of his or her time in the system. Understanding where a patient spends his or her time gives insight to other potential attributing factors to inefficiencies and delays. If a patient spends his or her time in a location where “value is added” it would be plausible to see if the number of staff members available, medical materials stocked, or scheduling causes delays.

A patient can complete processes in 4B short stay/4B or in pre-op. In 4B short stay/4B, a patient completes four processes which include, waiting in short stay, waiting for paperwork,

and waiting for his or her name to be written and seen on the board. In pre-op, a patient goes through three processes that include surgical prep, waiting for his or her surgical team, and the administration of an IV. The total time that a patient spends in 4B is the time a patient arrives to pre-op to the time he or she is escorted to the OR. A veteran spends on average, 101.05 (31.01) minutes in 4B short stay/4B and 34.79 (19.47) minutes in pre-op. Thus, a patient spends 137.90 (27.85) minutes to get through the system, including transportation time from the two pre-surgical locations (4B short stay/4B and pre-op). This suggests that the inefficiency in the system is not caused by the patient or completion of value added subprocess, but how tasks are routinely completed by staff, as 73.32 % of a patient's time is spent waiting in 4B. Value-added subprocesses are processes where a patient is obtaining a service from a staff member that prepares him or her for surgery. While a patient requiring additional prep in pre-op is thought to be rare, it was observed for two of the 39 patients. However, due to its rarity those two data points did not provide enough information to formulate a process and fit a distribution, and thus these data points were removed from the process. Although this data was not included in the analysis, recommendations will be provided for patients who require additional prep.

### **5.3 On-time Starts**

A patient's total time in the system determines if a patient has a late or an on-time start to surgery. An on-time start is determined by the time a patient enters the operating room. If a patient arrives to his or her operating room before or at 8:00am, he or she is considered to have an on-time start. If a patient arrives to his or her operating room after 8:00am he or she

is considered to have a late start. As shown in Figure 3, only 14 of the 39 patients studied had an on-time start.

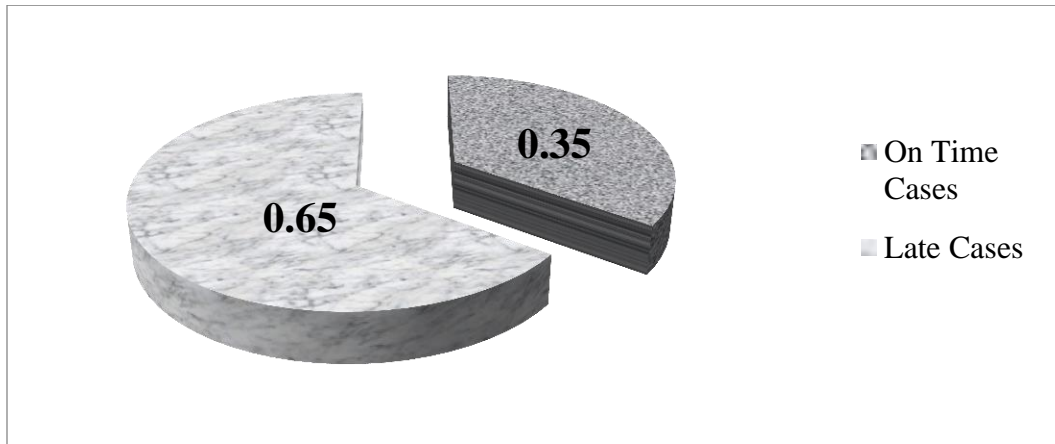


Figure 3: Percent of First Case On-time Starts

#### 5.4 Delays

Each of the 25 late cases studied were divided into seven categories based upon the primary cause of delay. The number of occurrences for each reason that a patient was delayed was estimated, as shown in Figure 4. The patients were assigned categories based on the length of time that a patient spent in a process or when the process occurred. All subprocesses occur at a specific point in the overall process, except IV administering.

An IV was administered during a patient's surgery preparation and pre-op interview or after a patient's briefing. In several cases, an IV administration was the last step in a patient's process prior to surgery. In such cases, a patient could have had an on-time start if the patient

had been given an IV during his or her prep or during the time he or she was waiting for his or her briefing. While those patients may have spent the majority of their time waiting for paperwork, all their tasks were completed prior to 7:59am and thus could have been transported to the OR to have an on-time start, if they did not still need an IV.

The primary reason for a patient having a delay in the process to be admitted to the operating room was paperwork being completed less than 30 minutes prior to or any time after 8:00am. In addition, a patient's IV administration was another primary reason for a patient's delay. Other reasons for a patient's delay include (i) waiting for the surgery team for briefing, (ii) surgery preparation in pre-op, (iii) screenings the day of surgery, and (iv) first patient no show.

It was rare that a patient did not show up the day of his or her surgery. In only one of the 39 late cases studied, a patient no showed. The decision to make the second patient the first case was not made until 7:45am. In this case the second patient took 39 minutes to get through the system from the time he or she was switched to be a first case. If the decision to make the second patient a first case had been made earlier, the second patient potentially could have had a first case on-time start.

When patients are waiting for their surgical team for their briefing they are essentially considered to be idle in the pre-surgical system. Even if a patient spent the majority of his or her time awaiting paperwork, a patient could have still had an on-time start if his or her time

through the pre-op system was optimized. Thus, if a patient had a large proportion of his or her time in the pre-op system spent waiting for his or her briefing team; the primary delay was attributed to this.

In two of the 39 late cases studied, a patient received additional surgery preparation in pre-op. In one case a patient was given a regional block and the other, a spinal block by anesthesia. The patients in both cases were more than a half an hour late to the OR. Lastly, there was one patient that was ordered to have a screening the morning of his or her surgery. In this case, the patient was admitted to the OR 44 minutes late.

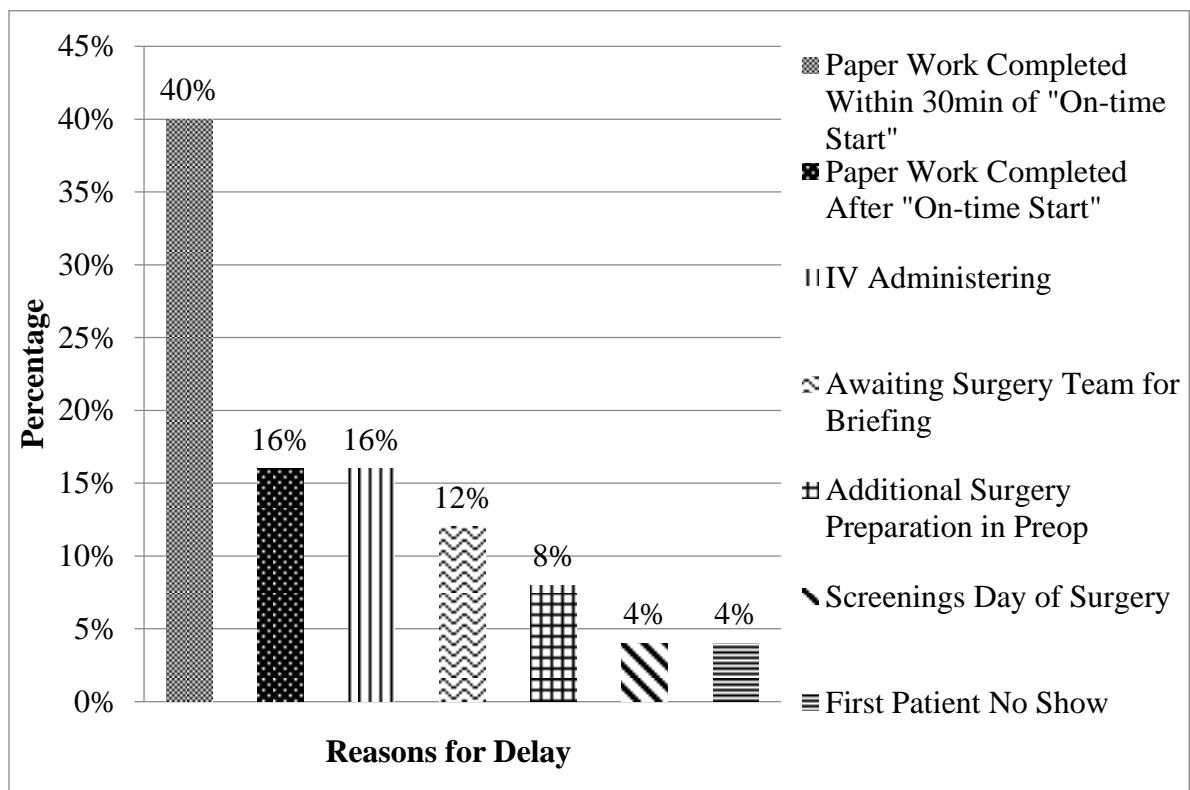


Figure 4: Reason for Delay of 25/39 Cases



The bottleneck in system was the time a patient spent waiting for paperwork. This outcome makes sense as 72% of patients observed had their paperwork completed after 7:00am, as shown in Figure 5. In these cases, patients were not able to be admitted to pre-op when it opened at 7:00am. This is a clear indication that there is inefficiency in the system. Ideally, a patient should have his or her paperwork completed prior to 7:00am to be able to progress to pre-op upon its 7:00am opening.

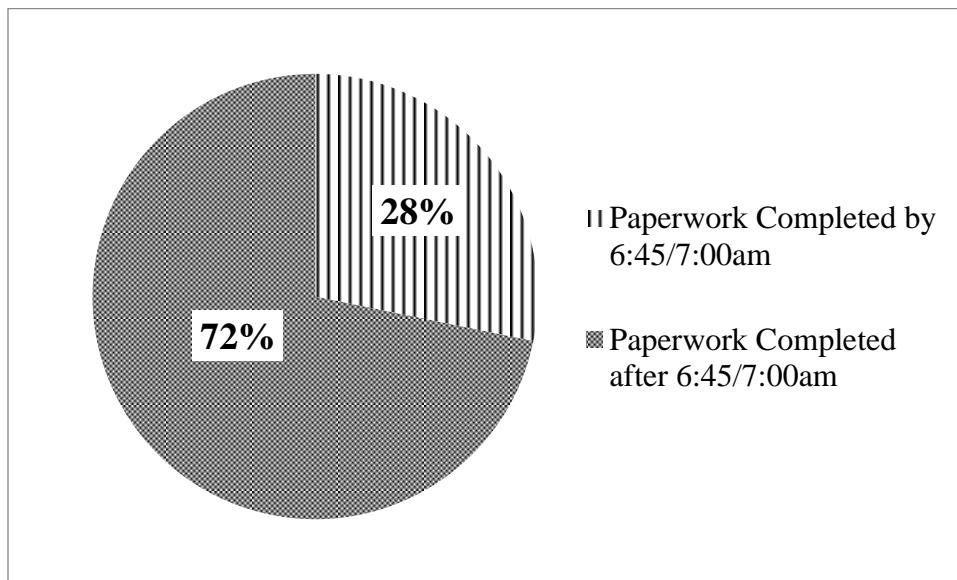


Figure 5: Paperwork Completion Time Percentages

### 5.5 Data Validation

The VA produces reports that track the percent of on-time starts each quarter. The time study data was validated by comparing the percent of on-time starts from our data collection to the percent of on-time starts from the VA's quarterly reports. The data was collected at the

Durham VA in Q3 of 2015. According to the VA's quarterly report, 37.7 % of starts were on-time in Q3. The results from the time study showed 35% of cases studied during that quarter had an on-time start. To ensure accuracy, two checks were completed to calculate the number of on-time starts. A tally was taken of each studied case that started on time. Also, an on-time start for each case was calculated based on the time the patient arrived to the OR in the data. The observed percent of on-time starts had a 95% confidence interval of (27.75%, 38.25%), with a half width of 0.42. Thus, the 37.7% of on-time starts reported by the VA were within the 95 % confidence interval of the time study percent of on-time starts and cannot be declared statistically different.

The analysis obtained from the observed data provided insight on the average time that a patient spent completing a process, the percent of on-time starts, and the primary causes of delay. A simulation model will be designed to imitate a patient's process based on observed data. The model will also be used for statistical analysis and to test recommendations for possible improvements in efficiency.

## **Chapter 6 Simulation Models**

Simulation modeling is a useful tool for understanding how a system functions and analyzing key attributes that affect the behavior of a system. It is especially important to use for testing how changes to a process would affect efficiency without actually changing the real system. Unlike an assembly line manufacturing parts, paperwork going through a chain of command or the route a bus follows through a city, a patient's process in a hospital can rarely be "experimented" on for improvements. A patient's well-being and quality of experience cannot be risked to test how changes in his or her surgical process can affect the efficiency of the system. An Arena simulation model was developed to imitate how the patient flows through his or her pre-operation process. This offers the opportunity to analyze the effects of changes in attributes, resources, process times, and the placement of a process within the pre-surgical system. A discrete event simulation model, designed in Arena modeling software, was developed to represent the process in which a patient will go through the day of his or her surgery. The model tracks the system dynamics over a given period of time.

### **6.1 Simulation Review**

The set-up and inputs for all processes are designed to imitate what was observed during the time study. There are nine operating rooms at the VA, of which one room is reserved for cardiac cases. Since cardiac patients were not included in the study, that room is not modeled. As a result, the model accounts for eight patients to fill the eight rooms. There are eight types of resources that can be utilized throughout the model. The resources are an

attending, resident, OR nurse, anesthesiologist, pre-op nurse, OR administrative nurse, escort and a 4B nurse. The simulation is modeled like a parallel system, where there are no shared resources. This is because the processing times are based on the data collection. For example, the time a patient waits for his or her briefing team is a queue time, thus additional time does not need to be modeled to represent a patient waiting for a resource. Queue times were accounted for in each process when the data was collected. All resources are delayed, while the process is seized, and then released. The seize delay and release action indicates that the process should be delayed to attend to the current entity, seizing the resource. Then, the module should delay for the service time. Each module represents one of the eight processes. Lastly, the resource should be released so that it can then be utilized by other entities. The priority of each process queue is that the first patient in, will be the first patient out.

## **6.2 Input Data**

The 39 time stamps for each of the eight processes were used to calculate the time it took each patient to complete the process. The 39 data points were used to fit distributions, using Arena's input analyzer. Due to the limitation in the number of data points, it was best to fit continuous empirical distributions for all of the processes, except the briefing time. The distributions were linearly interpolated based upon the probability assigned to each event/data point, as described in Appendix B. The briefing time was provided by nurses and doctors as expert opinion and was fit to a triangular distribution, with a minimum of 2 minutes, most likely time of 3 minutes, and maximum of 11 minutes. The simulation of the Durham VA pre-surgery process encompasses eight processes, and two routers. Routers are

station transfers that send an entity from one station to another. The routers transfer a patient from 4B to pre-op and then from pre-op to the OR. The model is divided into three processes based on locations in the Durham VA. The three locations are 4B short stay/4B, Pre-operation, and the operating room.

### **6.3 Patient Processing**

The 4B short stay/4B process consists of four subprocesses, as shown in Figure 6. During the processes, patients arrive to check-in and are (1) placed in 4B short stay, (2) await paperwork, (3) wait for their name to be written on the board, and then (4) wait for their name to be seen on the board. A separate module is used to duplicate the one patient entering the system so that seven additional patients are able to arrive. A total of eight patients arrive at 4B short stay to check-in. The patients arrive according to a uniform time distribution from 5:30am to 6:30am. One resource, a 4B nurse, is seized, while the process is delayed, to document that the patient has arrived, put him or her in a gown, and place them in 4B. The 4B nurse is then released to assist the next patient that checks in. The OR administrative nurse then determines if a patient's paperwork is completed. There is a 28% chance that a patient's paperwork is completed at that given time. If a patient's paperwork is not completed, the patient waits in 4B until it is complete. A patient's name is written on the board once his or her paperwork is completed. During that process, the OR administrative nurse is seized and the process is delayed as he or she walks to write the patient's name on the board. The OR administrative nurse is released once he or she has returned from writing the patient's name. Lastly, the patient's name is seen on the board, by a 4B nurse that is

seized. The process is delayed until 7:00am or until an escort is available to transport the patient to pre-op. Once the patient arrives at pre-op, then escort is released.

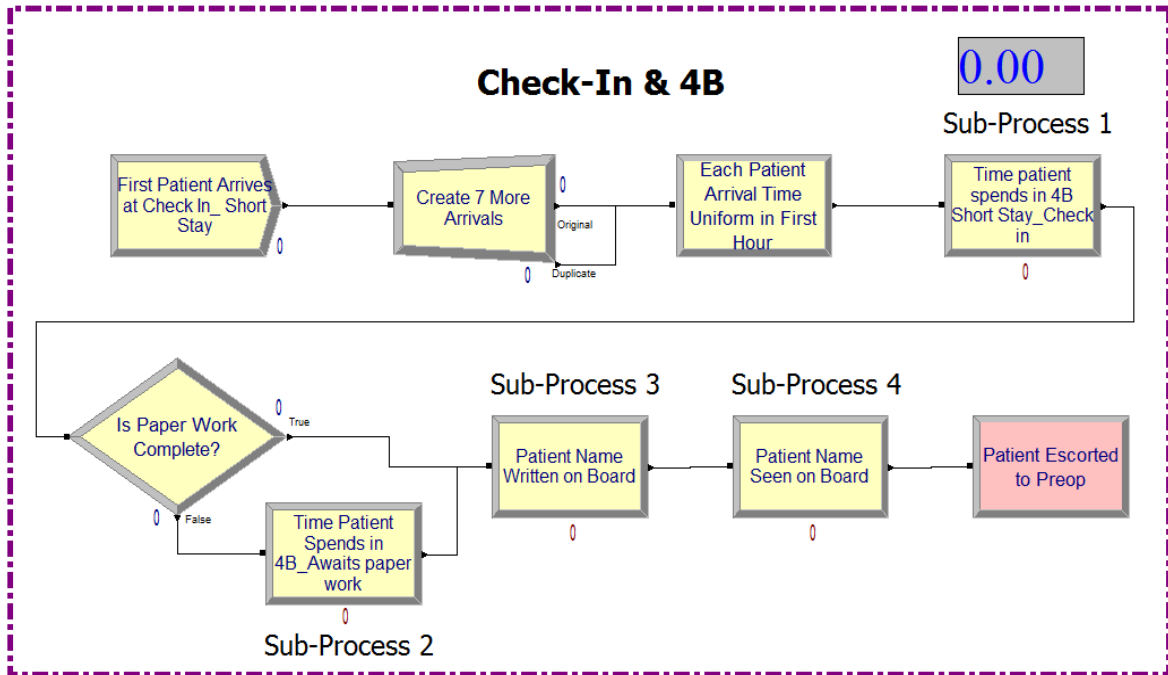


Figure 6: Arena Simulation Model of 4B shortstay/4B

The pre-operation process consists of four subprocesses. The processes include (1) a veteran receiving a pre-op interview and surgery preparation, (2) awaiting his or her briefing team, (3) being briefed, and then (4) being administered an IV. The four processes can be seen in Figure 7.

During the pre-op interview and patient prep, two resources are seized. A pre-op nurse ensures that the patient is aware and ready for surgery and has all pre-surgical preparation

completed. The patient's anesthesiologist or pre-op nurse may give him or her an IV during that time. The process is delayed until anesthesia or the pre-op nurse has completed his or her tasks. After they have finished with the patient, the resources will be released. A patient will then wait for his or her briefing team to arrive at the OR. The process is delayed until every member of the briefing team has arrived. Next, the patient receives the briefing. The patient's anesthesiologist, attending, OR nurse, and resident is seized. The process is delayed until the patient's briefing is completed. The briefing team is released when they have completed the briefing. The decide module allows 59% of the patients to be escorted to the OR once their briefing is completed. Typically, 41% of patients have not received an IV and need an IV administered after their briefing. Those patients proceed to the IV administering process in which, one resource is seized. The patient's anesthesiologist administers the patient's IV. The process is delayed until the patient has obtained a successful IV. Once the patient is finished getting his or her IV, anesthesia is released. Last, the patient is escorted to the operating room by his or her anesthesiologist.

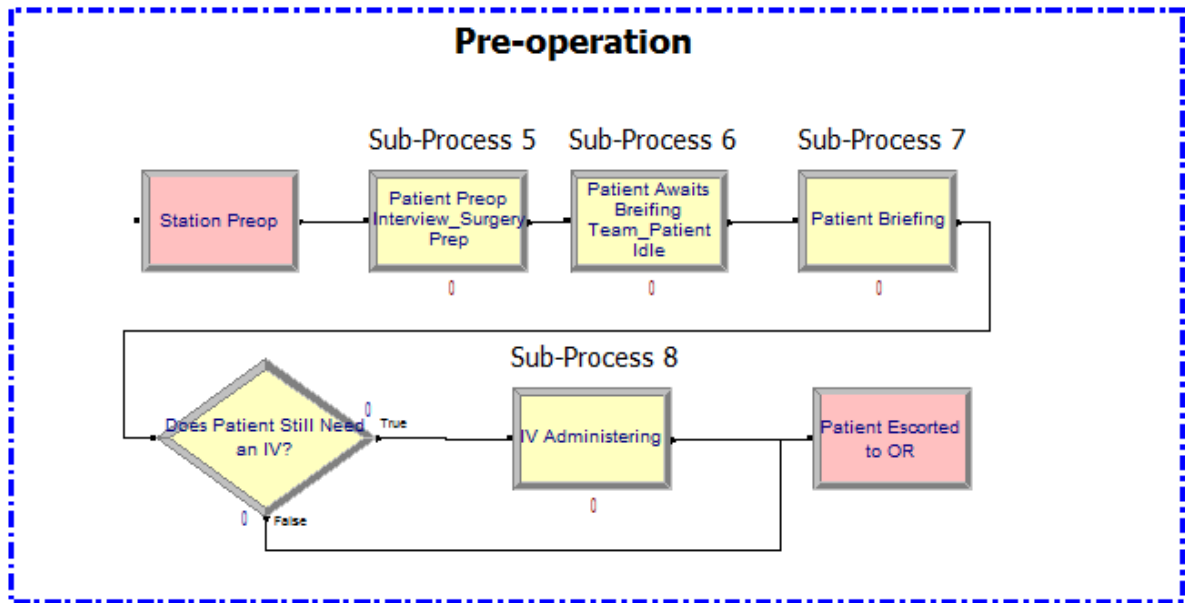


Figure 7: Arena Simulation Model of Pre-op

Figure 8 shows the simulation model of the operating room. If a patient arrives to the OR by 8:00am, he or she is considered to have an on-time start. The number of on-time starts is calculated in the operating room process of the simulation because an on-time start is based on the time a patient arrives to the OR. In Arena, "TNOW" represents the current time of the simulation. The simulation starts at 5:30am; thus, 8:00am corresponds to a "TNOW" time of 150, in minutes. If the "TNOW" is less than or equal to 150, the patient is considered on-time.



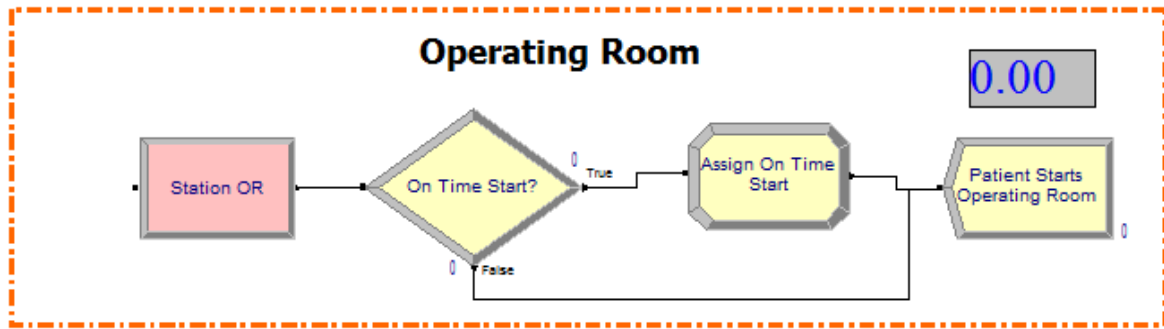


Figure 8: Arena Simulation Model of the OR

## 6.4 Simulation Parameters

The simulation ran for 50 replications of the eight first case patients going through the system. Each replication was run for 4 hours to simulate a patient being monitored from 5:30am until 9:30am. In the data collected during the time study, every patient completed his or her pre-surgery process prior to 9:30am. A variable was created to observe the time a patient arrives to pre-op. In addition, an “on-time start” variable was created to record the number of on-time starts per replication. The model also collected statistics for the entities, resources, queues, and processes, including the average number of on-time starts, patient time in pre-op, patient time in 4B short stay/4B, and the total time in system. Since the simulation was run for 50 replications, for 8 patients per day, a total of 400 patients were simulated in the model.

## **6.5 Simulation Results**

The simulation results show that there were no queue times, which is accurate as a patient's progression to the next process was solely contingent on the time it took to complete an individual process and was not delayed due to a lack of resources. Queue times were embedded in each process during the data collection. In addition, there would not be any queue times since a process is never held up by a previous patient, since all the patients in the simulation are first case patients and are not affected by any other patient's processing times. All 400 patients in the system were able to complete the entire process. Table 6 provides the average time it took patients to complete each process in the simulation model. On average it took patients 2 hours and 15 minutes to complete the pre-surgical process. Patients spent on average 1 hour and 42 minutes in 4B short stay/4B and 32.73 minutes in pre-op. The shortest time a patient was able to arrive at the OR from the time he or she checked in was 1 hour and 30 minutes. The longest time it took a patient to arrive at the OR from the time he or she checked in was 2 hours and 49 minutes. Overall 33% of patients had on-time surgery start times.

Table 6: Simulation Average Processing Times of Original System

<b>Processes</b>	<b>Time (Minutes)</b>	<b>Half width</b>	<b>Minimum</b>	<b>Maximum</b>
Tavg_system	134.86	4.99	90.03	168.80
Tavg_4B/shortstay	102.13	4.51	66.28	127.90
Tavg_shortstay	11.74	0.95	0.04	34.40
Tavg_paperwork	68.90	4.29	0.09	137.55
Tavg_wroteonboard	8.43	1.22	0.04	51.33
Tavg_readonboard	13.06	1.23	0.02	49.50
Tavg_escortpreop	1.00	-	-	-
Tavg_preop	32.73	1.56	17.80	45.19
Tavg_ptprep	17.11	1.45	0.50	61.44
Tavg_waitbriefing	5.80	0.84	0.00	38.47
Tavg_adminIV	4.55	0.75	0.00	17.49
Tavg_briefing	5.26	0.24	2.25	10.81
Tavg_escortOR	1.00	-	-	-

Figure 9 shows the distribution of the average percent of time a patient spends completing the eight processes. The simulation shows that a patient spends on average 51.09% of his or her time waiting for his or her documents to be completed, which is comparable to the 49% that the time study data showed. Furthermore, a patient only spends 25% of his or her total time in the system receiving a service from VA personnel. The patient prep, the briefing, and the IV administration are the processes in which a patient receives a service from VA personnel. This means that approximately 75% of a patient's time is exhausted waiting for a service.

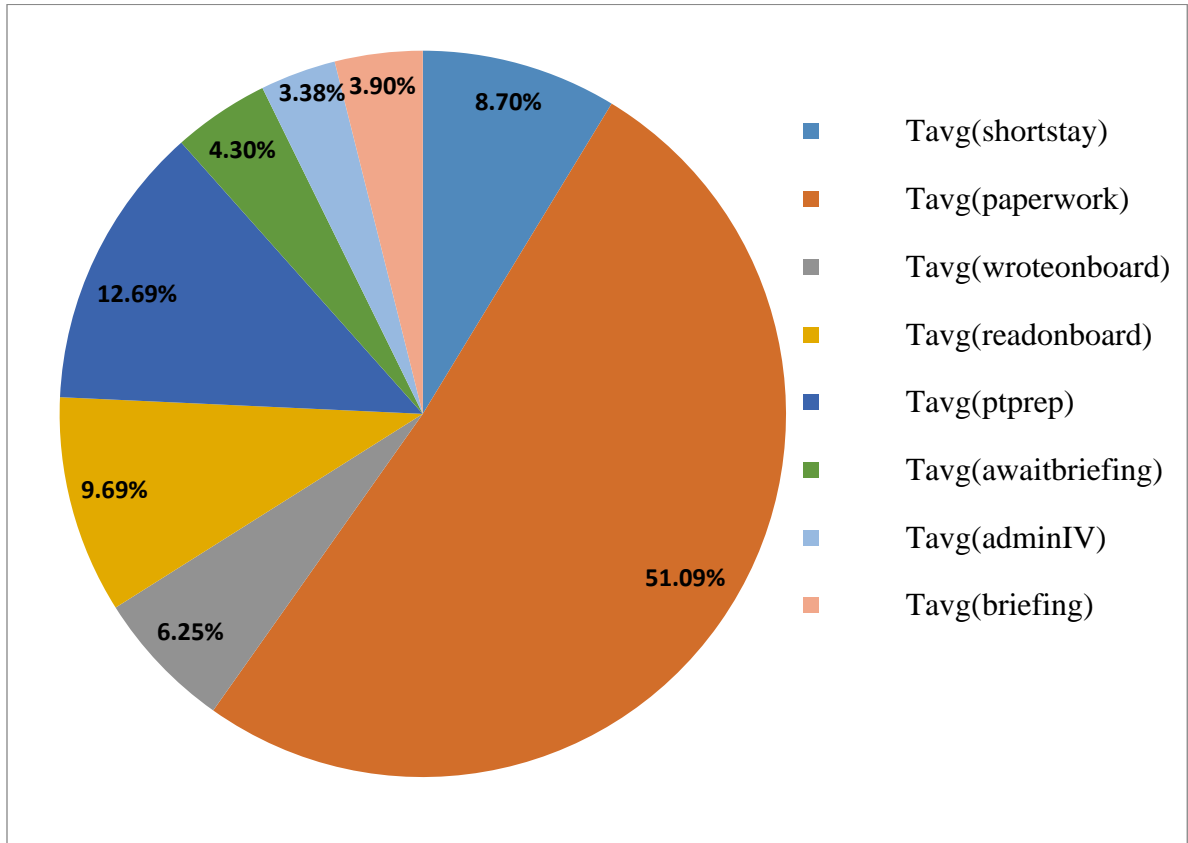


Figure 9: Average Percent of Time Patient’s Spend in Overall System

## 6.6 Simulation Verification & Validation

Variables were placed at check points to verify the model was performing as expected. There was a variable placed in 4B short stay/4B to record the time associated with a patient being escorted to the OR. The variable should not display a time greater than the maximum time that a patient spent in 4B from the time study. The second variable was placed in pre-op to display if a given patient was considered an on-time start. There is a decide module in the OR to decide if a patient is an on-time start. The patient is an on-time start if the current simulation time is 8:00am or earlier. This variable collects the number of patients per run that

are considered on-time. The visual checks allow the user to see if the number of on-time starts exceeds eight patients or counts a patient that was considered “false” in the decide module. In both cases this shows if there is error in the simulation. After the model was verified the statistics from the runs were validated.

The simulation was validated using three methods. Using Excel’s data analysis tool, the descriptive statistics were calculated for each major and subprocess. From the statistical analysis, confidence intervals were calculated at a 95% level of confidence for the Durham VA pre-surgery observed processing times in minutes. The Arena model simulated 50 replications of the overall process. The average and half widths from the Arena statistical analysis summary were used to calculate the 95% confidence intervals for each process.

The first method of validation was to determine if the data between each subprocess collected at the VA during the time study was comparable to that of the simulation model. This method provided insight regarding which specific processes had statistically significant differences. If any average subprocess time in the time study was statistically different than the model, we explored what factors may account for that difference. If there was a difference, additional statistical analysis was performed to analyze how that process would affect the overall outcome of the simulation processing time. The confidence intervals for all subprocesses overlap at a 0.05 level of significance, as shown in Table 7. Thus, the actual time patients spend in each process at the Durham VA, and the simulated time cannot be declared statistically different

Table 7: 95% Confidence Intervals (C.I.) for Method 1 Validation in minutes

<b>Subprocess</b>	<b>Durham VA- Observed Averages</b>	<b>Durham VA- Observed C.I.</b>	<b>Simulation Model C.I.</b>
Tavg_shortstay	12.03	(8.84, 15.21)	(10.79, 12.69)
Tavg_paperwork	67.54	(55.53, 79.55)	(64.61, 73.19)
Tavg_wroteonboard	7.92	(4.23, 11.62)	(7.21, 9.65)
Tavg_readonboard	12.79	(8.56, 16.99)	(11.83, 14.29)
Tavg_ptprep	17.59	(12.53, 22.65)	(15.66, 18.56)
Tavg_awaitbriefing	5.28	(2.86, 7.71)	(4.96, 6.64)
Tavg_briefing	*	*	(5.02, 5.50)
Tavg_adminIV	4.59	(3.23, 5.95)	(3.80, 5.30)

\*Briefing time was utilized from expert opinion to have a triangular distribution of (2, 3, 11)

The second method of validation was to evaluate if there were any statistical differences in the major processes. It was important to analyze how each subprocess affected the total average time that a patient spent in a major process/location, and the overall average patient time in the system. As shown in Table 8, the confidence intervals for all major processes overlap at a 0.05 level of significance. All observed point estimates lie within the simulated confidence intervals. Thus, the actual time patients spend in each major process and total time at the VA prior to surgery at the Durham VA cannot be declared statistically different than the simulation model.

Table 8: 95% Confidence Intervals for Method 2 Validation in Minutes

<b>Major Process</b>	<b>Durham VA- Observed Averages</b>	<b>Durham VA- Observed C.I.</b>	<b>Simulation Model C.I.</b>
Tavg_4B/shortstay	101.05	(91.00, 111.10)	(97.62, 106.64)
Tavg_preop	34.79	(28.48, 41.12)	(31.17, 34.29)
Tavg_system	137.90	(128.87, 146.93)	(129.87, 139.85)

The third method was to validate the number of on-time first cases between the VA quarterly reported data, the time study data, and the simulation model. The percentage of on-time starts reported by the VA, the time study, and simulation model are shown in Figure 10. In the third quarter of 2015, the VA reported 37.7% of the first cases were on time, and the time study shows 35.0% on-time starts for the observed OR first cases. The simulation model estimated an average of 33.0% of on-time starts with a half width of 0.42, providing a 95% confidence interval of (27.75%, 38.25%) of on-time starts. The confidence interval of the simulated model includes the observed 2015 third quarter value and the time study observation. Thus, the observed percent of on-time starts and the Durham VA quarterly reported percent of on-time starts cannot be declared statistically different than the simulated percent of on-time starts.

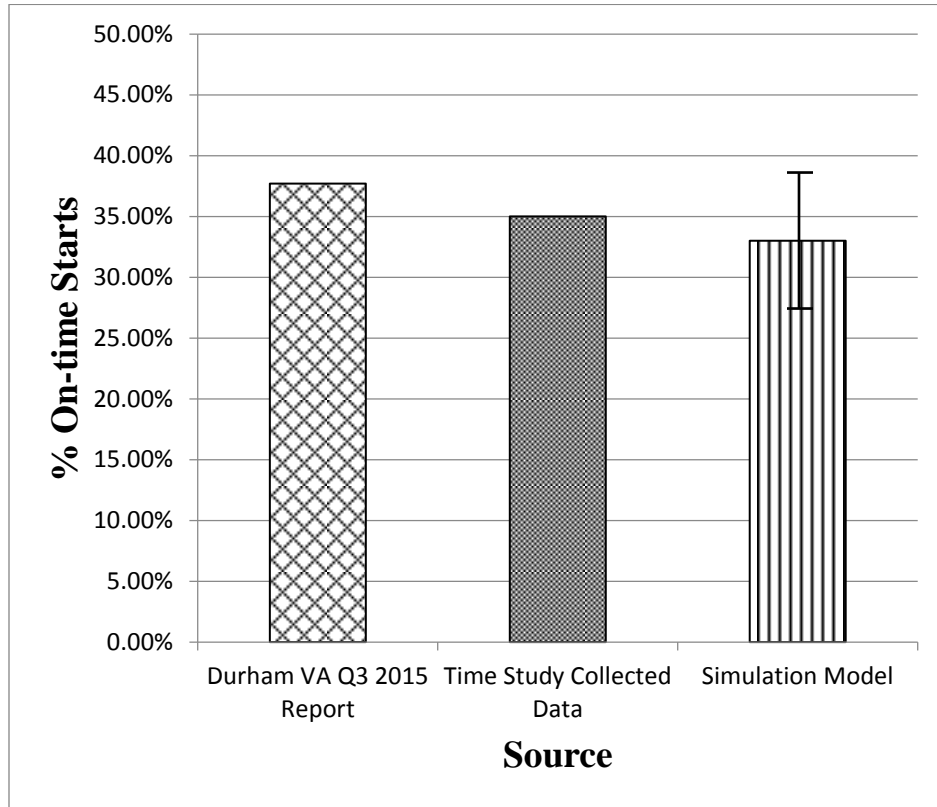


Figure 10: Percent of On-time Starts by Source of Data

## 6.7 Simulated Recommendations

Simulating a process is useful for operational systems, especially systems that affect the well-being of people. Recommendations can be controlled by manipulating the simulation model as opposed to running trials at the VA Medical Center. The simulation of the current system can be adjusted to identify constraints that will decrease processing times. Two constraints were imposed. The first constraint was to improve the bottleneck in the system to improve the processing time of that specific process. The second constraint was to vary the processing times in which a patient is not interacting with a surgical team member. Constraints 1 and 2



restrict processing times to improve the overall time that a patient spends in the pre-surgical process.

### **6.7.1 Imposing Constraint 1**

Constraint 1 explores improving the bottleneck. The bottleneck in the process is the time that the patient spends waiting for his or her paperwork to be completed. The time that a patient spends waiting for his or her paperwork to be completed, accounted for 51% of the patient's total time in the system. The time a patient spends awaiting paperwork in the simulation model has a continuous empirical distribution that encompasses all of the 39 data points. The simulation model for Constraint 1 has a triangular distribution that has a minimum time of 1 minute, a most likely time of 30 minutes and a max of 60 minutes. The distribution was changed from a continuous empirical distribution to a triangular distribution to force a targeted processing time. The 4B area does not "open" until 6:00am, which means patients are not able to leave 4B short stay until then. This time is accounted for in the time a patient spends in 4B short stay. That gives a one hour window for paperwork to be completed, since pre-op does not open until 7:00am. Since no system is perfect and some of the attendings are only at the Durham VA the days they have surgery, the percent of patients that have their paperwork complete upon being admitted to 4B remains the same. If a patient's paperwork is not completed upon being placed in 4B, the time in which his or her paperwork is completed follows the triangular distribution. A patient's paperwork is targeted to be completed within 30 minutes of him or her arriving to 4B, and in worst case scenario, completed within 1 hour.

Most patients have their paperwork completed within 30 minutes of arriving to 4B because the most likely value of the triangular distribution is 30 minutes.

Table 9 shows the average completion time for each process when imposing Constraint 1. All of the process completion times were comparable to that of the base case simulation, except for the average completion time for patient documentation. Veterans on average waited 31.34 minutes for their paperwork to be completed, compared to an average of 68.90 minutes that they would have to wait currently. The overall time that a patient spent in the system was reduced by 33.1% under Constraint 1.

Table 9: Comparison of Average Process Completion Times and (Half Widths)

<b>Processes</b>	<b>Original Model (Minutes)</b>	<b>Constraint 1 (Minutes)</b>	<b>Constraint 2 (Minutes)</b>
Tavg_system	134.86 (4.99)	96.56 (3.56)	94.84 (3.39)
Tavg_4B/shortstay	102.13 (4.51)	64.69 (2.41)	65.12 (2.50)
Tavg_shortstay	11.74 (0.95)	12.09 (0.93)	12.28 (0.91)
Tavg_paperwork	68.90 (4.29)	31.34 (1.34)	31.31 (1.44)
Tavg_wroteonboard	8.43 (1.22)	7.93 (1.23)	8.39 (1.25)
Tavg_readonboard	13.06 (1.23)	13.35 (1.54)	13.14 (1.48)
Tavg_escortpreop	1.00	1.00	1.00
Tavg_preop	32.73 (1.56)	31.87 (2.06)	29.72 (1.78)
Tavg_ptprep	17.11 (1.45)	17.29 (1.72)	17.83 (1.64)
Tavg_waitbriefing	5.80 (0.84)	4.81 (0.65)	2.00 (0.04)
Tavg_adminIV	4.55 (0.75)	4.31 (0.75)	4.57 (0.77)
Tavg_briefing	5.26 (0.24)	5.46 (0.25)	5.33 (0.21)
Tavg_escortOR	1.00	1.00	1.00
% of On-time Starts	33% (0.42)	53.75% (0.47)	57.25% (0.44)

## 6.7.2 Imposing Constraint 2

The second constraint focuses on improvements to the processes in which a patient waits.

Processes that involve a patient receiving care or interacting with a surgical team member are not adjusted as those processing times are harder to control as they are based upon the skill of the expert that is outside of the scope of the project. These clinical processes include patient preparation, pre-op interview, patient briefing, and IV administration. The processes that are adjusted are the time that a patient waits for paperwork to be completed and the time a patient spends idle, awaiting the briefing team. The time that a patient waits for his or her paperwork to be completed has the same distribution as Constraint 1, with a triangular distribution that has a minimum time of 1 minute, a most likely time of 30 minutes and a max of 60 minutes. This requires a larger percentage of patients to have their paperwork complete by 7:00am. The time that a patient spends idle, awaiting his or her briefing team has the same continuous empirical distribution as the original model. A decision module is added, that determines if the patient's surgical team is there. Constraint 2 requires all of the surgical team members to be in pre-op by the time their patient arrives in 95% of cases. Ideally, the surgical team will be at pre-op once they see that the entire patient's documentation is completed and is being escorted to pre-op. This reduces the delay caused by the briefing team. Since no system is perfect, the simulation model has 5% of patients who have to wait for their briefing team.

Table 9 also shows the average completion time for each process when imposing Constraint 2. All of the process completion times were comparable to that of the simulation model when

constraint 1 is imposed, except the average time a patient waited for his or her briefing team. In addition to changing the time a patient waits for paperwork, 95% of patients no longer have to wait for their briefing team to arrive. This constraint would reduce the average time a patient waits for the briefing team to 2 minutes, compared to 5.28 minutes that patients currently wait. The total time that a patient spent in the system was reduced by 34.8%. While this is only about a 2% difference between the total time that a patient spends in the system from Constraint 1 and Constraint 2, this translates to eight additional patients having an on-time start based on the 400 simulated patients.

### **6.7.3 Comparison of Simulated Recommendations**

Table 9 provides a comparison of the original simulation model and the simulation model of Constraint 1 and Constraint 2. Under Constraint 1, the new percent of on-time starts is 53.75%, which is a 62.88% increase, compared to the base case simulation model of 33%. Under Constraint 2, the new percent of on-time starts is 57.25%, which is a 73.48% increase, compared to the original simulation model of 33%. Constraint 2 would potentially increase patient satisfaction as his or her waiting time would substantially decrease and as a result, he or she would spend less time in 4B and pre-op. The improvements made under Constraint 2 are ideal compared to the current simulation and the simulation for Constraint 1, as it offered the most on-time starts. In an ideal system, if every patient's paperwork was completed by the time pre-op opens at 7:00am, this could have a significant impact on the percentage of on-time starts.

## **Chapter 7 Recommendations**

There are seven proposed process improvements to address the seven reasons for delays in the system. The first recommendation is to prevent a delay due to the placement of a patient's IV administration during his or her pre-op process by standardizing when patients receive their IVs. Patients typically receive their IV when they first arrive to pre-op, which is accounted for in the patient prep time process. In 41% of cases a patient did not get an IV until it was time for him or her to be escorted to the OR. It is recommended that all patients receive their IV at a set time, during their patient prep time, upon arrival to pre-op.

The second recommendation is to prevent a delay due to a patient receiving additional surgery preparation in pre-op by limiting the performance of a block. A block should only be performed if there is enough time to do so without affecting a patient's on-time start. Some anesthesiologists find it beneficial to do a block in pre-op due to the number of pre-op nurses available that could assist with the block. It is recommended that a block not be performed in pre-op unless there is enough time to do the block and still have an 8:00am arrival to the OR. The time left for an anesthesiologist to do a block in pre-op is based upon the judgment and expertise of the anesthesiologist.

In some cases, a patient will need additional screenings the day of his or her operation. The time study showed that these patients had the latest on-time starts of all late patients. It is recommended to allow the second scheduled surgical patient to take the first case slot if the

original first case patient needs additional screening. Alternatively, it was recommended that any type of patient that would typically need day of screenings and testing, be scheduled for a surgery time after the first case. Identifying patients that would typically require screenings the day of surgery is based upon the judgement of the expert.

The fourth recommendation is to eliminate delays due to day of scheduling changes by reviewing all cases 24/48 hours prior to a patient's surgery if possible. In rare cases, a surgeon would decide that a patient should not be a first case. If the decision is made the morning of the patient's operation, the second patient that will be in that OR room should be switched to be a first case prior to 7:00am.

One patient observed during the time study was considered a "no show." The fifth recommendation is to set a cut-off time for patients to still be considered a first case. This would give the OR administrative nurse enough time to contact the second patient and potentially move him or her to be a first case. During the time study, the second patient was notified, but not until after 7:00am. The second patient made it through the system in 48 minutes after being notified. If the veteran was notified prior to 7:00am, the veteran could have made it through pre-op in time to have had an on-time start.

In most cases, the veterans are idle in pre-op waiting for their briefing team. It was observed that the surgical team did not have clear communication regarding where a patient was in the process. The exact reason for a patient being prevented from being escorted to pre-op was

also unclear. As a result, the surgical team members would come and go at different times, checking to see when their patient would arrive. The lack of communication would also cause a delay in a patient's briefing as a surgical team member may have left pre-op right before a patient arrived. The veteran would then have to wait until the surgical team member checked in again to see that the patient had arrived and was ready for his or her briefing. While the time was not extensive in some cases, the time can be completely eliminated. This could potentially offer more patients an on-time start, since some of their pre-op wait time will be reduced or eliminated. It was recommended that the surgical team utilize an "OR Documentation Monitoring tool." The tool can be placed on a shared drive with restricted access that shows the status of each patient being seen in the OR. The surgical team can use the Excel-based tool to view their patient's document completion status and if their patient is ready to be escorted to pre-op. If the surgical team utilizes the tool, they would be better able to time when to arrive to pre-op.

The greatest reason for a patient being admitted to the OR after 8:00am was the time when a patient's paperwork was complete. It is recommended that the surgical team utilize the "First Case On-time Start Roadmap." Figure 11 shows the suggested guideline for the latest time that each activity in the pre-surgical process should be completed for an on-time start. The "procedure time" specified in the roadmap is a targeted time that each step should be completed for an on-time start. The roadmap is a framework that can be updated to meet the needs of the surgical team, while helping to ensure surgeries start by 8:00am.


		
<b>Durham VA: First Case On-Time Start Roadmap</b>		
Step	Activity	Procedure Time
1	Surgical Tech and Circulator to Review Case Supplies	Day Before
2	Patient Check In	5:30 AM
3A	Preop Staff Arrives	6:00 AM
3B	Patient Placed in 4B	6:00 AM
4	All Paper to be Complete	7:00 AM
5	Patient Arrival to Preop	7:00 AM
6	Preop Staff Complete Assessment	7:05 AM
7	Patient Prep	7:10 AM
8	RN/Anesthesiologist Completes Interview	7:15 AM
9	Preop RN Administer IV	7:20 AM
10	Staff Complete Briefing in Preop Holding	7:30 AM
11	Surgeon in room- Huddle with OR	7:40 AM
12	Anesthesia to Transport Patient to OR	7:45 AM
13	Scheduled in Room Time	8:00 AM
NOTE: DRAFT ONLY!		

Figure 11: First Case On-time Start Roadmap

Currently, the completion and monitoring of patient paperwork is documented daily on paper. An OR administrative nurse role was created at the VA in an effort to have a staff member focused on monitoring and recommending first case improvements across all surgical types. Unfortunately, the OR administrative nurse does not have the time to analyze the system and assist the surgical team with improvements. The administrator takes the entire working shift to manually track if seven key tasks and documents have been completed in order for a patient to proceed to the next step in his or her surgical process. A delay in paperwork was the number one cause of late starts in the operating room. A “Visual Basic for



Application” (VBA) tool was created to make the documentation and tracking of patient paperwork completion easier. Furthermore, the VBA tool provides a hard copy paper trail of documentation that will better assist with the security of patient information and legal proof of paperwork completion. In addition, one of the reasons for delay was due to a patient waiting for his or her surgical team. The team will be able to access the tool anywhere throughout the VA from a shared drive that will allow the team to view what is complete and missing from a patient’s paperwork. This will assist the residents and attendings in directly seeing what their patient is missing that is preventing them from progressing in the process. Lastly, the tool stores the data electronically so that the process improvement staff member and quality engineer can analyze this data.

# Chapter 8 VBA Tool

## 8.1 VBA Background

VBA tools are used to automate procedures in Excel such as data collection, analysis, forecasting, etc. The program executes commands, customized to fulfil the user's needs more efficiently, with reduced error. Currently, the OR administrative nurse goes into the VA database and pulls up each patient's documents, using the patient's first and last name, and last four digits of the patient's Social Security number. There are four documents, two signatures, and one evaluation that each patient must have completed before being admitted to pre-op. The OR administrative nurse will periodically check each of the eight first-case patient's files within the VA's database and write down the date and time that each requirement has been fulfilled. The VA has been keeping a paper trail of the completion of each patient's vital documentation. While this system has been effective and used for many years, there is a more efficient and secure way to monitor the completion of each patient's documents.

An "OR Documentation Monitoring Tool" was created to assist the OR administrative nurse with more efficient and accurate monitoring of patient documentation needed for surgery. The tool offers flexibility to accommodate two types of users. It can be used by a user that would prefer the program to execute commands to store and update data, while offering the user ease of use. On the other hand, the tool can be used by a user that prefers to write directly to the spreadsheet to manipulate the file as he or she pleases. Regardless of the

format used, the data can be used to inform the surgical team in the “surgical team” user form of the status of all patients for a given day.

We recommend the use of this tool as it was designed to facilitate more effective communication within the surgical teams. The tool’s capabilities include user forms, error handling, message boxes and input boxes that have been put in place to make the user’s experience easy, fast, and error free.

## 8.2 Navigating the Home Screen

The VBA tool begins with a home screen user form that is displayed upon opening the Excel workbook, as shown in Figure 12. The user forms will open on the monitor in which the user opened the file. Thus, if a user is using dual monitors, he or she would have to open the file on the monitor in which he or she would like to view and make changes. The user form will display on one screen and the Excel file will display on the other.



Figure 12: Documentation Monitoring Tool- Main Menu Screen

From the home screen, a user can select one of three options, indicating if he or she is administration, a surgical team member, or would like to exit. The OR administrative nurse will have complete access to make any necessary changes, with the exception of changing the underlying VBA code. The OR administrative nurse will be able to update any patient's identification information as well as his or her surgical documentation completion status. The OR administrative nurse will also be able to save any changes made to the file. As shown in Figure 13, if the user selects "Administration," an input box will appear, allowing the user to insert a preset password.



Figure 13: Documentation Monitoring Tool- Password Required

The administration access is password restricted to allow only the OR administrative nurse to write to the Excel file. The user will be redirected to the main menu if an incorrect password is entered.

### 8.3 Navigating the Admin Screen

If the user enters the correct password, an administration user form will display, giving the admin the option to select from four options. He or she can choose to “Add a new patient,” “Go to spreadsheet,” “Start a new week,” or “Exit,” as shown in Figure 14.

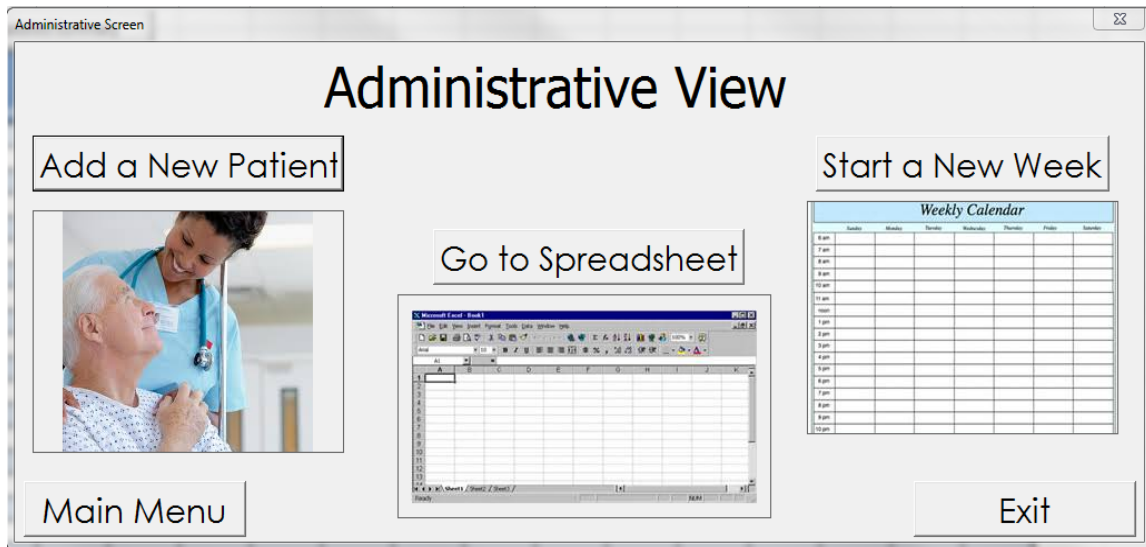


Figure 14: Documentation Monitoring Tool- Administrative Screen

If the user selects “add a new patient” to the current week, a new patient user form will display. Figure 15 shows that a message box will display, asking the user to confirm if he or she would really like to add a new patient. This will help prevent the admin from accidentally adding patients or going into the “new patient” user form unnecessarily.

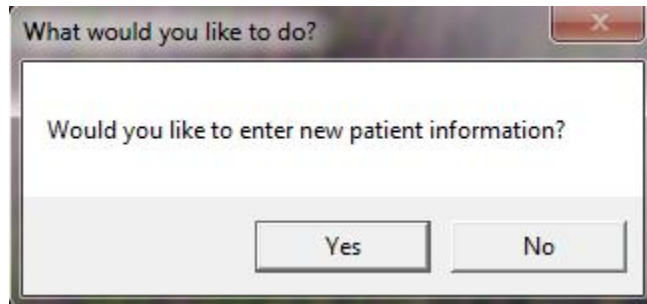


Figure 15: Documentation Monitoring Tool- Adding a New Patient

As shown in Figure 16, the user will be asked to select a date in which he or she would like to add patients. Once the user selects the day, the user is prompted to input the patient he or she would like to add, first name, last name and last four digits of his or her social security number. When the user is finished adding a given patient's information, he or she will then have to select the "add new patient button" to add the patient to the spreadsheet.

The image shows a software window titled "New Patient" with a standard Windows-style title bar (minimize, maximize, close buttons). The window contains a form with the following elements:

- A label "Date" above a date selection dropdown menu.
- A label "Last Name" above a text input field.
- A label "First Name" above a text input field.
- A label "Last 4 Social" above a text input field.
- A button labeled "Add New Patient" centered below the input fields.
- Two buttons at the bottom: "Go to Admin Menu" on the left and "Go to Spreadsheet" on the right.

Figure 16: Documentation Monitoring Tool- New Patient Information

The user can choose to go back to the Admin Menu or go into the spreadsheet if he or she has finished adding patients. If the user chooses to “Go to spreadsheet,” the user form will close and allow the user to write directly in the workbook. Figure 17 shows that there are three buttons at the top of each worksheet in the workbook. The buttons allow the user to go to the main menu, go back and add a new patient, or to save the file.

Back To Main Menu		Add New Patient		Save				
2/29/2016								
Case	Pt Name	Pt last 4	First Case	Service	Ward	Room	Attending	RES-ATT Note (30 Days)
1								
2								
3								
4								
5								
6								

Figure 17: Documentation Monitoring Tool- Spreadsheet

If the user selects to start a new week, an input box will be displayed, asking the user to enter a password. Requiring a password will prevent new weeks from being created accidentally. This is especially important as it is imperative that only the admin is creating and writing to one file for any given week, not creating accidental duplicates. Once the user enters a correct password, the user will be asked to input Monday's date for the week he or she is creating, in mm/dd/yy format, as shown in Figure 18.

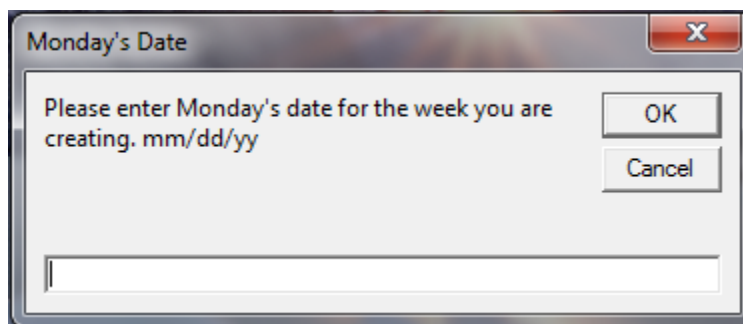


Figure 18: Documentation Monitoring Tool- Creating a New Week



After the user enters Monday's date, a new spreadsheet will be created for the new week. The prior spreadsheet will be saved and closed, not affecting the new spreadsheet. The new spreadsheet will be saved as "OR Documentation Monitoring Tool mm\_dd\_yy to mm\_dd\_yy" of the week of the date that the user inputs. The user should then select the "Add new patient" button to begin adding patients to that newly created week. Lastly the OR administrative nurse can return to the main menu or exit the document. If the admin decides to exit the document, he or she will need to enter a password in order to save.

#### **8.4 Navigating the Surgical Team**

If the user selects that he or she is a surgical team member (anesthesiologist, resident, attending, OR nurse) another user form will open, allowing the team member to select a date and room from the drop down menu, as displayed in Figure 19. The date will correspond to the day of the current week that the user would like to view the status of a patient. The room should correspond to the room that the patient is assigned to for his or her surgery.

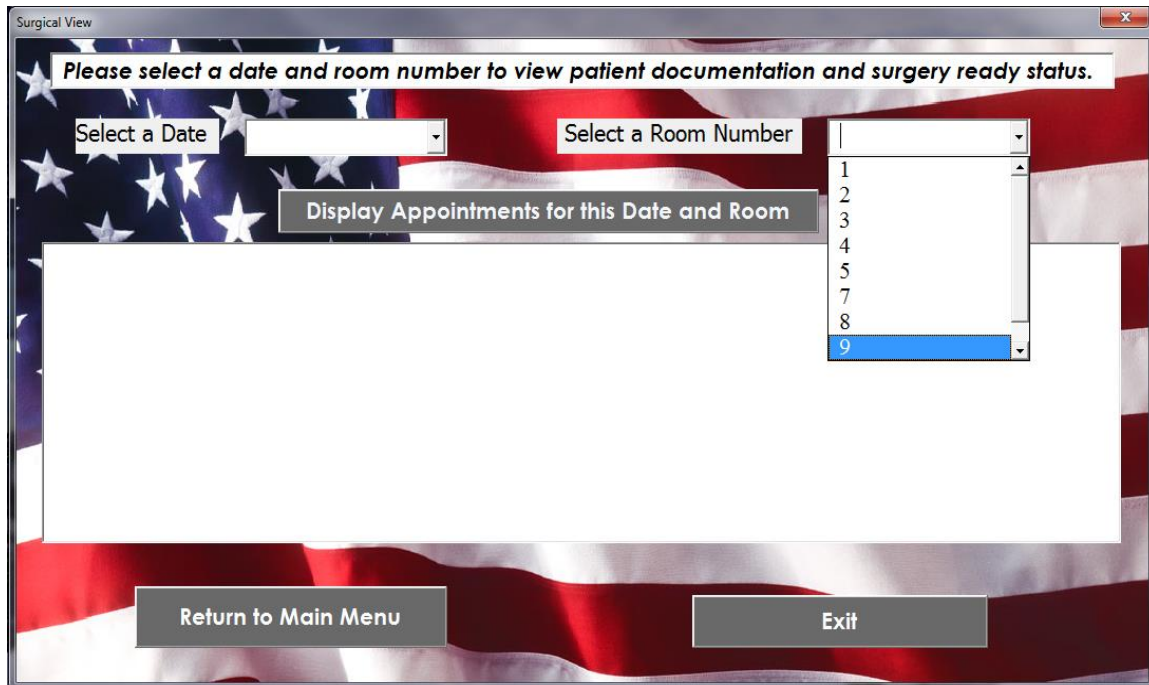
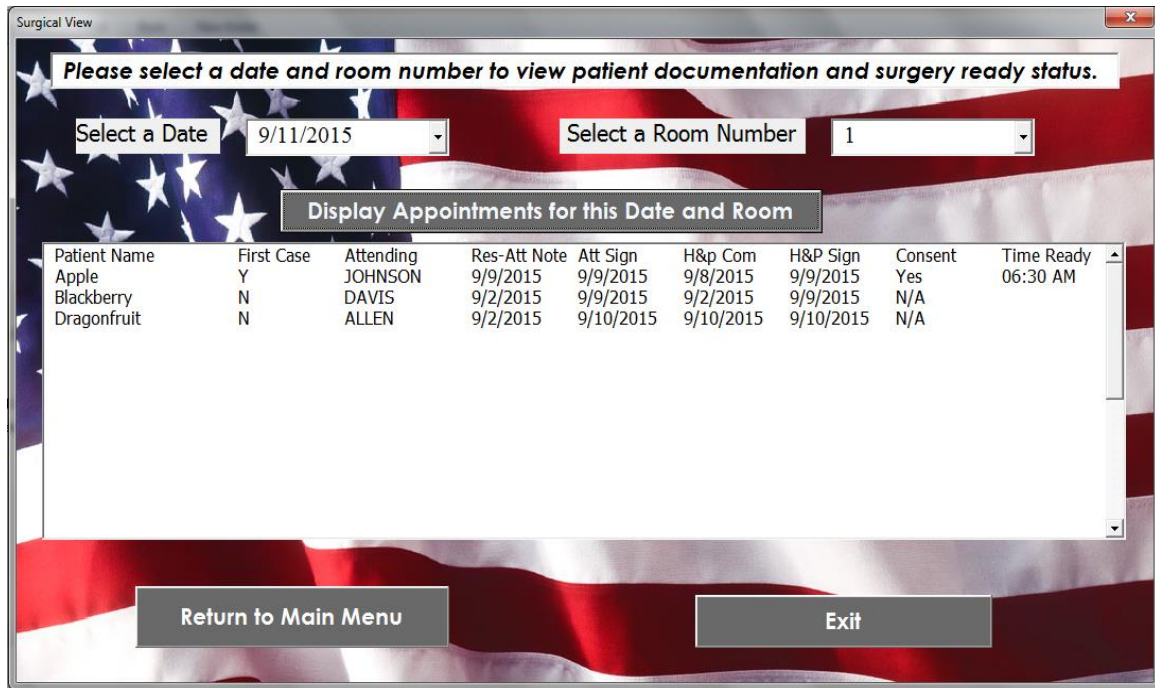


Figure 19: Documentation Monitoring Tool- Surgical Team Selection Screen

After the surgical team member selects the date and room, the user should click on “Display appointments for this date and room.” Once the button is clicked, a list box will display the patient’s information and the status of all patients in the selected room on that day, as shown in Figure 20. The patient information that will be displayed includes: the attending assigned to each patient, the documents that have been completed, the date each document was completed, an indication if the patient is the first case in that room, and the time the patient was considered ready. This will allow every member of any given surgical team to be fully informed about the status of a patient as it pertains to whether he or she is ready to be escorted to pre-op.



(The information displayed does not represent any real patient or provider information)

Figure 20: Documentation Monitoring Tool- Surgical Team Data Screen

Figure 21 shows that once the surgical team member is finished viewing the status of his or her patient, he or she can choose to return to the main page or to exit the form. If the surgical team member selects to return to the main menu, the team member will be able to search and view the status of patients in a different room or on a different date. If the surgical team member selects “Exit,” a message will be displayed asking the user if he or she is sure he or she wants to exit.

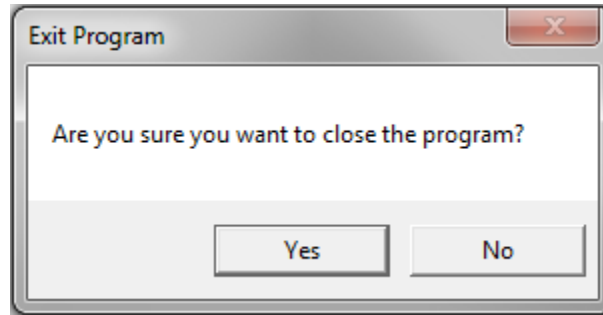


Figure 21: Documentation Monitoring Tool- Exiting the Tool

If the user selects “No,” he or she will remain on the surgical team member screen. If the user selects “Yes,” the user will be asked to enter a password to save the document before closing. Lastly, the VBA code can be accessed by selecting “Administration” from the home screen, entering the admin passcode, and then entering another password in the VBA access window to view or make changes to the VBA code.

# **Chapter 9 Conclusion**

## **9.1 Summary & Contribution**

The goal of this thesis is to assist the Durham VA with fulfilling all daily cases within the current scheduling demand; while increasing the cases in a day, optimizing the utilization of employees, work space, and resources; and reducing a patient's overall time in the OR while increasing patient satisfaction. The goals were fulfilled by achieving the following objectives: (1) providing the distribution of patient's time spent throughout the system and attributes to the current efficiency rate of on-time starts; (2) developing an improvement strategy to increase the percent of on-time starts; (3) developing a model to simulate the current and improved system by providing; and (4) improving the efficiency of paperwork documentation.

A time study was conducted to assess the Durham VA's current pre-surgical processing times and overall efficiency. Several factors were considered such as the processes that a patient must complete, the paperwork required, and the duties of staff members. The resources such staffing and surgical tools were determined to not be a concern. Thus, it was concluded that the resources alone are not negatively influencing processing times or the timing of first case starts and would not be a major factor in the research. Data was collected on all of the main factors and a thorough analysis was completed to determine the primary causes for delayed starts. In addition, each process was assessed to conclude where a patient

spent most of his or her time and how that process impacted the percent of on-time starts per quarter.

A simulation model was designed to imitate the pre-surgical process using the time study data. Several conclusions were made from the simulation model results. It was concluded that patients spent on average 2 hours and 15 minutes at the VA from the time they checked-in to the time they were escorted to the OR. A patient spent on average, 51% of his or her time, waiting for vital documents to be completed. A patient spent an average of 75% of his or her time waiting for a service, as opposed to receiving actual surgical preparation. The time a patient spent waiting for paperwork and the time a patient spent waiting for his or her briefing team in pre-op were the two processes targeted for improvement. Improving these times would allow for other processing time improvements and an increased number of cases that have on-time starts. The greatest bottleneck, paperwork, was addressed first. A constraint was imposed to force all paperwork to be completed by 7:00am. This constraint increased the percentage of on-time starts to 53.75%. The second constraint followed recommendations provided in the roadmap. Imposing constraints requiring most paperwork to be completed by 7:00am and eliminating the time that 95% of patients had to wait for their surgical team increased on-time starts to 57.25%. Thus, the simulation under Constraint 2 was the optimal solution evaluated to improve on-time starts. In a more perfect system, the percent of on-time starts would be substantially higher if all patient paperwork was completed by 7:00am, since on average a patient takes about 30 minutes to complete processes in pre-op if he or she does not have to wait for his or her briefing team.

The results of this analysis suggest that the main factors contributing to delays can be controlled by the surgical team members and staff members. Several recommendations were provided as well as tools to assist with improving the start times of first cases. A roadmap was developed to help the VA staff by providing a guideline for optimal times for each process, which would result in patients being admitted to the OR prior to 8:00am. Lastly, a VBA tool was designed to assist with the monitoring of paperwork. The tool includes features that would assist the surgical team members communication, enabling them to know what documents are preventing a patient from being escorted to pre-op, as well as where a patient should be in the system. While the research has the potential to help the VA improve first case surgical start times, there are some areas for future work.

## **9.2 Future Work**

The core philosophy behind quality improvement methods is the Japanese idea of kaizen, the “continuous search for opportunities for all processes to get better” (Berwick, 1989). “Many service-oriented industries use quality improvement techniques to improve efficiency and quality. The healthcare industry, however, has been comparatively slow to adopt these tools” (Edwards, 2008). It is imperative to have continuous quality improvement strategies in any system, especially in the medical field. There are many opportunities to expand on this research. Additional research could be done to identify inefficiencies in surgeries throughout the day, not just first cases. Improvements in surgical start times would increase the amount

of time left at the end of a surgical day. Additional cases could then be added per day, allowing more veterans to schedule surgeries. Also, the research could be extended to improve patient scheduling. There were late first cases observed during the time study due to scheduling. Patients who needed day of testing were scheduled as first cases and thus had a late start. Those patients potentially could have had an on-time start if they were not made the first case, were given advanced notice and enough time prior to surgery to complete testing. Scheduling was not within the scope of the research, but would be recommended to be considered at the Durham VA.

Further improvements could be recommended if additional data were available. RFID can be studied to understand how the VA's current RFID capabilities can be utilized to collect patient processing data. While there are time stamps in the computer system that could be utilized to obtain data regarding when documentation was completed and signed, the study would be more reliable if there was a system that was tracking each patient's tasks and times throughout the hospital. RFID would reduce data collection error and offer exact times for which a patient progressed through the system. Furthermore, with a more robust and reliable source of data, the simulation model can be further validated.

The data collected during the time trials were used to assist in getting time stamps for data that was not observed during time trials. This can present a certain level of error when verifying the model's percentage of on-time starts against what was collected and reported in the VA's system. While the percentage of on-time starts and the times for each process are



comparable to the VA reports, RFID stored data could provide more certainty due to the repetition and quality of data collected. Due to time and resource limitations, 39 data points were collected for each process, additional data points can be collected to potentially offer a better distribution and graphical fit. In addition to improving the data and model, the VBA tool can be further developed.

While the monitoring tool enables major improvements within the current documentation system, it can be updated to be more robust and user friendly. Currently, the administrator must have a base level of Excel knowledge to input information into the Excel spreadsheet. The tool could be updated so that the user enters data solely via the user form. Furthermore, when the admin logs in, the monitoring tool gives the user the option to input a patient's information (name and last four digits of the Social Security number) through the user form to populate in the corresponding Excel spreadsheet. The patient information that the user inputs was obtained from a pdf file provided from an internal VA source. The source of the information that was provided in the pdf can be used to automatically populate the Excel spreadsheet, eliminating potential user error and making the process more efficient. Lastly, after the recommended changes are implemented, the system can be reanalyzed and evaluated to provide continuous improvement options and strategies.

Seven process improvements were proposed to address the seven reasons patients had a delayed start to surgery. The distribution of patient's time spent in the system and attributes to the current efficiency rate of on-time starts were identified. Also, an improvement strategy

was developed to increase the percent of on-time starts. In addition, a simulation model of the current and improved system was provided and a tool was developed to assist in improving the efficiency of paperwork documentation.

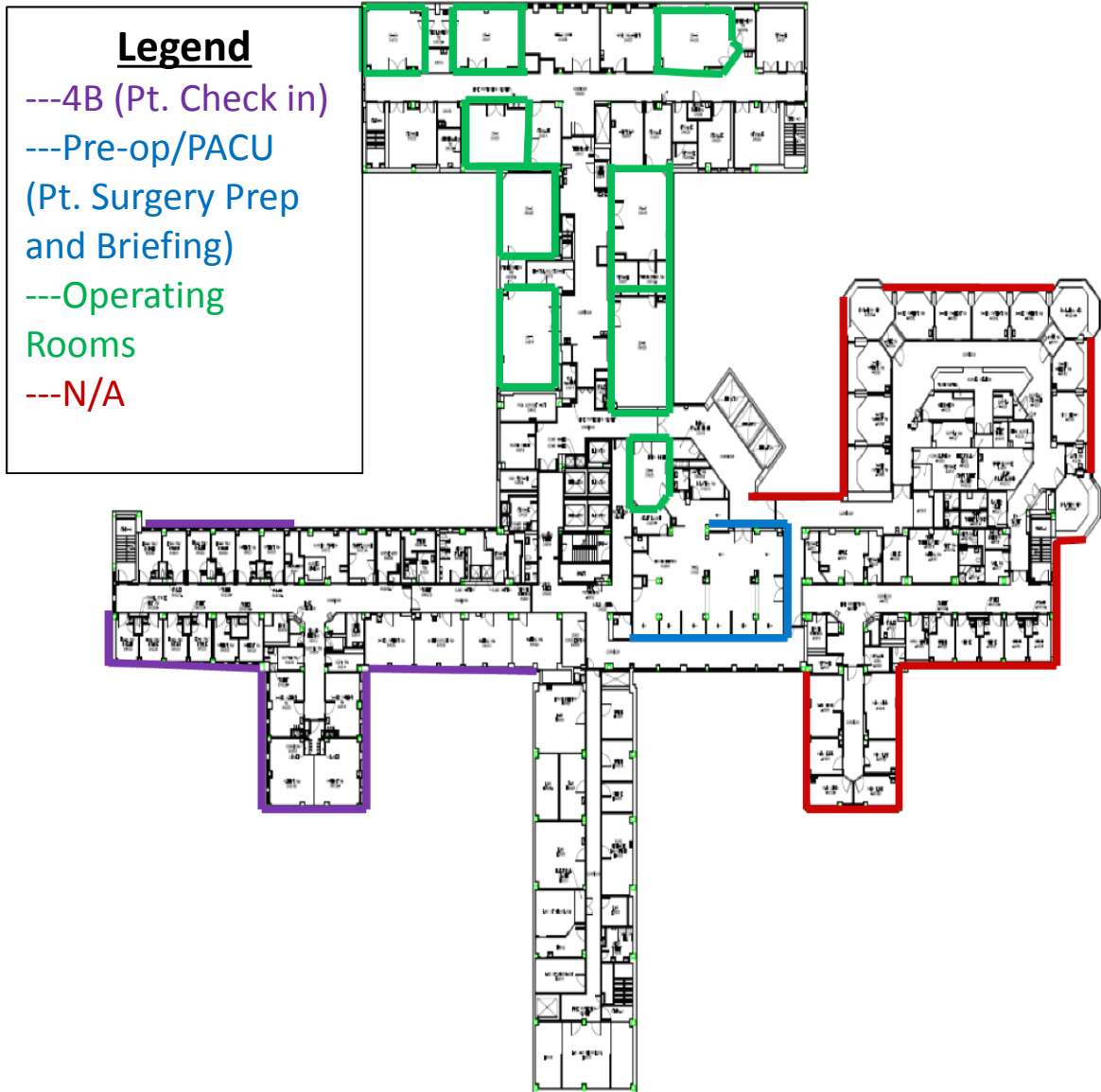
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## APPENDICES

Appendix A – Durham VA Surgical Unit Layout



Appendix B - Time Study Data

Case	Process 1	Process 2	Process 3
	Time patient spends in 4B Short Stay_Check in	Time Patient Spends in 4B_Awaits paper work	Patient Name Written on Board
1	30	30	15
2	0	0	2
3	24	100	3
4	5	138	2
5	5	55	7
6	5	112	3
7	5	63	2
8	5	70	6
9	30	98	2
10	30	112	5
11	15	43	2
12	12	30	0
13	30	55	5
14	10	65	3
15	11	99	5
16	26	96	4
17	15	125	2
18	5	82	3
19	10	55	5
20	1	0	30
21	5	77	3
22	10	17	13
23	5	25	0
24	5	88	2
25	5	83	51
26	5	25	45
27	5	101	6
28	5	83	2
29	5	130	2
30	30	68	2
31	14	63	2
32	34	63	2
33	14	63	2
34	5	25	24
35	15	90	16
36	5	125	1
37	18	30	10
38	5	25	10
39	5	25	10

Case	Process 4	Process 5	Process 6	Process 8
	Patient Name Seen on Board	Patient Preop Interview_Surgery Prep	Patient Awaits Briefing Team_Patient Idle	IV Administering
1	14	45	0	5
2	14	6	13	1
3	2	1	8	13
4	14	1	14	1
5	10	25	2	6
6	7	9	3	5
7	15	6	1	17
8	4	4	1	1
9	15	6	1	17
10	9	5	0	4
11	3	61	16	10
12	28	41	13	12
13	10	12	21	2
14	4	31	1	4
15	8	12	1	4
16	1	13	0	4
17	5	3	0	4
18	5	2	0	4
19	29	15	3	1
20	49	21	4	1
21	2	16	1	4
22	49	23	1	6
23	28	51	0	2
24	2	15	5	4
25	0	22	0	4
26	9	18	2	3
27	8	7	0	1
28	17	1	5	1
29	2	2	4	4
30	4	25	7	4
31	7	27	5	2
32	8	31	10	4
33	7	27	5	1
34	6	38	11	1
35	0	2	0	1
36	7	1	3	1
37	31	1	38	10
38	24	39	2	6
39	42	21	5	4

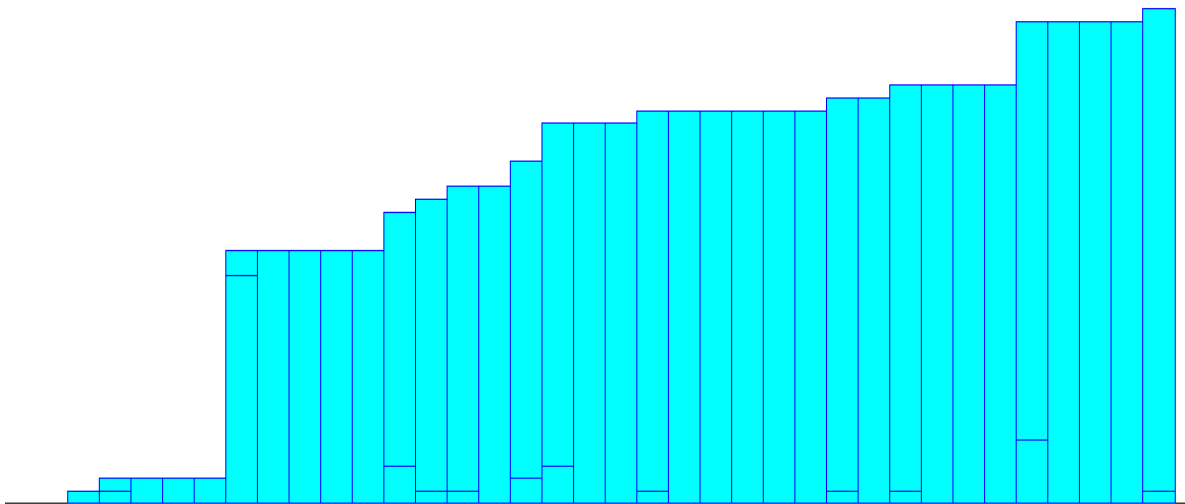


Case	Was IV separate in data from any other process?	When did patient get IV?	Surgical Block?	Did someone in the briefing team miss the briefing?
1	Yes	After Briefing	No	No
2	No	During Pt care	No	Yes
3	Yes	After Briefing	No	No
4	No	Awaiting Briefing team	No	No
5	No	During Patient Care	No	No
6	No	During Patient Care	No	No
7	Yes	After Briefing	No	No
8	Yes	After Briefing	No	No
9	Yes	After Briefing	No	No
10	Yes	After Briefing	No	No
11	No	While awaiting briefing team	No	No
12	No	Before briefing	No	No
13	No	While awaiting briefing team	No	No
14	No	While awaiting briefing team	No	No
15	Yes	After Briefing	No	No
16	No	Awaiting Briefing Team	No	No
17	Yes	After Briefing	No	No
18	Yes	After Briefing	No	No
19	No	During Patient Care	Yes- 43 min	No
20	No	While Awaiting Team	No	No
21	No	During Patient Care	Yes-27min	No
22	Yes	After Briefing	No	No
23	No	During Patient Care	No	No
24	No	Awaiting Team	No	No
25	No	During Patient Care	No	No
26	Yes	After Briefing	No	No
27	Yes	After Briefing	No	No
28	No	During Awaiting briefing team	No	No
29	No	During Awaiting Briefing team	No	No
30	No	During Patient Care	No	No
31	Yes	After briefing	No	Yes
32	No	During awaiting Briefing Team	No	No
33	Yes	After Briefing	No	Yes
34	Yes	After Briefing	No	No
35	No	During Patient Care	No	No
36	No	During awaiting team	No	No
37	Yes	After Briefing	No	No
38	No	While Patient care	Yes	No
39	No	During Patient Care	No	No

Case	Start of surgery (Time pt goes into room)	Total time in 4B	Total time in Preop	Total time in system	Time pt arrival to register to all paper work complete
1	7:52 AM	89	51	142	60
2	8:37 AM	17	20	39	0
3	8:11 AM	129	24	155	124
4	9:10 AM	159	29	190	143
5	7:50 AM	77	31	110	60
6	8:28 AM	127	19	148	117
7	8:22 AM	85	25	112	68
8	8:21 AM	85	24	111	75
9	8:23 AM	145	26	173	128
10	8:44 AM	156	36	194	142
11	8:18 AM	63	88	153	58
12	8:00 AM	70	60	132	42
13	7:56 AM	100	44	146	85
14	7:54 AM	82	40	124	75
15	8:23 AM	123	19	144	110
16	8:04 AM	127	21	150	122
17	8:34 AM	147	20	169	140
18	7:54 AM	95	7	104	87
19	8:39 AM	99	68	169	65
20	7:54 AM	80	33	115	1
21	8:35 AM	87	50	140	82
22	8:04 AM	89	43	134	27
23	7:59 AM	58	59	119	30
24	7:57 AM	97	23	122	93
25	8:44 AM	139	23	164	88
26	8:02 AM	84	36	122	30
27	8:12 AM	120	10	132	106
28	7:57 AM	107	8	117	88
29	8:35 AM	139	14	155	135
30	8:05 AM	104	49	155	98
31	7:53 AM	86	39	127	77
32	8:02 AM	107	47	156	97
33	7:51 AM	86	37	125	77
34	8:03 AM	60	61	123	30
35	7:55 AM	121	7	130	105
36	8:27 AM	138	7	147	130
37	8:11 AM	119	58	179	78
38	8:13 AM	64	67	133	30
39	7:58 AM	82	34	118	30

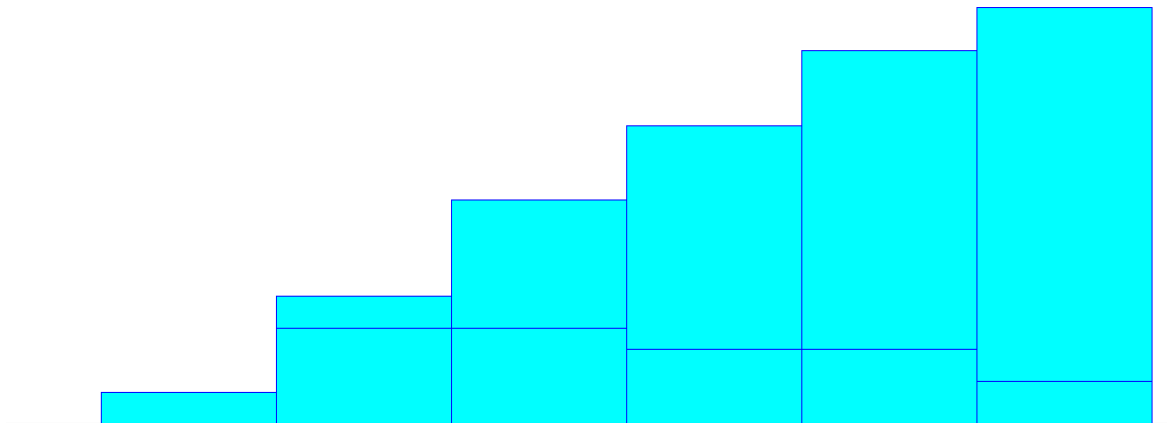
Appendix C1 – Distributions for Simulation of Process 1

<b>Process 1: Patient Arrival to Registration</b>	
Expression	CONT (0.000, 0.000, 0.026, 0.500, 0.051, 1.500, 0.051, 2.500, 0.051, 3.500, 0.051, 4.500, 0.513, 5.500, 0.513, 6.500, 0.513, 7.500, 0.513, 8.500, 0.513, 9.500, 0.590, 10.500, 0.615, 11.500, 0.641, 12.500, 0.641, 13.500, 0.692, 14.500, 0.769, 15.500, 0.769, 16.500, 0.769, 17.500, 0.795, 18.500, 0.795, 19.500, 0.795, 20.500, 0.795, 21.500, 0.795, 22.500, 0.795, 23.500, 0.821, 24.500, 0.821, 25.500, 0.846, 26.500, 0.846, 27.500, 0.846, 28.500, 0.846, 29.500, 0.974, 30.500, 0.974, 31.500, 0.974, 32.500, 0.974, 33.500, 1.000, 34.500)
Data Summary	Number of Data Points = 39 Min Data Value = 0 Max Data Value = 34 Sample Mean = 12 Sample Std Dev = 9.83
Histogram Summary	Histogram Range = -0.5 to 34.5 Number of Intervals = 35



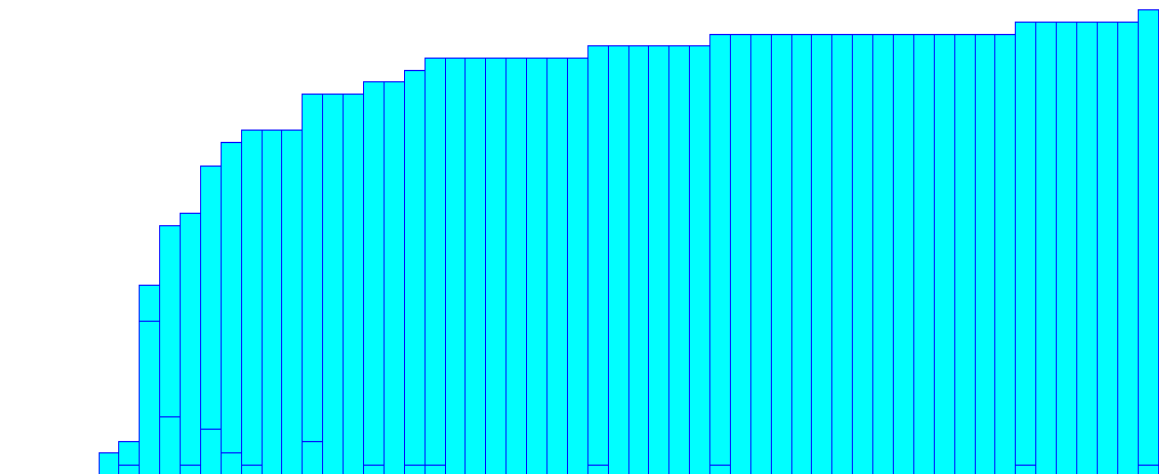
Appendix C2 – Distributions for Simulation of Process 2

<b>Process 2: Paperwork Completion</b>	
Expression (Continuous Empirical Distribution)	CONT (0.000, 0.000, 0.077, 22.999, 0.308, 46.000, 0.538, 69.000, 0.718, 92.000, 0.897, 115.001, 1.000, 138.001)
Data Summary	Number of Data Points = 39 Min Data Value = 0 Max Data Value = 138 Sample Mean = 67.5 Sample Std Dev = 37
Histogram Summary	Histogram Range = -0.001 to 138 Number of Intervals = 6



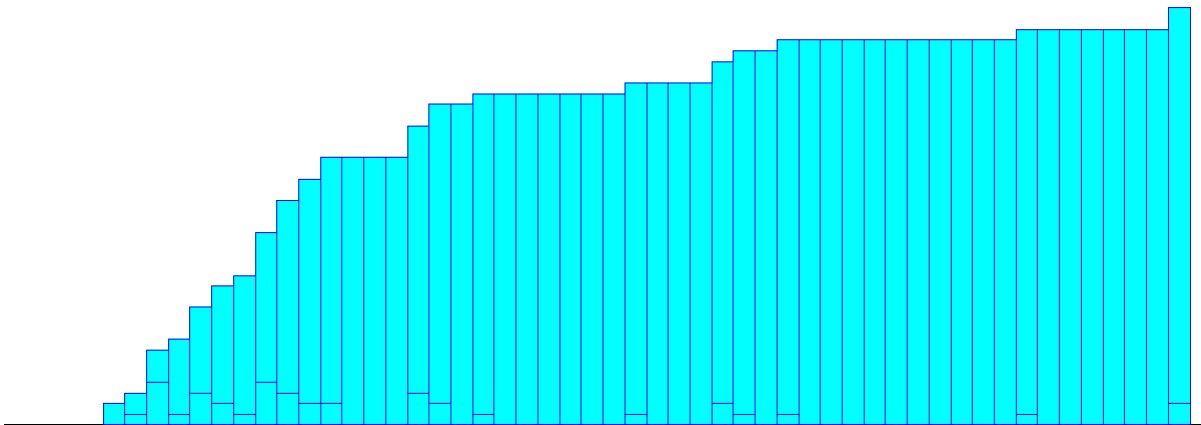
Appendix C3 – Distributions for Simulation of Process 3

<b>Process 3: Patient Name Written</b>	
Expression (Continuous Empirical Distribution)	CONT (0.000, 0.000, 0.051, 0.500, 0.077, 1.500, 0.410, 2.500, 0.538, 3.500, 0.564, 4.500, 0.667, 5.500, 0.718, 6.500, 0.744, 7.500, 0.744, 8.500, 0.744, 9.500, 0.821, 10.500, 0.821, 11.500, 0.821, 12.500, 0.846, 13.500, 0.846, 14.500, 0.872, 15.500, 0.897, 16.500, 0.897, 17.500, 0.897, 18.500, 0.897, 19.500, 0.897, 20.500, 0.897, 21.500, 0.897, 22.500, 0.897, 23.500, 0.923, 24.500, 0.923, 25.500, 0.923, 26.500, 0.923, 27.500, 0.923, 28.500, 0.923, 29.500, 0.949, 30.500, 0.949, 31.500, 0.949, 32.500, 0.949, 33.500, 0.949, 34.500, 0.949, 35.500, 0.949, 36.500, 0.949, 37.500, 0.949, 38.500, 0.949, 39.500, 0.949, 40.500, 0.949, 41.500, 0.949, 42.500, 0.949, 43.500, 0.949, 44.500, 0.974, 45.500, 0.974, 46.500, 0.974, 47.500, 0.974, 48.500, 0.974, 49.500, 0.974, 50.500, 1.000, 51.500)
Data Summary	Number of Data Points = 39 Min Data Value = 0 Max Data Value = 51 Sample Mean = 7.92 Sample Std Dev = 11.4
Histogram Summary	Histogram Range = -0.5 to 51.5 Number of Intervals = 52



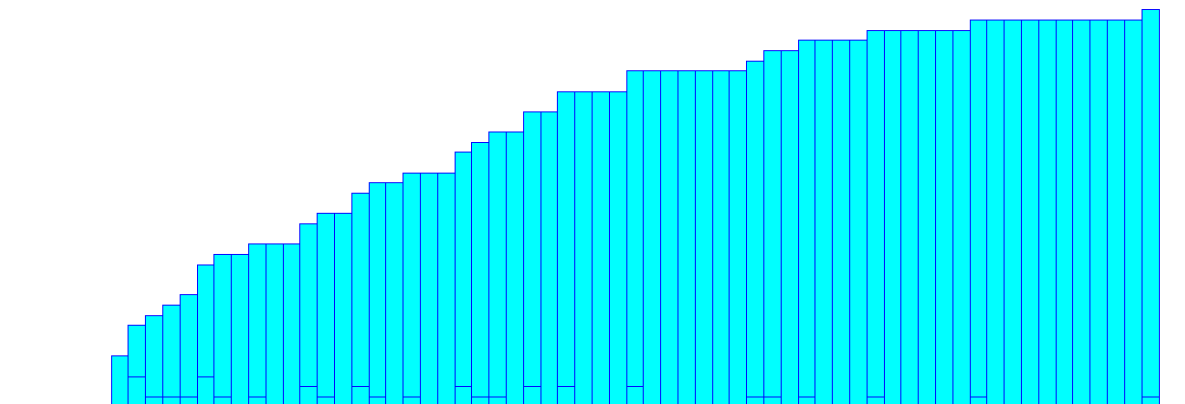
Appendix C4 – Distributions for Simulation of Process 4

<b>Process 4: Patient Name Seen</b>	
Expression (Continuous Empirical Distribution)	CONT (0.000, 0.000, 0.051, 0.500, 0.077, 1.500, 0.179, 2.500, 0.205, 3.500, 0.282, 4.500, 0.333, 5.500, 0.359, 6.500, 0.462, 7.500, 0.538, 8.500, 0.590, 9.500, 0.641, 10.500, 0.641, 11.500, 0.641, 12.500, 0.641, 13.500, 0.718, 14.500, 0.769, 15.500, 0.769, 16.500, 0.795, 17.500, 0.795, 18.500, 0.795, 19.500, 0.795, 20.500, 0.795, 21.500, 0.795, 22.500, 0.795, 23.500, 0.821, 24.500, 0.821, 25.500, 0.821, 26.500, 0.821, 27.500, 0.872, 28.500, 0.897, 29.500, 0.897, 30.500, 0.923, 31.500, 0.923, 32.500, 0.923, 33.500, 0.923, 34.500, 0.923, 35.500, 0.923, 36.500, 0.923, 37.500, 0.923, 38.500, 0.923, 39.500, 0.923, 40.500, 0.923, 41.500, 0.949, 42.500, 0.949, 43.500, 0.949, 44.500, 0.949, 45.500, 0.949, 46.500, 0.949, 47.500, 0.949, 48.500, 1.000, 49.500)
Data Summary	Number of Data Points = 39 Min Data Value = 0 Max Data Value = 49 Sample Mean = 12.8 Sample Std Dev = 12.9
Histogram Summary	Histogram Range = -0.5 to 49.5 Number of Intervals = 50



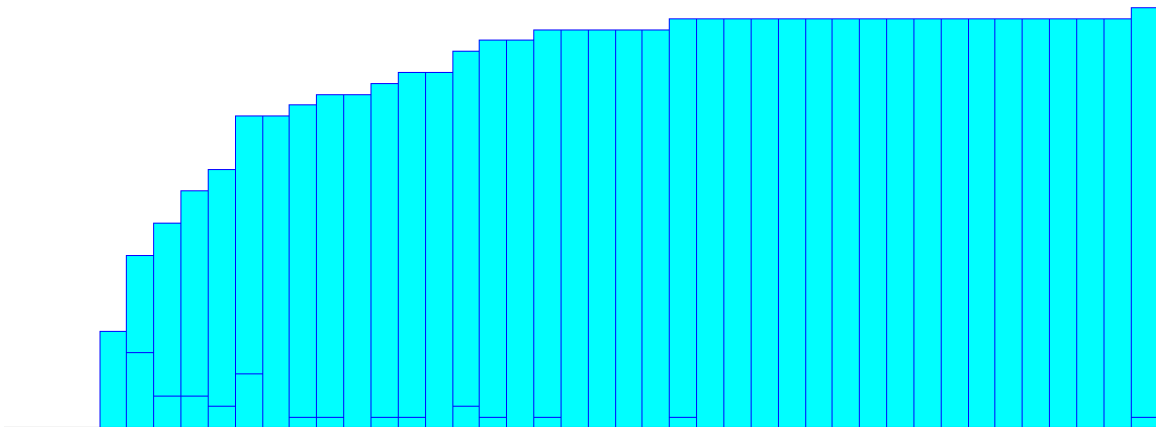
Appendix C5 – Distributions for Simulation of Process 5

<b>Process 5: Patient Prep</b>	
Expression (Continuous Empirical Distribution)	CONT (0.000, 0.500, 0.128, 1.500, 0.205, 2.500, 0.231, 3.500, 0.256, 4.500, 0.282, 5.500, 0.359, 6.500, 0.385, 7.500, 0.385, 8.500, 0.410, 9.500, 0.410, 10.500, 0.410, 11.500, 0.462, 12.500, 0.487, 13.500, 0.487, 14.500, 0.538, 15.500, 0.564, 16.500, 0.564, 17.500, 0.590, 18.500, 0.590, 19.500, 0.590, 20.500, 0.641, 21.500, 0.667, 22.500, 0.692, 23.500, 0.692, 24.500, 0.744, 25.500, 0.744, 26.500, 0.795, 27.500, 0.795, 28.500, 0.795, 29.500, 0.795, 30.500, 0.846, 31.500, 0.846, 32.500, 0.846, 33.500, 0.846, 34.500, 0.846, 35.500, 0.846, 36.500, 0.846, 37.500, 0.872, 38.500, 0.897, 39.500, 0.897, 40.500, 0.923, 41.500, 0.923, 42.500, 0.923, 43.500, 0.923, 44.500, 0.949, 45.500, 0.949, 46.500, 0.949, 47.500, 0.949, 48.500, 0.949, 49.500, 0.949, 50.500, 0.974, 51.500, 0.974, 52.500, 0.974, 53.500, 0.974, 54.500, 0.974, 55.500, 0.974, 56.500, 0.974, 57.500, 0.974, 58.500, 0.974, 59.500, 0.974, 60.500, 1.000, 61.500)
Data Summary	Number of Data Points = 39 Min Data Value = 1 Max Data Value = 61 Sample Mean = 17.6 Sample Std Dev = 15.6
Histogram Summary	Histogram Range = 0.5 to 61.5 Number of Intervals = 61



Appendix C6 – Distributions for Simulation of Process 6

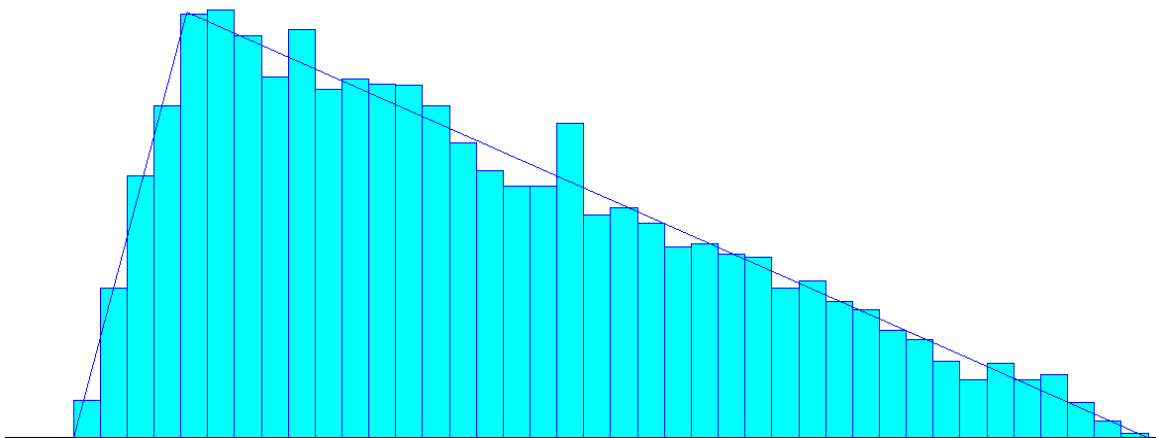
<b>Process 6: Patient Awaits Briefing Team</b>	
Expression (Continuous Empirical Distribution)	CONT (0.000, 0.000, 0.231, 0.500, 0.410, 1.500, 0.487, 2.500, 0.564, 3.500, 0.615, 4.500, 0.744, 5.500, 0.744, 6.500, 0.769, 7.500, 0.795, 8.500, 0.795, 9.500, 0.821, 10.500, 0.846, 11.500, 0.846, 12.500, 0.897, 13.500, 0.923, 14.500, 0.923, 15.500, 0.949, 16.500, 0.949, 17.500, 0.949, 18.500, 0.949, 19.500, 0.949, 20.500, 0.974, 21.500, 0.974, 22.500, 0.974, 23.500, 0.974, 24.500, 0.974, 25.500, 0.974, 26.500, 0.974, 27.500, 0.974, 28.500, 0.974, 29.500, 0.974, 30.500, 0.974, 31.500, 0.974, 32.500, 0.974, 33.500, 0.974, 34.500, 0.974, 35.500, 0.974, 36.500, 0.974, 37.500, 1.000, 38.500)
Data Summary	Number of Data Points = 39 Min Data Value = 0 Max Data Value = 38 Sample Mean = 5.28 Sample Std Dev = 7.48
Histogram Summary	Histogram Range = -0.5 to 38.5 Number of Intervals = 39





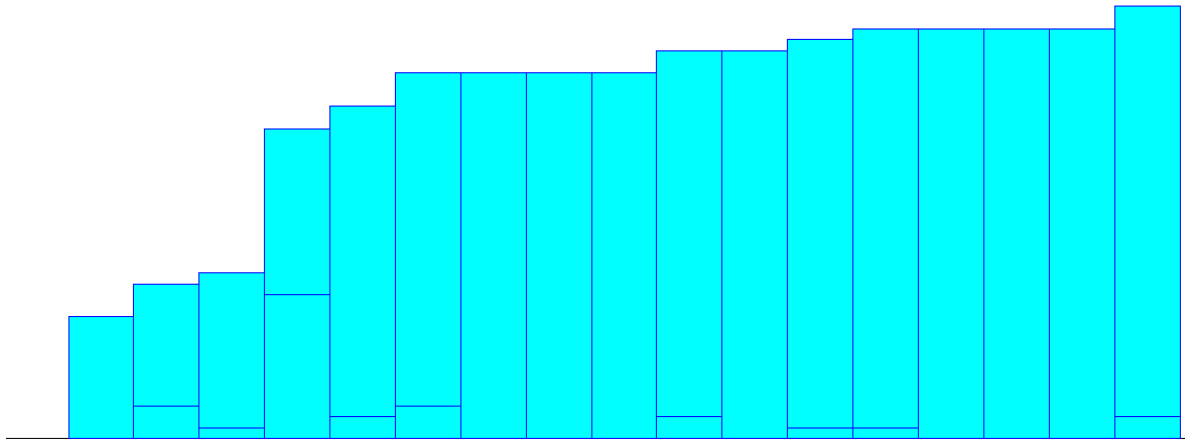
Appendix C7 – Distributions for Simulation of Process 7

<b>Process 7: Patient Briefing</b>	
Expression (Triangular)	Expression: TRIA(2, 2.95, 11) Square Error: 0.000161
Chi Square Test	Number of intervals = 39 Degrees of freedom = 37 Test Statistic = 35.6 Corresponding p-value = 0.535
Kolmogorov- Smirnov Test	Test Statistic = 0.00745 Corresponding p-value > 0.15
Data Summary	Number of Data Points = 5000 Min Data Value = 2.06 Max Data Value = 11 Sample Mean = 5.32 Sample Std Dev = 2.02
Histogram Summary	Histogram Range = 2 to 11 Number of Intervals = 40

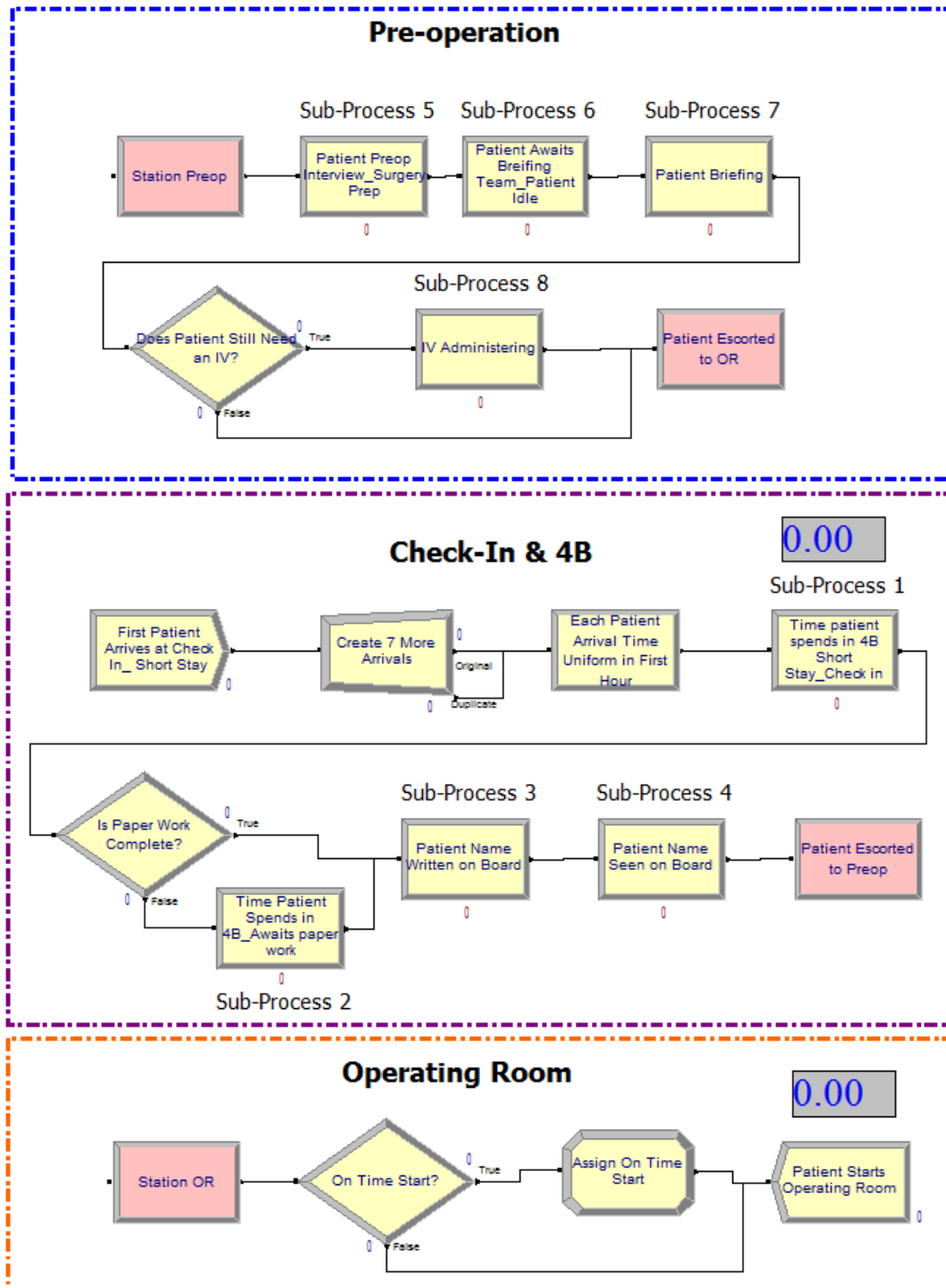


Appendix C8 – Distributions for Simulation of Process 8

<b>Process 8: IV Administering</b>	
Expression (Continuous Empirical Distribution)	CONT (0.000, 0.500, 0.282, 1.500, 0.359, 2.500, 0.385, 3.500, 0.718, 4.500, 0.769, 5.500, 0.846, 6.500, 0.846, 7.500, 0.846, 8.500, 0.846, 9.500, 0.897, 10.500, 0.897, 11.500, 0.923, 12.500, 0.949, 13.500, 0.949, 14.500, 0.949, 15.500, 0.949, 16.500, 1.000, 17.500)
Data Summary	Number of Data Points = 39 Min Data Value = 1 Max Data Value = 17 Sample Mean = 4.59 Sample Std Dev = 4.19
Histogram Summary	Histogram Range = 0.5 to 17.5 Number of Intervals = 17



## Appendix D – Overall Simulation Model



## Appendix E - VBA Code

```
'Administrative form, add a new patient command button
Private Sub cmdAddNewPatient_Click()
Dim answer As String

answer = MsgBox("Would you like to enter new patient information?", _
vbYesNo, "What would you like to do?")
If answer = vbYes Then
    frmNewPatient.Show
Else
    Exit Sub
End If

End Sub

'Administrative form, start a new week button
Private Sub cmdNewWeek_Click()
Dim wkdateM As String, wkdate(5) As Date
Dim response As String, k, i, p As Integer
Dim ws As Worksheet
Me.Hide
response = Application.InputBox _
("Please enter the correct password to execute", "Password Required!")

If Not response = "0690" Then
    MsgBox "You did NOT enter a correct password."
    Me.Show
    Exit Sub
End If

wkdateM = InputBox _
("Enter Monday's date for the week you are creating. mm/dd/yy", _
"Monday's Date")

If IsDate(wkdateM) = False Then
    MsgBox "You did not enter a proper date with format dd/mm/yy"
    Me.Show
    Exit Sub
End If

wkdate(1) = wkdateM
k = 1
For i = 2 To 5
    wkdate(i) = DateAdd("d", k, wkdateM)
    k = k + 1
Next i
```

```

Dim name1 As String, g As String, mo As String
p = 1

For Each ws In ThisWorkbook.Worksheets
    If InStr(LCase(ws.Name), "admin") Then
        ws.Select
        ws.Name = "Admin" & p
        Range("b4", Range("b4").End(xlDown).End(xlToRight)).Clear
        Range("d4", Range("d4").End(xlDown).End(xlToRight)).Clear
        Range("a2").Value = wkdate(p)
        name1 = "Admin_" & Month(wkdate(p)) & "_" & Day(wkdate(p)) _
            & "_" & Year(wkdate(p))
        ws.Name = name1
        p = p + 1
    End If

Next ws

Application.Visible = True

End Sub

'Administrative form, quit button
Private Sub cmdQuit_Click()
Dim answer As String
answer = MsgBox("Are you sure you want to close the program?", _
vbYesNo, "Exit Program")
If answer = vbYes Then
    Unload Me
    'Open the Main Menu user form once "Main Menu" has been clicked
    ThisWorkbook.Close
Else
    Unload Me
    frmMainMenu.Show
End If

End Sub

```

```

'Administrative form, quit button
Private Sub cmdQuit_Click()
Dim answer As String
answer = MsgBox("Are you sure you want to close the program?", _
vbYesNo, "Exit Program")
If answer = vbYes Then
    Unload Me
    'Open the Main Menu user form once "Main Menu" has been clicked
    ThisWorkbook.Close
Else
    Unload Me
    frmMainMenu.Show
End If

End Sub

'Administrative form, return to main menu
Private Sub cmdReturn_Click()
Unload Me
Application.Visible = False
frmMainMenu.Show
End Sub

'Administrative form, go to spreadsheet
Private Sub cmdSpreadsheet_Click()
Unload Me
Application.Visible = True
End Sub

'Main Menu, Admin
Private Sub Admin_Click()
Me.Hide
response = Application.InputBox _
("Please enter the correct password to execute", "Password Required!")

If Not response = "0690" Then
    MsgBox "You did NOT enter a correct password."
    Me.Show
    Exit Sub
End If

Unload Me
frmAdministrative.Show

End Sub

```

```

'Main Menu, New Week
Private Sub cmdNewWeek_Click()
Dim wkdateM As String, wkdate(5) As Date
Dim response As Integer
Me.Hide
response = Application.InputBox _
("Please enter the correct password to execute", "Password Required!")

If Not response = "0690" Then
    MsgBox "You did NOT enter a correct password."
    Me.Show
    Exit Sub
End If

wkdateM = InputBox _
("Please enter Monday's date for the week you are creating. mm/dd/yy", _
"Monday's Date")

If IsDate(wkdateM) = False Then
    MsgBox "You did not enter a proper date with format dd/mm/yy"
    Me.Show
    Exit Sub
End If

wkdate(1) = wkdateM
k = 1
For i = 2 To 5
    wkdate(i) = DateAdd("d", k, wkdateM)
    k = k + 1
Next i

```

```

Dim name1 As String, g As String, mo As String
p = 1

For Each ws In ThisWorkbook.Worksheets
    If InStr(LCase(ws.Name), "admin") Then
        ws.Select
        ws.Name = "Admin" & p
        Range("b4", Range("b4").End(xlDown).End(xlToRight)).Clear
        Range("d4", Range("d4").End(xlDown).End(xlToRight)).Clear
        Range("a2").Value = wkdate(p)
        name1 = "Admin_" & Month(wkdate(p)) & "_" & Day(wkdate(p)) & _
            & "_" & Year(wkdate(p))
        ws.Name = name1
        p = p + 1
    End If

Next ws

Application.Visible = True

End Sub

'Main Menu, Surgical Team
Private Sub cmdSurgicalTeam_Click()
Unload Me
frmSurgicalTeam.Show

End Sub

Private Sub ExitButton_Click()
    'Close the entire workbook when user hits quit
    Me.Hide
    response = Application.InputBox _
        ("Enter the correct password to save the document", _
        "Password Required!")

    If Not response = "0690" Then
        MsgBox "You did NOT enter a correct password, file will NOT be saved."
        Application.DisplayAlerts = False
        ThisWorkbook.Close
    Else
        Application.DisplayAlerts = True
        ThisWorkbook.save
        ThisWorkbook.Close
    End If

End Sub

End Sub

```



```

Private Sub cmbDateNew_Change()
Dim k As String

'make date string
k = cmbDateNew.Value
For Each ws In ThisWorkbook.Worksheets
    Sheets(ws.Name).Select
    k = Range("a2").Value
    If k = cmbDateNew.Value Then
        For Each cell In Range("b4:b100")
            If cell.Value = "" Then
                lblCase.Caption = cell.Offset(0, -1).Value
                h = 8
                Exit For
            End If
        Next cell
    End If
    If h = 8 Then Exit For
Next ws

End Sub

'New Patient
Private Sub cmdNewPatient_Click()
Dim k As String

If Me.cmbDateNew.Value = "" Then
MsgBox ("Please Select a Date")
End If

k = cmbDateNew.Value
For Each ws In ThisWorkbook.Worksheets
    Sheets(ws.Name).Select
    k = Range("a2").Value
    If k = cmbDateNew.Value Then
        For Each cell In Range("b4:b100")
            If cell.Value = "" Then
                cell.Value = txtLast.Value & _
                "," & txtFirst.Value
                cell.Offset(0, 1).Value = txtSocial.Value
            Exit For
        End If
    Next cell
End If

```

```

Next ws

For Each ws In ThisWorkbook.Worksheets
    If InStr(LCase(ws.Name), "admin") > 0 Then
        Sheets(ws.Name).Select
        Exit For
    End If
Next ws
'
Application.Visible = True
Unload Me

End Sub

'New Patient Menu, Return to Main Menu

Private Sub cmdReturns_Click()
Unload Me
frmAdministrative.Show

End Sub

'New Patient Menu, Go to spreadsheet
Private Sub cmdSpredSheets_Click()
Unload Me
Application.Visible = True
End Sub

'New Patient Menu, Initialize
Private Sub UserForm_Initialize()
Dim possibledates(5) As Variant

p = 0
For Each ws In ThisWorkbook.Worksheets
    Sheets(ws.Name).Select
    datess = Range("A2").Value
    u = ws.Name
    If InStr(LCase(u), "admin") > 0 Then
        possibledates(p) = datess
        p = p + 1
    End If
Next ws
Me.cmbDateNew.List = possibledates
End Sub

```

```

'Surgical Team
Private Sub cmdEnter_Click()
Dim cell As Range, i As Integer, j As Double, surgical() As Variant
Dim ws As Worksheet, sheetname As String
Dim datess As String, g As String, m As String

For Each ws In Worksheets
    Sheets(ws.Name).Select
    datess = Range("A2").Value
    If Me.cmbDate.Value = datess Then
        Sheets(ws.Name).Select

        Exit For

    End If
Next ws

Range("G4", Range("G4").End(xlDown)).Name = "roomNum"
j = Range("roomNum").Rows.Count
ReDim surgical(j, 9)
i = 1

    surgical(i, 1) = "Patient Name"
    surgical(i, 2) = "First Case"
    surgical(i, 3) = "Attending"
    surgical(i, 4) = "Res-Att Note"
    surgical(i, 5) = "Att Sign"
    surgical(i, 6) = "H&p Com"
    surgical(i, 7) = "H&P Sign"
    surgical(i, 8) = "Consent"
    surgical(i, 9) = "Time Ready"

For Each cell In Range("G4", Range("G4").End(xlDown))
    g = cell.Value
    All = g
    If Me.cmbRoom.Value = g Then
        surgical(i + 1, 1) = cell.Offset(0, -5).Value
        surgical(i + 1, 2) = cell.Offset(0, -3).Value
        surgical(i + 1, 3) = cell.Offset(0, 1).Value
        surgical(i + 1, 4) = cell.Offset(0, 2).Value
        surgical(i + 1, 5) = cell.Offset(0, 3).Value
        surgical(i + 1, 6) = cell.Offset(0, 4).Value
        surgical(i + 1, 7) = cell.Offset(0, 5).Value
        surgical(i + 1, 8) = cell.Offset(0, 6).Value
        surgical(i + 1, 9) = Format(cell.Offset(0, 9).Value, _
            "hh:mm AM/PM")
        ' "hh:mm")
        i = i + 1
    End If

```

```

Next cell
Me.lstRoomSummary.List = surgical

If Me.cmbRoom.Value = "" Then
MsgBox ("Please Select a Date")
End If

End Sub

'Surgical Team, Exit
Private Sub Exit_Surg_Click()
answer = MsgBox _
("Are you sure you want to close the program?", vbYesNo, "Exit Program")
If answer = vbYes Then
    Unload Me
    Application.DisplayAlerts = False
    'Open the Main Menu user form once "Main Menu" has been clicked
    ThisWorkbook.Close
Else
    Unload Me
    frmMainMenu.Show
End If

End Sub

Private Sub UserForm_Initialize()
Dim room(9) As Integer, i As Integer, dates(5) As String
Dim possibledates(100) As Variant, u As String
'Filling in the room numbers
For i = 1 To 5
    room(i) = i
Next i
k = 7
For j = 6 To 9
    room(j) = k
    k = k + 1
Next j
Me.cmbRoom.List = room

```

```
'Filling in the dates, setting them equal to what ever date is in
'A2 of a worksheet that starts with the title "Admin"
p = 1
For Each ws In Worksheets
    Sheets(ws.Name).Select
    datess = Range("A2").Value
    u = ws.Name
    If InStr(LCase(u), "admin") > 0 Then
        possibledates(p) = datess
        p = p + 1
    End If
Next ws
Me.cmbDate.List = possibledates

End Sub
```