WPI

Implementing Lean Process Improvement in the Sterile Processing Department at The Academic Medical Center

By: Diego Adrianzen; Zachary Dombroski; Shahbaz Soofi; Stephen Young

Sponsored by: The Academic Medical Center

Presented to: Professor Sharon Johnson
School of Business
Term C 2014
Project SAJ-UM01

Submitted in Fulfillment of
The Major Qualifying Project
Worcester Polytechnic Institute
Worcester, Massachusetts

Abstract

Sterile Processing Departments (SPD) within hospitals are using lean methods to improve process efficiency. In this project, the team utilized the Lean A3 problem solving methodology to examine the root causes of missing instruments at The Academic Medical Center. The team developed several countermeasures through 5S sub-projects, focused on inventory management, facility layout and process flow. The team recommended updating the inventory management system, posting visual work standards and reducing kit variety.

Acknowledgments

The team would like to acknowledge the following people for their unique contributions to the success of this project:

Professor Sharon Johnson, Lead Advisor – For the advice and coaching that made this project possible

The Process Improvement Department – For supporting our efforts with vigor and enthusiasm

SPD Team – For enabling us to understand the work procedures and promote a culture of change

Without the full support of these parties, this project could not have been successful.

Table of Contents

Table of Figures

Authorship

This section describes who took leadership for each section of the project. The responsibility of each team member is explained in context of his major. Areas of responsibility were assigned to match the skills expected of a graduate with each degree area who participated on this project.

Management Major: Zach Dombroski

The purpose of the management degree is to build leadership, enhance written and oral communication skills, and to generate the ability to use financial analysis in decision making. As a result, Zach was responsible for the delivery of the proposal and final reports to WPI, managing communication with project sponsors at The Academic Medical Center and deadlines for work to be completed.

Management Engineering Major: Diego Adrianzen

The purpose of the management engineering degree is to build the skills to apply the complex knowledge of management and engineering to design and deliver solutions for manufacturing, product development, and service delivery. As a result, Diego was responsible for analyzing the data obtained and brainstorming ideas for the implementation plan to identify solutions. Diego was also responsible of taking the minutes at the meetings with professor and sponsors at The Academic Medical Center.

Industrial Engineering Major: Shahbaz Soofi and Steve Young

The purpose of the industrial engineering degree is to build the skills necessary to effectively consider how engineering and technology, and management, business, and people fit into solutions designed for process improvement. Shahbaz's role was to consider how the Sterile Processing Department technicians, equipment, services, and products interacted with one another to produce high missing instrument rates, and to develop solutions to reduce the missing instrument rates through improving the process. Stephen's role was to consider how Lean tools and practices could be brought to SPD in order to cut waste from the process.

Executive Summary

The Sterile Processing Department at The Academic Medical Center is responsible for cleaning instruments used during surgeries and preparing them for future surgeries. Sterile processing technicians face demanding roles. They are responsible for having a nuanced understanding of instruments and kits needed for a variety of surgeries. The role of the technician begins at the completion of a surgery; they must rinse instruments, reassemble kits and then sterilize them to be used again in future operations. Technicians routinely feel pressure in their work due to the time sensitive needs of the operating rooms.

The department sought to improve performance by reducing the rate of defects. Defects are defined an observed problem with a kit that originates from the Sterile Processing Department (SPD). Kits are inspected prior to operations, so defects are meant to be caught before they could have an impact on patients in surgeries. The major cause of defects within SPD was missing instruments. Missing instruments are counted when an instrument that is required in a surgical kit is not found in the kit when it is checked in preparation for surgery. Kits are preassembled sets used in surgeries that can contain anywhere from ten instruments to upwards of 100 depending on the type of surgery. Because kits are designed for general types of surgeries, not all instruments in a given kit are used in a particular operation. Therefore, a missing instrument does not necessarily have a direct impact on surgery. Our team's goal was to assess the causes for missing instruments and implement changes in an effort to reduce this rate.

An overall Lean methodology was followed; the first step in the process was to identify the major causes for missing instruments within the department. The team determined that the root causes of missing instruments originated from three major sources: reliance on human knowledge, the work processes in place and the facility layout. Each of these areas had several sub-causes. Measurement of missing instruments was a challenge because the metrics that were used within the department were not focused on such operational measures, and employee performance was not directly linked to this rate.

Based on these findings, the team designed a series of sub-projects to address the root causes identified. The team first evaluated potential sub-projects to define the effort required for each sub-project as well as the sub-project's impact. The sub-projects chosen were those generally requiring low effort but having high impact. The sub-projects that were considered to require high effort and have a high impact were generally outside of the scope of the overall project.

The team completed four sub-projects with the help of SPD employees. These projects are briefly described here. In the assembly station project, the team reorganized the layout of the workspaces and created standardized workstations for all technicians in SPD. The second project addressed the racks of unsterile storage, which are a series of five movable inventory storage units designed to hold instruments that have not yet been sterilized. This project removed unnecessary instruments from storage areas and created a more organized system by which to sort and store instruments. The facilities layout

project reorganized the physical structures within the SPD workspace in order to save walking time for technicians. The team built a computer program to assist in the replacement of damaged or outdated inventory.

Due to the complexity within SPD, it was difficult to identify and improve every root cause of missing instruments within the scope of the overall project. Despite this challenge, the team was able to justify the positive effects of each of the four sub-projects, through self-collection of data and a comparative analysis of the before and after state of chosen root causes. The sub-projects were particularly effective in saving time for technicians. Our team was able to reduce non-value added time spent searching for missing instruments and walking between different areas of the department. Total time savings averaged between 6 and 8 seconds per kit assembled.

At the end of the project the team developed a set of recommendations and two guidebooks for The Academic Medical Center to continue the improvement work in SPD. These recommendations are to continue establishing clearly written work procedures, to reduce kit variety and to update Censitrac, the current inventory system.

1.0 Introduction

Health care is a vital component of modern society, presenting a vast array of social, political, technological and economic challenges. Despite these challenges health care professionals strive to deliver the highest quality care possible. The primary indicator of a health care establishment's success is its patient outcomes (Seavey, 2010). The ability to provide impeccable preventative care consistently is of great importance to achieving the goal of reducing the overall cost of health care for patients and providers alike. Despite a growing emphasis on preventative care in the health care system, 51.4 million surgical procedures were performed in America in 2010 alone (Centers for Disease Control and Prevention [CDC], 2010), demonstrating the continued prominence of surgery in American health care. It is therefore of utmost importance that health care facilities improve the delivery of care for those undergoing surgery, who often represent the most vulnerable of patients.

Although surgeries cure patients of a variety of life-threatening conditions, the invasiveness of surgical procedures can pose substantial risks to patients. From simple surgeries to the most complex, many factors are involved in the success or failure of the operation. An unnoticed or accidental deviation from surgical norms that can occur within a particular case can cause serious harm to the patient. In most cases, while resources are available to ensure each surgery is prepared for without fault, any errors that need to be addressed place additional strain is placed upon the system (Seavey, 2010). The scope of surgery goes beyond the interaction between patient and surgeon in the operating room (Seavey, 2010). In order for a surgeon to have the best chance of performing a successful operation, he or she requires a proper set of sterile instruments.

Due to the design of surgical instruments and their costs, which can amount to tens of thousands of dollars per instrument, instruments cannot be thrown out and repurchased after each surgery (Swanson, 2008). Rather, they must be collected, decontaminated, sterilized and organized into surgical kits in preparation for the next surgery. The Sterile Processing Department (SPD) is responsible for this series of tasks referred to as instrument reprocessing. It is a complex process driven by the needs of the operating rooms they support. Therefore, hospitals across the country are working to improve their SPDs to ensure safety and effectiveness. These departments work behind the scenes to make sure that surgeries can proceed with needed equipment and in most situations patients are not even aware of the work performed within these departments. In short, surgeons and hospitals would not be successful without their SPD supporting them.

The role of a sterile processing technician can be demanding (Swanson, 2008). Technicians are responsible for having a vast understanding of instruments and kits needed for a variety of surgeries. The role of the technician begins at the completion of a surgery; they must rinse instruments, reassemble kits and then sterilize them to be used again in future operations. Technicians routinely feel time pressure in their work due to the time sensitive needs of the operating rooms.

The Academic Medical Center one of the largest healthcare systems in the state delivers a wide variety of care to both children and adults. This project focused on one of the hospitals in the The Academic Medical Center. Our team has studied the causes of the missing instruments that occur in the Sterile Processing Department (SPD) of this hospital while utilizing an A-3 problem solving approach as recommended by The Academic Medical Center. We used Lean process improvement and a 5S methodology to drive change. Lean is a method of increasing process efficiency by reducing non-value-added time. 5S is a Lean tool that increases efficiency and is characterized in the five steps of Sort, Set in Order, Standardize, Shine and Sustain. A3 is a problem solving process that can use Lean methods (Jacobs Et Al, 2013).

The goal of this project was to reduce the missing instrument rate by focusing on specific areas identified as root causes of defects that are currently occurring in the SPD. A defect is defined as any surgical kit variation that could result in the kit being unstable and requiring that a new kit be used in an operation. Defects originate from the SPD, but are recorded in the operating room. The most common causes of defects were kits missing instruments. A missing instrument is defined as anytime a required instrument is not located in a kit during the time of an operation. Because missing instruments comprised such a large component of the total defect rate, this project focused specifically on mitigating the causes of missing instruments. The missing instrument rate is measured by the percent of surgeries in which a missing instrument is recorded. The initial missing instrument rate for January - August 2013 stood at 9% and our goal was to reduce this rate by approximately 20%.

The team first examined the problem and defined the scope. Then we sought to understand the initial state of SPD operations and identify the root causes of missing instruments. Next we defined more specific goals surrounding the reduction of the missing instrument rate and identified potential solutions, evaluated them for impact and effort, and chose several areas of focus including human knowledge, time pressure and process improvement. Four sub-projects were completed to support these goals. The project began in August 2013 and ends with this report.

Chapter 2 of the report is a review of the literature on sterile processing, ergonomics, Lean and case studies of Lean improvement in hospitals. Chapter 3 presents the steps of the A3 problem solving methodology. Chapter 4 describes the results obtained by following the A3. Chapter 5 provides an overview of each of the four sub-projects completed. Chapter 6 analyzes the results in a holistic way. Chapter 7 concludes the report and offers recommendations for future improvements.

2.0 Literature Review

In order to analyze the root causes of the missing instrument rate in the Sterile Processing Department (SPD), it was important to know more about the following areas: sterile processing, ergonomics, Lean improvement and case studies of Lean improvement in hospitals. This research helped define the technical knowledge needed to undertake the core work of the project. The literature review concludes with a discussion of how work on this project compared to similar sterile processing improvement projects that have been previously undertaken, in other healthcare organizations.

2.1 Sterile Processing Departments and Standards

Introduction to Surgical Kits

A surgical kit is a collection of tools that can be used to aid a surgeon in the performance of a surgery ("Surgical Instruments and Procedures", 2010). A surgical instrument is a specific tool that a surgeon can use in a surgery for a particular purpose. There are thousands of different surgical kits available and each kit may contain hundreds of different instruments. Not every surgery will require every instrument in a particular kit, but the goal of having large kits is to ensure that a surgeon will have everything that he or she may need to successfully complete an operation.

Instruments are typically divided into three major categories; hand held, endoscopes and powered tools ("Surgical Instruments and Procedures", 2010). Hand held instruments typically are divided further into forceps, scissors, retractors and needle holders. Endoscopes are tools that are used to look inside the body of a patient. Powered instruments can be used for a variety of purpose; the only commonality between these instruments is the fact that they are battery operated.

The greatest variety is found among the hand held instruments ("Surgical Instruments and Procedures", 2010). Almost every instrument comes in a variety of sizes that account for the differences in surgical areas of the body as well as the variation in sizes of a patient. Furthermore, a single instrument of one size could have many varieties based on which edges are sharp, what direction the blades curve if at all and how much of the tip of the instrument has ridges.

Most instruments used in operations are made from stainless steel at operating grade quality. Before being brought to a hospital for use, instruments undergo a passivation process to reduce the likelihood of rust because stainless steel can actually stain. Through repeated sterilization, instruments are oxidized which further passivates them, reducing their likelihood further of rusting ("Basics on Processing & Sterilization", 2012; "Surgical Instruments and Procedures", 2010).

Instruments are available in four main finishes: satin, mirror, matte or non-glare ("Surgical Instruments and Procedures", 2010). Satin and matte instruments are dull to the eye so they do not cause glares in the operating room, but these instruments are more

likely to rust. The mirror finish can reflect in surgery and cause distractions for the surgeon, but it is less likely to rust. Non-glare instruments are used specifically in laser surgery where it is important to keep heat concentrated in one specific area.

Introduction to Sterile Processing Standards

The work of any sterile processing department begins immediately following the transportation of kits used in an operating room case ("Basics on Processing & Sterilization", 2012). Before sterile processing can begin, kits that were used in a surgery must be moved from the operating rooms to the sterile processing department. The instruments are typically sorted and placed into closed containers by members of the operating room staff at the completion of an operation and are then be moved on a covered cart to the sterile processing department.

In order for sterile processing technicians to begin their work, they should follow certain cleanliness standards ("Basics on Processing & Sterilization", 2012; "Surgical Instruments and Procedures", 2010). Appropriate attire for a sterile processing technician is a scrub covered by a moisture-resistant layer, gloves that are plastic or rubber, covers for shoes and nets for hair. If the technician is likely to encounter splashing, such as when performing manual washing, goggles and a facemask should be worn to prevent contaminants from coming into contact with the technician.

Once used instruments enter SPD, they can proceed in two ways ("Basics on Processing & Sterilization", 2012). Most instruments proceed to washing while others must be soaked. Instruments that require soaking are those that have complex designs that could allow contaminants to become trapped within or those that cannot easily be rinsed. After soaking, instruments can rejoin the regular washing cycle.

The instruments that are designated directly to washing may be handled in a variety of different ways, depending on the specific needs of SPD ("Basics on Processing & Sterilization", 2012). The variation is the result of a variety of machines being available for washing. Some machines automate the entire washing process, while others wash only heat-tolerant equipment. Typically, instruments that are sensitive to heat, such as those with electronic components, are washed by hand while the rest are sent to a high-heat washing machine.

Once instruments are fully washed, they should be inspected before proceeding any further in the process ("Basics on Processing & Sterilization", 2012; Purdy, 2010). The inspection station is expected to ensure that instruments function exactly as intended; instruments with blades should align perfectly and all instruments should be checked for chipping or rust. If the technician notices a problem, the instrument should be sent to be rewashed or repaired, depending on the specific instrument and problem identified.

At this stage, instruments should be reassembled into kits ("Basics on Processing & Sterilization", 2012; Kimsey, 2010). Each kit has specific places for each instrument so that once the entire kit has been sterilized, it will remain so until needed in an operating case. Each kit typically comes with a set of instructions detailing exactly what

instruments are to be located within the kit. It is important to note that items at this stage are not yet sterile and may contain remnants of contamination.

After the kits have been assembled, they must be sterilized ("Basics on Processing & Sterilization", 2012; Purdy, 2010; "Surgical Instruments and Procedures", 2010). Sterilization can happen in more than one way, but typically the kits are again separated based on heat tolerance. Kits that can tolerate high-heat are typically placed in a steam sterilizer. Steam is an effective sterilization agent because no organism can survive steam exceeding 120 Degrees Celsius for a period longer than 15 minutes. Because not all kits can tolerate heat, the remaining kits are often sterilized using Ethylene Oxide. This substance kills cells by interfering with the metabolic process of proteins. Ethylene Oxide is used only for heat sensitive kits because it can be toxic to technicians and this process typically requires nearly a full day in order to complete a sterilization cycle.

After sterilization, kits should be placed in a storage room inventory ("Basics on Processing & Sterilization", 2012). It is from this inventory of sterilized kits that a surgeon receives a kit for an operating case. It is important that this storage area is well organized so that the correct kits arrive in the operating rooms.

Indicators should mark sterile equipment so that when a surgeon receives a kit, he knows that it is sterile ("Basics on Processing & Sterilization", 2012). Often sterile markers are found both outside of and inside of the kits. If any of the markers are indicative of non-sterile equipment, the surgeon returns the entire kit to the sterile processing department and requests a new kit.

This section provides a general overview of processes found within a Sterile Processing Department. The specific processes of The Academic Medical Center are discussed in Section 3.2.

AAMI Standards

The Association for the Advancement of Medical Instrumentation (AAMI) is a widely recognized organization that determines standards to be followed by medical device manufacturers, as well as by operating room nurses and technicians, and sterile processing technicians (AAMI, 2005). The Academic Medical Center follows these standards. Though the standards for proper use of medical devices exist, including standards for use, care, evaluation, processing, and sterilization, they are voluntary. Only when mandated by a regulatory authority do the standards become obligatory, and it then becomes the responsibility of the regulatory authority to ensure users and manufacturers comply. Hence, a device manufacturer does not have to comply with AAMI standards unless they claim to do so in their labeling. Even professionals in healthcare do not need to comply with the standard practices recommended by AAMI, unless required by law, such as in the state of New Jersey (where compliance with AAMI's flash sterilization recommendations is required).

AAMI and the American National Standards Institute (ANSI) have established dozens of device standards, like those for Table-top steam sterilizers, sterilization of healthcare products involving biological indicators for ethylene oxide sterilization, and liquid barrier performance and classification of protective apparel and drapes. While the standards exist and new standards continue to be developed and disseminated to the healthcare industry at large, it is often times entirely up to medical device manufacturers and individual healthcare professionals whether or not they want to follow the guidelines put forth to them, but they have strong incentives to do so (AAMI, 2005).

Sterile Processing Trends

Sterile Processing Technicians must be able to communicate effectively with those in the operating rooms to ensure the best patient outcomes by providing the appropriate instruments in surgical kits ("Basics on Processing & Sterilization", 2012). The job of a Sterile Processing Technician is complex; they must process large numbers of instruments and manage limited resources. The way that employees respond to these challenges impacts the patient directly (Rodak, 2012). Now more than ever, Sterile Processing Technicians must be knowledgeable about the different types of instrument kits and how they can best be used in surgeries to help patients and prevent cost overruns.

With advancing technology, it is crucial for SPD technicians and managers to stay up to date on current industry knowledge and technologies, in order to ensure their successful use (Douglas, 2013). In a 1998 article, Chobin attributed an increase in procedural costs to a 15-minute delay of surgery that resulted from an instrument processing error (Chobin, 1998; Swanson, 2008). A survey provided in the article, also indicated that new employees were responsible for reduced productivity. These new employees were estimated to be only 25% as productive as the average SPD technician six months after hire. The estimated cost of 20 instruments errors that created delays in the OR was $3,385. If a similar error were to occur, the annual cost to the hospital will be of about $48,000. Other research has shown that OR time is valued between $10 to $30 per minute (Chobin, 1998; Swanson, 2008). As a result, every minute saved makes a big different in the hospital's profitability. In addition, if an error leads to a patient infection, the costs to the hospital multiply exponentially.

There have been a variety of recent training innovations for Sterile Processing Technicians (Chobin, 1998). In one hospital new Sterile Processing Department employees are required to participate in 10 weeks of classroom simulation and hands-on training and are periodically tested on their knowledge. Upper management was involved with the implementation of the course and upon completion of the 10 week program, all of the technicians passed their licensing exams. All health care facilities should develop a comprehensive training program. Successful training programs are aimed at SPD certification that attracts committed individuals who possess both a thirst for learning and the ability to be flexible in this constantly changing environment of technological advancements (Chobin, 1998; Kovach, 2012).

Sterile Processing Technicians must be able to communicate effectively with those in the operating rooms to ensure the best patient outcomes by providing the appropriate

instruments in surgical kits. The job of a Sterile Processing Technician is complex; they must process large numbers of instruments and manage limited resources. The way that they respond to these challenges impacts the patient directly. Now more than ever, Sterile Processing Technicians must be knowledgeable about the different types of instrument kits and how they can best be used in surgeries to help patients and prevent cost overruns.

2.2 Ergonomics and Work Space Design

Introduction to Ergonomics & Workspace Design

Workspace design is an aspect of human factors engineering that entails designing systems that reduce human error, and improve productivity, safety, and comfort by accounting for differing anthropometric measurements (Wickens et al., 2004). When considering workplaces where employees are standing, walking, lifting, assembling, and actively moving, workspace design is crucial to making such environments safe and conducive to productivity. Workspace design includes several general principles that help establish parameters for an optimal working environment. The primary parameters take into account accommodations for the largest users and smallest users, adjustability requirements, visibility, and component arrangement.

In order to accommodate for large and small users, the design of a workspace must be such that the largest users, the 95th percentile, have the required amount of clearance (between and around equipment, etc.) and the smallest users (the 5th percentile) have tools, supplies, etc. within optimal reach (Wickens et al., 2004). Insufficient clearance can result in employees adopting uncomfortable positions that affect their comfort and productivity (Wickens et al., 2004), and the smallest users are slowed down if supplies are out of their reach. A concept that is also important for workspace design is work surface depth, which at the basic level entails the work area covered by a sweep of the arm. If the depth of a work surface is too high, then tools, supplies, etc. can be out of reach for the smallest users.

In every workplace there are people of all heights and sizes, and while designing clearance and reach for the largest and smallest users respectively, it is still crucial to incorporate adjustability requirements. Work surfaces such as benches and tables, and the placement of tools and supplies should be easily adjustable, so that a particular workspace can be more or less universal to anyone who uses it. There are several approaches to workplace adjustment which include adjusting the workplace, adjusting the employee position relative to the workplace, adjusting the workpiece, and adjusting the tool (Wickens et al., 2004). Adjusting the workplace entails altering the shape, location, and orientation of the workplace in order to establish a good fit between employees and the tasks. Adjusting the employee's position requires changes such as changing the employee's seat height or using platforms and step-up stools. Adjusting the workpiece includes solutions such as clamps in order to hold a workpiece in place for easier viewing and using part bins that can help organize parts for better accessibility. Lastly, workplace adjustment can be achieved by adjusting the tools, such as using adjustable hand tools in

order to allow people with different anthropometric measurements to comfortably use the same tools yet adjusted to their needs (Wickens et al., 2004).

The principle of visibility entails designing workspaces that include visual displays that are easily seen and read by employees, which means adhering to the concept of normal line of sight. The normal line of sight is the naturally preferential direction of people's gaze, which most researchers consider to be about 10° to 15° below the horizontal plane (when a person looks straight ahead) (See Figure 1). As long as visual displays are within ±15° in radius around the normal line of sight they are at optimal viewing placement (Wickens et al., 2004).

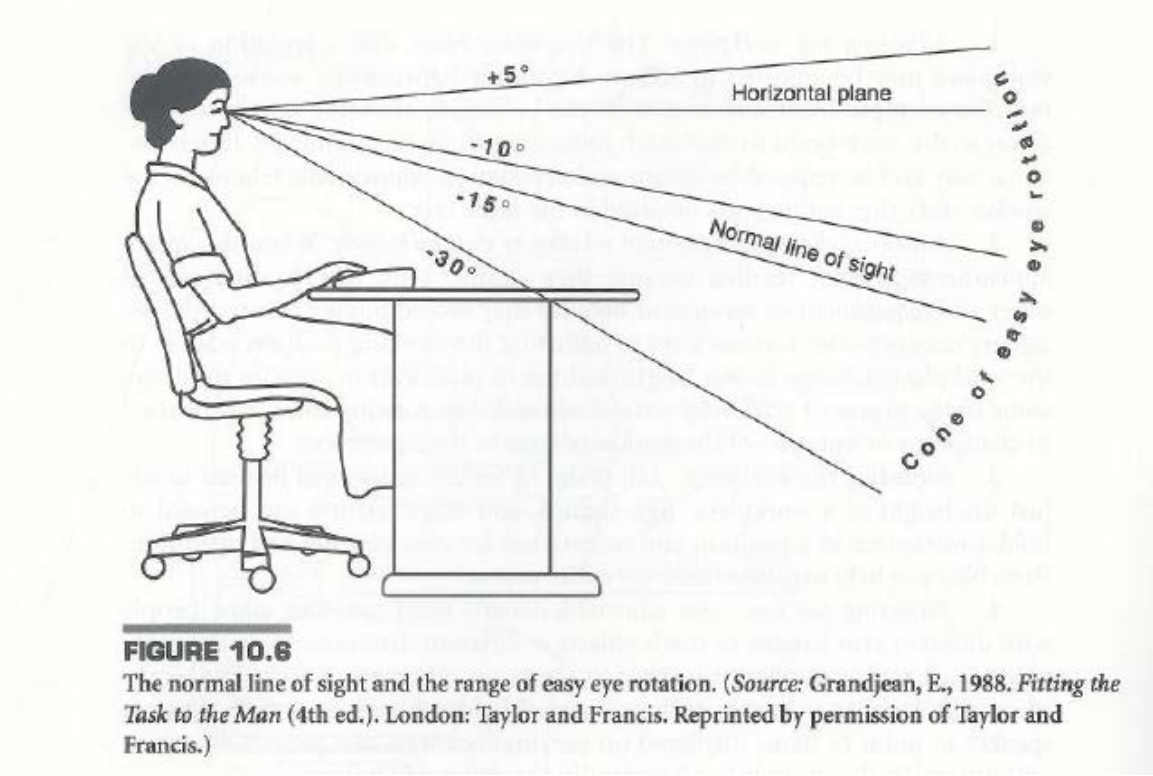

FIGURE 10.6
The normal line of sight and the range of easy eye rotation. (*Source:* Grandjean, E., 1988. *Fitting the Task to the Man* (4th ed.). London: Taylor and Francis. Reprinted by permission of Taylor and Francis.)

Figure 1: Normal Line of Sight & Range of Easy Eye Rotation

The last principle, component arrangement, consists of several guidelines. The first guideline, the frequency of use principle, states that the most frequently used components should be in the easiest to reach places, and should be placed in the primary viewing area. Adherence to the importance principle entails placing components that are the most crucial to the process in convenient locations. The sequence of use guideline dictates that components that are used in a sequence should be located next to each other in the particular sequence in which they are used. The consistency principle involves components being located in the same locations, so as to minimize potential for error in memory and reduce the need to search for components. This is especially important when standardizing across several different workspaces. The control-display compatibility principle of colocation entails keeping control devices close to their associated displays. The clutter-avoidance principle very simply states that space is valued and as a result workspaces should be kept clear of unnecessary components and that there should be

space between controls, so as not to confuse them. The last principle, the functional grouping principle, requires that components that have similar functions should be located near each other (Wickens et al., 2004).

Using workspace design principles helps to reduce strain, fatigue, and injury, and helps to increase productivity, and use of space. Overall the goal of workspace design is to make the workplace comfortable and efficient for employees. Particularly, in active work environments, the principles of workspace design can make a huge impact in improving the working conditions for employees.

2.3 Lean Improvement

Introduction to Lean

Developed primarily from the Toyota Production System (TPS), Lean manufacturing was not known as such until the 1990s (Jacobs et al. 2013; "What is Lean", 2009). TPS formed after World War II, when Ford's manufacturing assembly lines were studied and revised in order to make improvements. The Lean production approach assesses processes from a customer perspective, to reduce waste as much as possible in order to offer the most value at the least possible cost to the end customer. In a broad sense, Lean is a systematic approach that impacts an entire business or organizational structure. The most basic element of the methodology is identifying and eliminating non-value added time or waste in a process through the utilization of Lean techniques and tools that will result in continuous improvement in the process.

When taking a Lean approach to problem solving, it is important to understand the key concept of value-added time (Jacobs et al. 2013; "What is Lean", 2009). Lean itself is a problem solving technique that involves the elimination of waste from a process. Waste can be defined as anything that a customer would not value. Value is defined as anything for which a customer would be willing to pay. In SPD, an example of waste is when a tool does not pass inspection and needs to be rewashed.

One of the core concepts behind Lean thinking is eliminating non value-added time. Some non-value-added time is simple to identify, such as the tool that does not pass inspection, but other sources of waste are harder to identify.

According to Lean methodology there are eight wastes within an organization: unused human potential, waiting, inventory, transportation, defects, motion, overproduction, and processing (Jacobs et al. 2013). Identifying these sources of waste within an organization and implementing courses of action to eliminate them, aids in creating a Lean environment. Methodologically though, in order to eliminate such sources of waste to bring into effect a Lean environment, W.E. Deming's PDCA cycle comes into play again. Following the steps of planning, doing, checking, and acting are what help to affect change, and if done properly positive change. Accordingly, Lean concepts, A3 thinking, and PDCA are complementary (Kiff, 2012).

Lean requires continuous thinking about improvements, problem solving, and questioning the status quo (Jacobs et al. 2013; "What is Lean", 2009). In any area for improvement, there are preconceived notions about from where the problems stem, but to be able to really understand a problem, it is necessary to reduce biased notions. Using Lean methodology requires that teams continue to ask "why" until the true roots of the problem are uncovered. Three basic assumptions made in err when problem solving are that one knows what the issues are without actually observing what is happening, one knows what the issues are without determining the cause, and the actions being taken to fix the problem are working without any validation of whether that really is the case.

Lean has methodological steps that bear resemblance to the PDCA cycle. An eight step process, it asks organizations to: identify and describe the problem, contain the problem, analyze the problem, develop and select the best solutions, make plans and implement the solutions, measure and evaluate the effectiveness, standardize the process, recognize and share achievement. Lean tacks on the "recognize and share achievement" step, an important aspect especially when working in organizations with cross-functional teams, where some functional groups may not be in roles where they have the ability to witness the achievement in by way of their day-to-day work.

Introduction to A-3 Problem Solving

The Academic Medical Center uses a methodology known as A3 to aid with root cause analysis and achieving solutions to challenges. Named for the largest paper size that can fit in a printer and copier, (11x17) and on which the process can be documented, the A3 problem solving approach is an in-depth version of W.E. Deming's Plan-Do-Check-Act (PDCA) or Plan-Do-Study-Act (PDSA) cycle ("Defining Value and the 7 Wastes", 2014; Sarkar, 2010; "What is Lean", 2009). The intent of the A3 format is to provide a basic framework to problem solving using a simple seven step process.

W.E. Deming's "Plan" step comprises four A3 methodology steps (Background, Problem Statement, Goal Statement, and Root Cause Analysis) (Sarkar, 2010; "What is Lean", 2009). The process begins by setting up the background, stating what challenges have been incurred and how they affect the goals of the hospital. Defining the problem statement in detail comes next, which includes the specifics of when and where the problem occurred, as well as defining the problem on a quantitative scale if possible. Establishing the goals being sought out from the problem resolution is the next step, and provides clarity in terms of satisfactory achievements and timelines. With the challenges defined, the root cause analysis follows intending to seek out the basic reasons for problems.

Developing countermeasures, or the "Do" step according to Deming's cycle, is where the plan and implementation of changes actually occur (Jacobs et al. 2013; Sarkar, 2010). The next step, effect confirmation, parallels W.E. Deming's "Check" or "Study" step, and involves examining the countermeasures to see if they were effective. Lastly, follow up action, the mirror step to Deming's "Act", requires that certain measures are put into place so that any changes are sustained so as to affect long-term results. Follow up action

could include actions such as standardization, audits, and reviews. The combination of Lean and A3 is called "Lean A3 Thinking" and they work well together, as they both relate back to the PDCA cycle, ("Defining Value and the 7 Wastes", 2014). The A3 format is a tool that helps to visualize the problem solving process, and the Lean concepts regarding waste help with root cause analysis. While the A3 methodology formally has seven steps, the combined Lean A3 Thinking methodology has eight steps: reasons for action, initial state, target state, gap analysis, solution approach, rapid experiments, completion plan, and confirmed state.

Other Lean Tools

Another tool utilized in Lean thinking is the fishbone diagram, which is used to aid with root cause analysis, ("Defining Value and the 7 Wastes", 2014; Jacobs et al. 2013). The head of the diagram includes the problem statement, while the branches off of the symbolic body of the fish state what the problems and challenges are specifically. As the detailed reasons for the overall problems are identified, each branch will include its own tier of branches, where the last tier of branches state the root causes. This is not the only tool to be used with Lean thinking. Pareto charts, failure mode effect analysis (FMEA), and cause and effect matrices can all aid with cause and effect analysis.

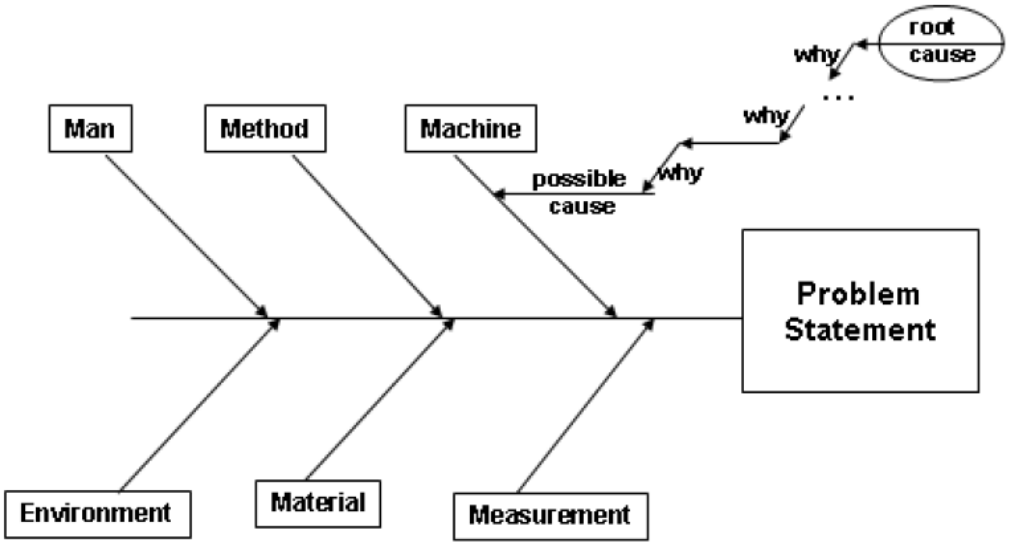

Figure 2: Fishbone Diagram

5S, standard work, and value stream mapping are other Lean tools that are widely used and implemented across organizations as well, (Jacobs et al. 2013). 5S is about implementing standards within an organization. The "S" in 5S is representative of five Japanese words that begin with the letter "s" when translated to English. 5S is conceptualized as: set in order (organization), shine (cleanliness), standardize (consistency), sort (elimination), and sustain (discipline). Another tool implemented across organizations is standard work, which is written descriptions on how to perform task in the most efficient and safe way possible, so as to reduce variation and increase

consistency across the organization. Both the 5S and standard work concepts help to reduce the amount of human error, and thus decrease opportunity for defects to arise. As a Lean tool, value stream mapping provides a depiction of an organizational process, illustrating how work is organized and progresses through the process from start to finish. By illustrating the flow of work and information, value stream mapping helps to identify areas of non-value added time (waste), and aids in finding potential opportunities for improvement, as well as where standard work may be necessary.

Huddle Style Meetings

In unionized workforces, such as those involved in sterile processing, it is important to create positive and informative interactions between workers and management (Billikopf, 2003; Cranes, 1980; Elgin, 1983; "Meetings and Huddles | Labor Management Partnership", 2013). Holding meetings is one important way to open lines of communication between employees and management in order to facilitate problem solving. Because sterile processing is a rather technical job, meeting space is not abundant and employees do not have the scheduling flexibility to participate in traditional meetings. The huddle style meeting can provide a solution to this problem by allowing for quick and frequent updates between employees and management.

A huddle meeting differs from a traditional meeting in that it typically is quite short, usually no longer than fifteen minutes (Billikopf, 2003; Cranes, 1980; Elgin, 1983). While traditional meetings are often intended to generate discussion and debate, huddle style meetings are meant simply to provide information and not search for solutions. Topics that lead to discussion should be handled outside of huddle meetings. Huddles are most effective when they have a facilitator, typically a member of management, and no more than 20 participants. Each participant usually gives a quick update on their priorities so that the team knows the activities of its members. Huddles should occur frequently and many organizations will hold team huddles each day.

Every organization has challenges to address and huddle meetings are not meant to avoid challenges ("Meetings and Huddles | Labor Management Partnership", 2013). When an issue arises, it should be brought to the attention of management and a plan for a solution should be created. Huddles should serve as status updates on these resolutions, but discussion of any individual issue should not last longer than 2-3 minutes.

There are advantages that come along with both huddles and with traditional meetings. Depending on the needs and time restrictions of an organization, it may be appropriate to use huddles, meetings or both approaches to communication. Regardless of the format used, be it weekly staff meetings or daily huddles, it is important that staff and management form effective lines of communication and build the trust required to solve problems together.

2.4 Lean Improvement Case Studies

Information regarding the status of sterile processing department's at hospitals around the world is considerably limited. Information on process improvement projects in these departments is often devoid of robust sets of data. This idea is understandable considering the sensitivity of the information that would be provided. If patients were to see data on surgical kit defect rates out of context, they may consider the hospital producing those figures to be an unacceptable choice for surgery.

Case Study: BC Children's Hospital

In 2011, BC Children's Hospital (BCCH) found that the number of defective surgical kits coming from their sterile processing department was increasing over time (Blamey et al., 2013). The hospital created a task force to analyze the equipment assembly unit and recommended ways to stem the rise of defects and ultimately reduce them. Utilizing a team of physicians, sterile processing department staff, etc., the task force tracked the occurrence of various types of defects. According to their observations, package integrity, improper equipment assembly and missing equipment caused significantly more defects than other issues.

The hospital also observed the life cycle of surgical kits, identifying areas where defects may be caused. Defects originating in the operating room included instruments being placed in the wrong kits by surgical technicians, sets of surgical kits sent to the sterile processing department on separate carts, and kits not being brought to the sterile processing department in an acceptable span of time. Serious defects originating in the sterile processing department included instruments not being loosened and unassembled, unused equipment not leaned, biomass not loosened from instruments in the ultrasonic leaner. Kit wrappers were consistently torn or came undone over time and wrong or missing instruments were commonplace.

The team recommended a series of changes spanning from the operating rooms to the sterile processing department. Both departments were physically altered to allow better access to kit storage areas and sterile processing department specifically rearranged its decontamination layout. In the operating room, technicians were asked to coat instruments with enzymatic gel after use and reduce time between using the kits and sending them to sterile processing department. The sterile processing department also cut down redundant processing in decontamination through unspecified action. Unused instruments were now being processed and a formal process was created to sterilize and package high priority instruments.

The Academic Medical Center SPD is producing surgical kits with defects similar to those of BCCH. The two hospitals, although afflicted by the issue in varying magnitudes, both report missing instruments as one of the most significant causes of the defect rate. BCCH also suffers from defects, such as those known as "Holes", that are recognized issues at The Academic Medical Center, though they occur at a much lower rate than missing instruments. Therefore, some countermeasures taken by BCCH are not currently being considered for use at The Academic Medical Center. The decontamination room at The Academic Medical Center may be rearranged and introduced to procedures that

standardize the processing of high priority kits, similar to the countermeasures utilized by BCCH with the hope that they will produce similar results (Blamey et al., 2013).

Case Study: Lehigh Valley Health Network

In 2008, Lehigh Valley Health Network (LVHN), Allentown, Pennsylvania began using A3 problem solving to improve its sterile processing department before its upgrade and expansion that was planned for the following year, (Kimsey, 2010). Once a group made up of various hospital staff was recruited to aid the process, they used a gemba walk to identify various forms of waste in the daily operations of the sterile processing department and recorded the initial state of the sterilization process. Ultrasonic cleaners often failed to loosen biomass, causing team members to use scalpels and safety pins to remove the biomass, which can ruin instruments over time. Due to unknown malfunctions, SPD's sterilizers needed to run for 27 minutes to achieve desired results, as opposed to manufacturer's suggested 20 minutes.

Staff, recognizing that the sterilizers were taking a long time to process instruments, began to only run the sterilizers when once a full load was achieved, which took approximately one to two hours. As far as bringing tools to the sterilizers, staff had difficulty locating carts and had to walk a great deal of time to retrieve them. Flash Sterilization was used on most instruments that were hand washed due to staff concerns that hand washing may be inadequate. To address the issues of hardened biomass, the team had the ultrasonic cleaner recalibrated and provided staff with proper brushes and scrapers. Sterilizers underwent maintenance and returned to running when 50% or more full.

The staff was taught how to fix common problems such as rack jamming and minor routine maintenance in order to ensure such delays do not occur again. Utilizing 5s projects, the team took time to make some larger changes. They sorted all unused items which were then removed from highly used areas. Then the taskforce straightened the workspace for a better flow and scrubbed all machines, tested for air quality, humidity and containments. Standardizing work processes and posting work guides at all workstations helped employees complete work faster, and with more efficiency, which gave staff more confidence in the effectiveness of hand washing instruments. Finally, the team sustained progress by instituting an accountability mechanism to assure adherence to the new systems and techniques that were created.

The measurable effects of this project showed impressive results. The team was able to eliminate frequent flash sterilization, saving the sterile processing department 10 hours of work per day. With the sterilizers operating at optimal conditions and being run on half loads, sterilization capacity was increased by 30%. Rack jams and poor drying conditions in the sterilizers were also eliminated. Average utilization of equipment such as sterilizers, the ultrasonic cleaner and carts rose to 90% from 60%. Nonpreventative maintenance calls were reduced from six to two per month, decreasing the expenditures on nonpreventitive maintenance from $12,000 per month to $3,600 per month for a cost

savings of $100,800. Lastly, the planned physical upgrade and expansion of SPD was no long needed to allow SPD to function as needed which saves capital (Kimsey, 2010).

Our project employed a similar methodology to the one utilized successfully by the LVHN taskforce, The initial state of SPD at The Academic Medical Center was also similar in some respects to the past state of LVHN's SPD. Just as LVHN had mechanical issues contributing to the overall processing time, The Academic Medical Center has sterilizers that are currently run for 10 minutes beyond the manufacturer's suggestion due to the machine's inability to sufficiently dry the larger orthopedic kits within their normal run time. Despite this similarity, The Academic Medical Center SPD has continued to sterilize in small batches, unlike LVHN. This practice is more consistent with the basic principle of Lean manufacturing promoting single unit flow. Just as LVHN utilized a major 5 S project, The Academic Medical Center could benefit from a 5S transformation to address issues associated with inventory management, clutter and a non-"visual workplace". The countermeasures used in The Academic Medical Center SPD were expected to reap some of the benefits created at LVHN, namely greater overall process efficiency.

3.0 Methodology

The goal of this project was to reduce the rate of missing instruments within the Sterile Processing Department (SPD) by approximately 20%. The methodology of this project overall followed an A3, which is a method of problem solving that involves defining a problem, determining the initial state, determining root causes, developing goals and countermeasures and implementing change.

3.1 Defining the Problem

One campus of The Academic Medical Center reported a 9% missing instrument rate in surgical kits from January 2012 through July 2013. The scope was determined by speaking to each stakeholder, each of whom was an employee within SPD, in order for our group to understand the role of each of them and also to understand their respective goals for the overall project. Stakeholders in this project included SPD employees, The Academic Medical Center and hospital patients.

3.2 Determining the Initial State and Analyzing Root Causes

To have a better understanding of SPD we gathered background information on the way that instruments moved through SPD. We also determined the current conditions so we could proceed with the changes needed for improvement. As defined in the problem statement in Section 4.1, we first used the data given by our sponsor to provide an overview of the different types of missing instruments.

After analyzing the data, observations in the SPD area were also made. Figure 3 shows the cumulative number of hours spent on observations from September 1 – October 10 as well as what times the observations occurred each day of the week.

	Monday	Tuesday	Wednesday	Thursday	Friday
8:00	0	0	0	2	0
9:00	0	0	0	4	2
10:00	0	0	0	4	2
11:00	0	0	0	4	2
12:00	0	0	4	0	0
13:00	0	0	2	0	0
14:00	0	0	0	0	0
15:00	6	0	0	4	0
16:00	6	0	0	6	0
17:00	0	0	0	2	0
Total	12	0	6	26	6

Figure 3: Observation Schedule

Observation Tools

The team utilized spaghetti diagrams, time studies and a congestion map to study the initial state. These tools were also used to evaluate the impact of our countermeasures across the time spent in SPD by comparing our initial state against the final state of SPD in February. In order to ensure consistency, the necessary data for these tools was gathered during first shift on Wednesdays and Thursdays, which are known to be the busiest days for sterile processing.

Spaghetti Diagram

During observation, we drew on blueprints of SPD to track a single employee's movement throughout the facility. The routes employees took to accomplish various tasks were traced on these blueprints by hand. Two were selected and remade in PowerPoint to show during the team's initial project proposal to our sponsors. A total of 8 spaghetti diagrams were completed. By compiling spaghetti diagrams we looked to find consistent waste of motion responsible for forcing SPD technicians to rush through kit assembly.

Congestion Map

The hand-drawn spaghetti diagrams were also inputted into Excel in order to create a diagram referred to as a congestion map. By recreating the layout of SPD to scale in Excel and inputting each employee motion, we were able to further analyze employee movement by essentially combining our spaghetti diagrams. Each time an employee passed a given 3'x3' area of SPD, the value in the Excel cell that represents that area increases by one. One form of the congestion map shows the total sum of passes across each area while another displays the average number of passes across all spaghetti diagrams. These two maps show areas most travelled by employees and gave a better idea of where extreme examples of waste of motion occur. Although this tool was only used internally amongst the team, the congestion map helped highlight areas where some countermeasures would be focused.

Average Distance Traveled

Using the frequency at which a pathway was utilized based on the congestion map and the length of a pathway, the average distance traveled was calculated in order to understand how much walking each employee does on average when working on a kit. The average distance traveled was only calculated based on the main pathways in SPD, as show in Figure 4 below.

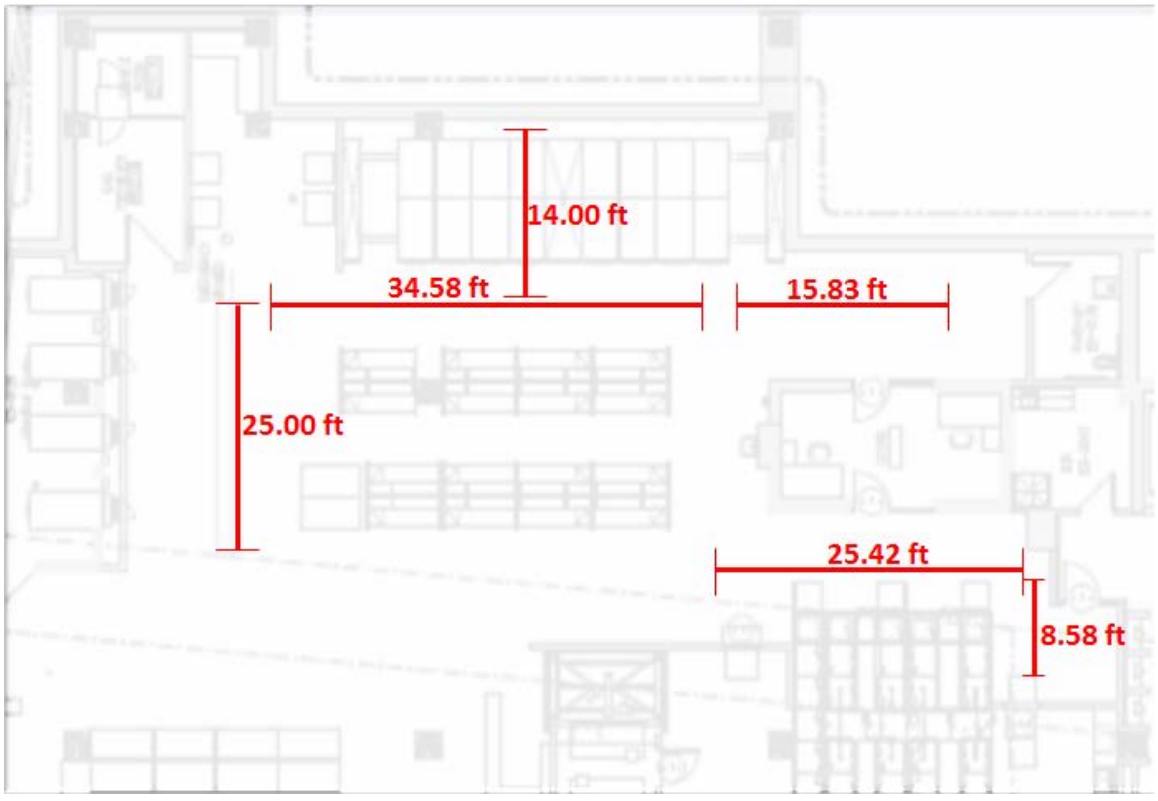

Figure 4: Facilities Map Pathway Distances

Time Studies

Team members followed technicians as they completed various tasks and recorded the duration of all activities completed by the technician they shadowed. After being recorded in Excel, the various subtasks were marked as either value adding or non-value adding in order to find the average amount of non-value time associated with these common tasks. After various countermeasures were put in place, time studies served as an indicator of success if non-value adding tasks are eliminated or shortened. Most emphasis was placed on following technicians working on kit assembly, however, one time study was completed for decontamination and the 'float' position.

As a major step in the project we needed to find the root causes. In order to identify the root causes of the missing instrument rate we first needed to understand how the process worked. As a result, our group divided ourselves in groups of two in order to have multiple observations of the processes. During our observations, we needed to constantly ask "Why?" in order to reach the root causes.

For most of the observations we had a basic plan of what we wanted to get. The first observations were to understand what each section of SPD meant and what occurred in each section of the department. There were two areas that needed to be inspected, the decontamination and assembly areas. Our second round of observations focused on issues that were related to missing instruments. During the observations we interviewed technicians.

3.3 Developing Goals

In order to determine our goals for the project we met, weekly for one hour with our sponsor, The Process Improvement Specialist, who helped us to determine what their expectations were surrounding improvements in SPD. We defined the metrics by which to measure our performance but focused on reducing the missing instrument rate.

3.4 Creating a Plan

Missing instruments was the product of a great many factors, though the team worked with The Academic Medical Center staff to choose from various countermeasures to enact. Standardization or the use of the 5S's became the cornerstones of the implemented changes. SPD's dependence on their technicians exposed them to greater risks of having kits with missing instruments. This SPD relied more heavily on technicians' knowledge than necessary because technology was not always available to provide important information about kit assembly. We chose four sub-projects to address missing instruments: Unsterile Storage, Assembly Stations, Facilities Layout, and Instrument Repair, Replace, Recycle Pipeline. These sub-projects were selected based on the Impact-Effort matrix in Section 4.7 and were determined to be of low effort, but high impact. These four projects were chosen from an original list of 12 projects, all of which are detailed in section 4.7.

3.5 Implementing Change

We used the preferred method of implementing change chosen by The Academic Medical Center. This method is based upon short tests-of-change. Employees were first educated on their role in the test, and then a proposed action was rapidly implemented for one or two days. After the test days were finished, their effects were analyzed and management determined whether or not the implemented changes were to remain in place. An important objective of the A3 methodology is to refrain from rushing process improvement in order to understand which countermeasures were effective and which were proven not to be. With this in mind, the team only implemented up to two countermeasures for any given test of change.

The basic implementation strategy took place in 5 stages; education, action, observation, study and decision. Once we had employee support a proposed countermeasure or two was acted upon for 5 days, which is longer than the normal test-of-change for SPD in order to provide more data on the effect of the change. After data and observations were collected, the effects of the countermeasures were evaluated and presented to SPD management. At this point, decisions were made to end the test and either keep the countermeasure in place or reverse the countermeasure, or extend the test pending more definitive results.

4.0 Results Using A-3 Method

This section is organized to show the results from the A3 problem solving process, as recommended by The Academic Medical Center project improvement team. We used techniques such as 5S to help drive change.

4.1 Problem Statement and Investigating the Missing Instrument Rate

The head of SPD expressed concerns over an elevated rate of missing instruments in surgical kits, which was at 9% at the outset of the project. Our task was to study the SPD process, determine root causes and implement countermeasures to reduce the number of missing instruments in surgical kits produced.

In order for our group to find the defect rate and confirm the results, we used the data (January 2013-July 2013) provided by the sponsor. This data was collected by counting defect sheets at the end of every day. Defect sheets are used by surgical technicians in the operating room to mark when there is a defect.

The purpose of the data, showcased in Figure 5, was to examine the specific surgical cases and to understand how missing instruments were calculated. The overall defect rate was calculated by looking at the total number of operations (7056) in those 7 months and then taking the total number of times the surgeons had a type of problem with their respective instruments kits (807). Of the 11% defect rate, 9% was due to missing instruments, which reinforced our focus on this area.

Service	Total #	Missing instrument #	%
ANES	1	0	0
CARD	8	0	0
COLO	476	34	7%
DENT	2	0	0
ENT	52	4	8%
GASTRO	102	3	3%
GEN	1272	140	11%
GYNOB	958	73	8%
GYNONC	236	31	13%
GYNREI	128	18	14%
GYNURO	153	21	14%
MED	1	0	0
NEURO	226	50	22%
ORTHO	925	208	22%
PEDI	32	5	16%
PLAS	44	1	2%
PULM	35	7	20%
RAD	29	0	0
SURGONIC	540	56	10%
THOR	185	28	15%
TRANS	1	0	0
UROL	1499	116	8%
VASC	211	12	6%
TOTAL	7116		
TOTAL Missing instrument #	807		
% Missing instrument	11%		

Figure 5: Missing instrument per Type of Surgery

4.2 Scope

This project focused on The Academic Medical Center. The project was contained within the SPD at The Academic Center. All other functional areas and departments of the hospital were out of scope. The project sought to reduce the rate of missing instruments that occurred in the operating rooms as a result of sterile processing procedures. Missing instruments that originated from a source outside of SPD were out of scope. The missing instrument rate was the primary metric, but other metrics such as a reduction of non-value added time were in scope.

The stakeholders associated with this project were Worcester Polytechnic Institute, The Academic Medical Center SPD, Operating Room Employees at The Academic Medical Center and Patients. Worcester Polytechnic Institute assumed responsibility for the output of the final report and the quality of this project reflects upon the institution. The Academic Medical Center SPD was directly affected by the missing instrument rate and this project served to support improvement in the department.

4.3 Initial State

The Academic Medical Center had a 9% missing instrument rate at their operation rooms from January through July 2013. Because different people defined defects differently, our team focused specifically on missing instruments.

The following is a walkthrough of the journey of an instrument from the operating room, to sterile processing and back. Figure 6, which visually depicts the process follows the sequence.

In the operating room a surgical technician receives an instrument kit and opens it, counting the tools in the kit. If there is an issue, indicated by an instrument that is missing, the issue is recorded as a defect and the kit is sent back to sterile processing through an elevator and a new kit is requested. If there is no defect, the surgeon proceeds with the scheduled operation. Following an operation, the surgical technician counts the instruments again and then sends them through an elevator to sterile processing.

At the other end of the elevator, the used or defective kits arrive in the decontamination room. When the kit is taken out of the elevator, a sterile processing technician scans a barcode on the kit to enter it into the computer system. The kit is then brought to the waiting table and opened. Here, instruments are separated into used and unused piles. All instruments are disassembled to make cleaning easier. Those instruments which have not been used or which have been used but are not visibly soiled are placed into a soaking bath. Instruments that are soiled and used are placed into an Ultrasonic cleaner before being soaked in a bath with the other instruments. Instruments that are delicate or cannot be exposed to heat are washed by hand, while others are placed into shadow boxes. The shadow boxes are then placed on a carrying rack and scanned into the computer system. At this point, these instruments are placed in a washer, marking the end of the decontamination process. Instruments that are washed by hand pass alongside the washer machines into the next phase as well.

Kits proceed to the assembly room. A technician divides the kits into hot and cold sanitation needs. Instruments that were washed by hand are likely to need cold sanitation, while other instruments probably will use the hot sanitation. A technician will bring kits to the assembly area. If the assembly technician detects any contaminants, the kit is sent back to the beginning of the decontamination process. If not, assembly begins. Kits are assembled according to a set of instructions that are printed out from a computer. Technicians compare the instruments that they place into the kits with the instruments on the list to make sure they match. Once a kit is assembled, sanitation indicators are placed inside so that the surgical technician will know that the kit is sanitary. The technician will then wrap the kit and tape it sealed. If the kit was prepared for the hot sanitizer, it will then be placed in the hot sanitizer machine. After the machine runs, the kits must be left to cool. If the kit was prepared for the cold sanitizer, it is placed in the cold sanitizer. At this point the kits are placed in sterile storage racks catalogued by kit type. The night before an operation, the necessary kits are removed from storage and placed on a cart. The day of the operation, the preassembled carts are sent up to the operating rooms. Figure 6 shows the processing of a single kit.

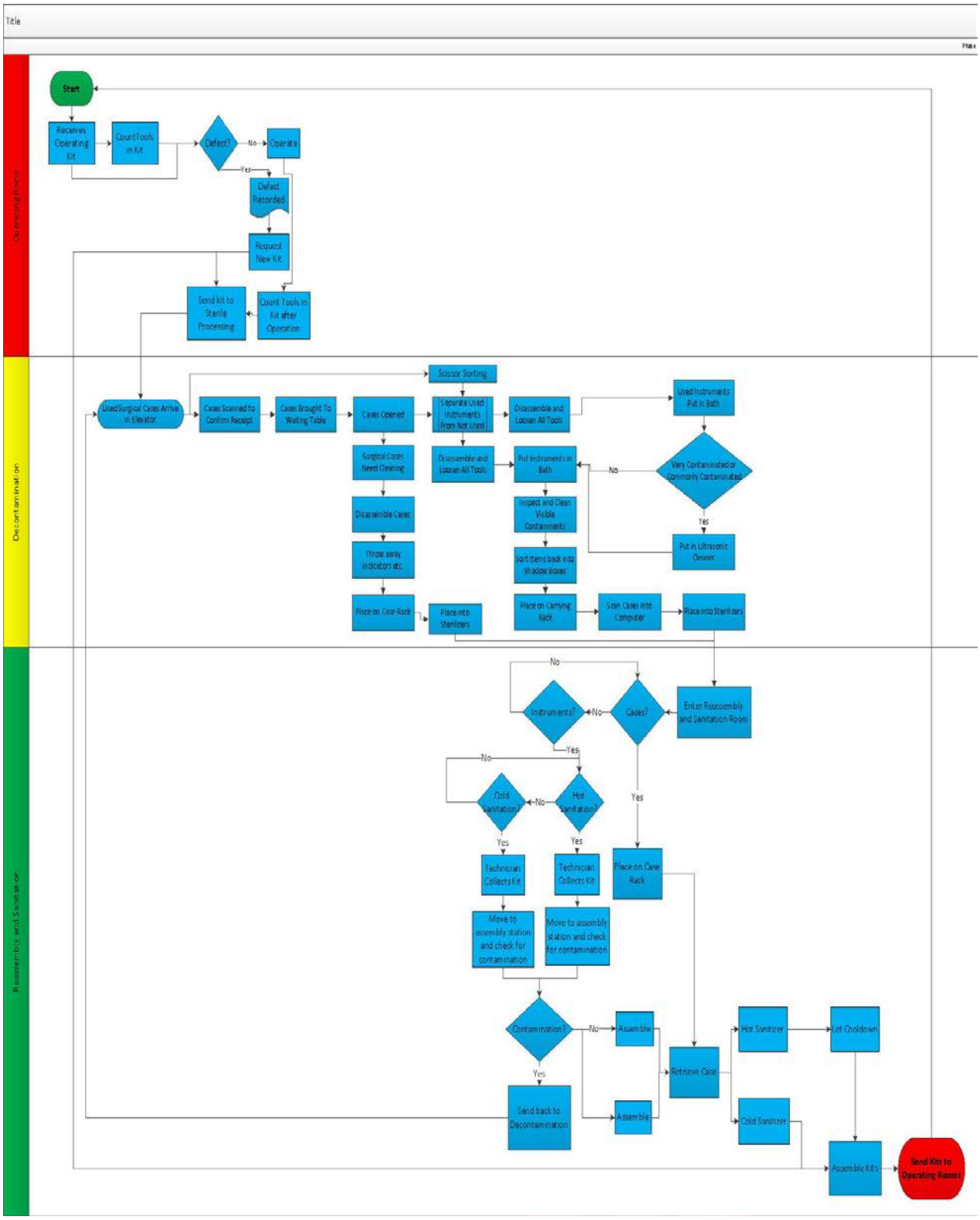

Figure 6: Process Flow Map

Spaghetti Diagrams

The spaghetti diagrams, Figures 7 and 8, illustrate the initial walking patterns that were present within SPD. The diagrams depict paths that employees took to complete a kit. Each diagram represents a different employee and kit. More spaghetti diagrams were completed, but these were chosen to highlight the differences between an efficient process, Figure 7, and a more laborious process, Figure 8. The purpose of the diagrams is to provide a visual aid to develop a deeper understanding of the process.

The diagrams depict a space that was not optimized for flow causing employees to have to walk back and forth in order to complete tasks. While in Figure 7 the employee clearly does far less walking than the employee depicted by Figure 8, it was still evident that the space could be organized better, so as to maximize the ergonomics of SPD. The two employees were working on different kits, the first on an endoscopic kit, and the second on an orthopedic kit. Some kits take longer than others, and considering that orthopedic kits usually have many more instruments than other types of kits, they have more room for error, such as missing tools. Hence, any employee could be in a similar situation as the one depicted in the Figure 7, where they must search several areas in SPD for missing instruments and parts. Much of the time spent walking could be used for value-added tasks, but instead that time was wasted looking for parts, missing instruments, and retrieving any necessary components for completing the kit at hand.

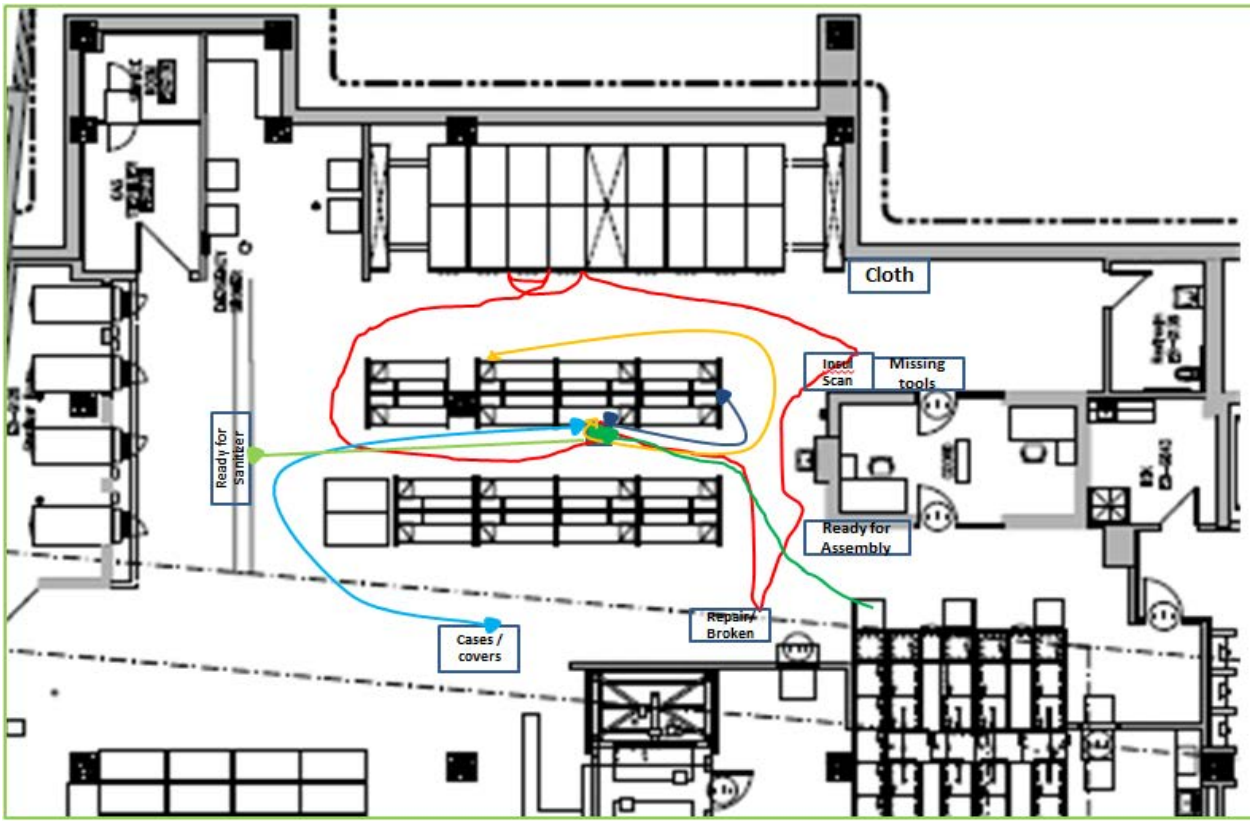

Figure 7: Spaghetti Diagram 1

Figure 8: Spaghetti Diagram 2

Congestion Map

From our observations and spaghetti diagrams we were able to track the frequency with which an area was walked through, from which we developed a congestion map, shown in Figure 9, to help us understand the facility layout better. The resulting congestion map indicated that there were several high traffic areas within SPD. In order to demonstrate the differences in level of congestion, we used a gradient from green to red. An area highlighted in green means that on average it has a low frequency of employees walking, yellow indicates more, and red indicates a high frequency of employees walking.

The congestion map illustrates that employees constantly had to walk by the inventory shelves in order to retrieve wrapping cloth for the kits. Because employees often had to visit the inventory shelves and the area where the wrapping cloth resides, relocating some of these necessary items closer to each employee would reduce their walking time and decrease the amount of non-value-added time. In conjunction with the spaghetti diagrams, it was clear that in order for employees to move more efficiently throughout the facility, SPD should be reorganized. Employees should be able to move throughout SPD more linearly, rather than having to constantly revisit spaces, in order to complete their tasks.

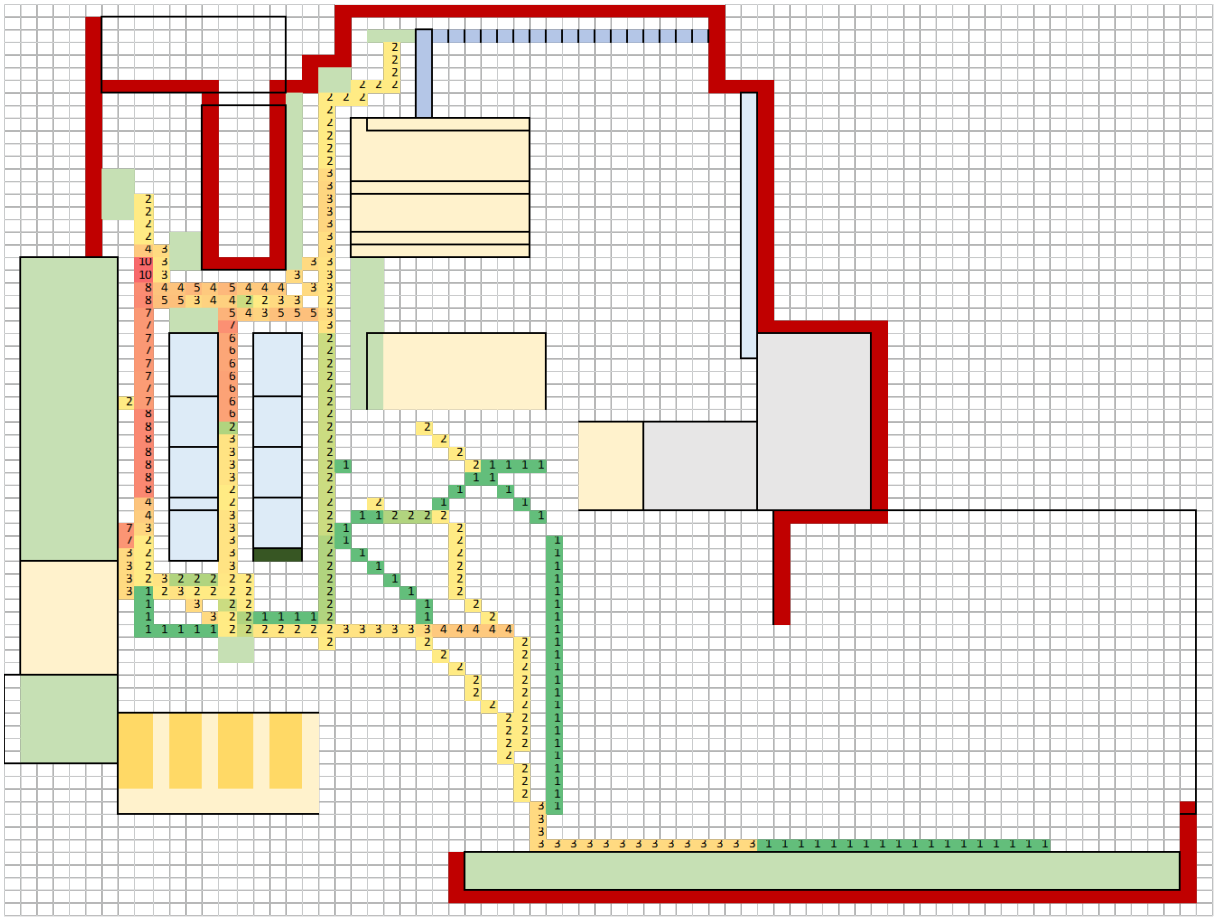

Figure 9: Congestion Map

Average Distance Traveled

From our observations we found that an employee walked a mean of 653 feet per kit, as seen in Figure 10. This accounted for all the travel incurred during the process of assembling a kit, including searching for missing instruments. Considering the longest distance of any given main pathway was equal to 34.58 feet, walking 653 feet to complete one kit reflected inefficiency. In order to complete one kit, an employee would walk the equivalent of the distance of the longest pathway almost 19 times. This metric made another strong argument for reorganization of the SPD facility.

	Number of Trips	Distance of Pathway (feet)	Average Distance Traveled
Pathway to Cloth	4.81	15.83	76.18
Pathway parallel to Inventory Shelves	5.14	34.58	177.89
Center Pathway	3.59	34.58	124.25
Front Pathway	1.75	34.58	60.51
Pathway perpendicular to washers	3.55	25	88.97
Pathway parallel to washers	2.56	25.42	65.29
Pathway parallel to sterilizers	1.70	25	42.50
Pathway to Decon Window	2.00	8.58	17.16
		Total Average Distance	**652.7817531**

Figure 10: Average Distance Traveled

Time Studies

From the two time studies conducted, shown in Figure 11, it was clear that kits require varying amounts of time to complete. Some kits had more non-value added time than others because of the particular state of that kit. The first kit that had an 11% non-value added time, while the second had 56%. This difference could have been due to a variety of reasons, such as employee training, placement of necessary assembly equipment, or missing tools. While the endoscopic kit had only 11% non-value added time, it still took almost as long as the laparoscopic kit to assemble. A large part of this time was because the employee working on the laparoscopic kit had to search for more than seven minutes for a missing pair of scissors. Moreover, there was a point of confusion early on and there were other points at which the employee needed to search for missing tools. While some kits, like the endoscopic kit, could be assembled quickly, many like the laparoscopic kit would take extra time to assemble due to confusion, the amount of time spent looking for instruments, and disorganization.

Summary - Karl Storz Endoscopic Kit Assembly	
Total Observation Time	26:10:00
Total Value Added Time	23:18
Total Non Value Added Time	2:52
Percent Value Added Time	89%
Percent Non Value Added Time	11%

Summary - Laparoscopic Kit Assembly	
Total Observation Time	29:10:00
Total Value Added Time	12:45
Total Non Value Added Time	16:25
Percent Value Added Time	44%
Percent Non Value Added Time	56%

Figure 11: Time Studies

4.4 Root Causes

Sterilization and instrument assembly in SPD occurred within a constrained system, which contributed to and exacerbated these primary and secondary causes of kits with missing instruments. The symptoms of this constraint may be split into three basic categories. In order of discussion, these categories were SPD's reliance on human knowledge, SPD facilities and processes. These root causes interact with one another and cannot be completely disentangled from one another. Therefore any changes implemented to address one root cause would likely mitigate the effects of another. For example, limiting the interruption of workflow allowed technicians to remain focused on their tasks, thus reducing the risk of placing the wrong instruments in a kit. The following section explains the grouping of root causes.

Reliance on Human Knowledge

In SPD, individual technicians used different methods to complete the process of decontaminating instruments and assembling them. For example, certain technicians would leave instruments loose in kits after decontamination in order to indicate they were in the wrong kit while other technicians would use this practice to indicate a need to examine the instrument with extra scrutiny. This lack of standards led to confusion and miscommunication between employees in decontamination and assembly, which may have increased the likelihood of wasting time during kit assembly.

During the project, managers in assembly were training employees to be able to complete each of the many functions of instrument assembly in order to relieve scheduling issues. This initiative had a direct effect on the process by taking technicians away from their area of expertise such as orthopedic kit assembly.

Becoming knowledgeable about the thousands of instruments used in the OR is a task that even veteran members of SPDs struggle with (Chobin, 34). Technicians had trouble identifying specific types of instruments that they were not familiar with. When technicians worked with unfamiliar instruments, they took longer to complete their tasks at an acceptable level, further straining the system. A contributing factor to this complexity was the immense variety of kits and instruments differentiated by surgical type or manufacturer. Even the names of instruments with the same function, but are manufactured by different companies, sometimes have different names.

The variation in naming conventions could confuse technicians when using the computer system, Censitrac, as well. Censitrac is a computer software system designed to track instruments and kits by barcodes on the kits, which produce a list of part numbers corresponding to a kit's instruments when scanned. There were a number of inaccuracies within the system. Moreover, because a consistent naming convention did not exist, technicians took longer to recognize what instrument a particular name was actually referring to. While some instruments in the system had pictures connected to them, not all instruments did, so the confusion persisted.

Facilities

The vast array of instruments and kits in various stages of assembly would be difficult to manage in any facility, however; this facility faced particular issues. The limited capacity of sterilizers and washers was a bottleneck in the process and interrupted the flow of material. Due to the time needed for these machines to process kits effectively, a single kit flow was not reasonable. Exacerbating these problems, one of the five washers in the decontamination area was thought to be broken. Additionally, the sterilization machines were being run for ten more minutes than recommended by the manufacturer due to poor drying. Dim lighting in decontamination was also an issue. Technicians in decontamination had noticeably duller lights than those in assembly or the OR, which might make it difficult to see contaminants. Tools also sometimes fall into the washers and might not found for indefinite periods of time.

The flow and placement of equipment impeded the work of technicians and contributed to a feeling of disorder in SPD. Tables, racks and shelves were consistently moved to inconvenient areas. For example, wrapping cloths, which are used in the assembly process, were located across the facility from the assembly stations. Scenarios such as these sometimes impeded employee movement while also complicating the task of finding certain materials and knowing where instruments and materials properly belong. In addition, the need for smooth employee movement was amplified by the placement of phones away from the technician's work desks. Due to the high frequency of calls from the OR, the time wasted from walking to the phones was considerable.

Process

Instrument assembly was a critical process subject to the demands of the OR. The changing needs of surgical technicians in the OR, as discussed in section 2.1, combined with the overall length of the assembly process produced consistent time pressures on technicians during certain shifts.

Kits were sometimes expedited through decontamination and assembly, increasing the risk of sending kits with missing instruments to the OR in an emergency situation. Even in shifts with limited need to rush, technicians felt constant pressure to push kit assembly in order to finish as soon as possible. This effect was compounded by constant interruption of workflow. When the OR called SPD, the technician nearest to a phone would answer it and attempt to resolve the issue. It was common to see half-finished kits on work desks, and carts that were supposed to be in transit strewn about Assembly and other stalled works-in-progress. Additionally, in the excitement of responding to the immediate needs of the OR, technicians might aid each other in tasks that only one person should be completing, such as bringing a requested kit to the OR.

During the project, employee turnover was high. Because The Academic Medical Center operates several hospitals, SPD employees were often rotated between hospitals. Such employees were known as "travelers." These travelers faced extra pressures as much of the knowledge required for the technicians was location specific; each SPD has physical

layout differences that create different work processes. This created confusion amongst these employees.

From time to time, technicians would send incomplete kits to the operating rooms. This would generally occur when an instrument that was not critical to the success of an operation was missing from a kit, but no replacement kit was available. For example, a kit may have a variety of sizes for a particular instrument, all of which are functionally equivalent. If one of five sizes was missing, but there was no available kit with all five sizes of that instrument, the technician may have sent the kit to the operating room. This was still counted as a missing instrument, even though it was not technically a mistake.

Figure 12 is a completed Fishbone diagram that categorizes the root causes of missing tools within SPD.

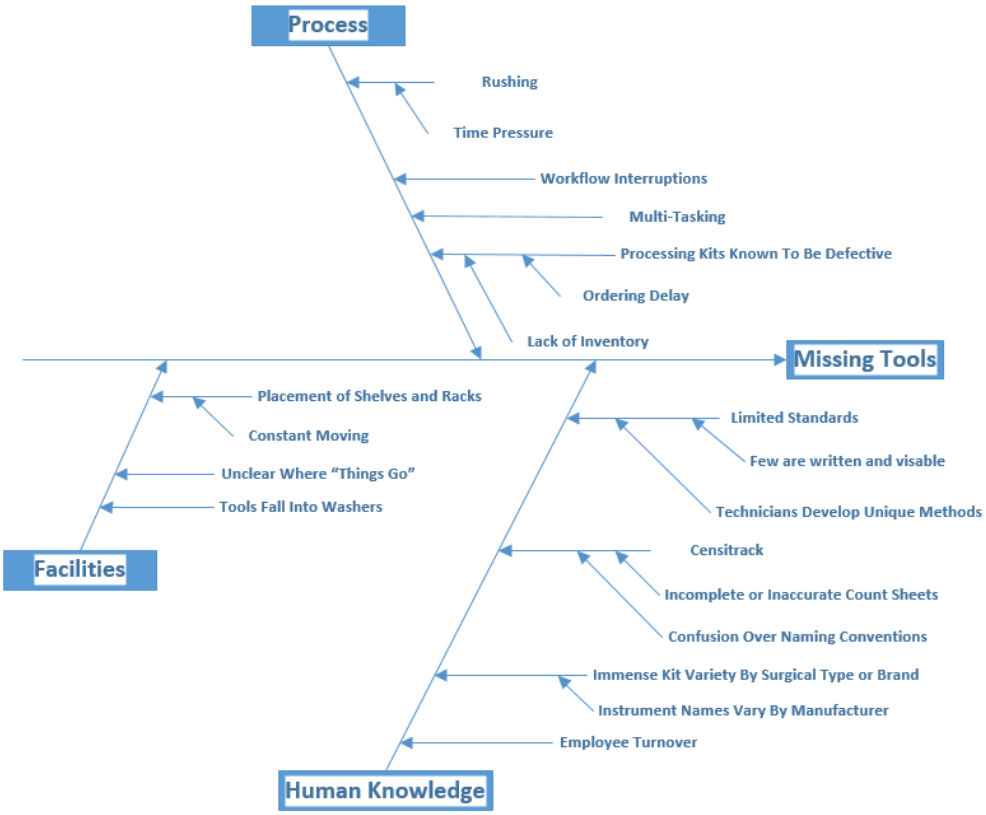

Figure 12: Completed Fishbone Diagram

4.5 Goal

Overall our goal for the project was to reduce the 9% missing instrument rate in surgical kits received by the operating rooms by approximately 20%. We sought to accomplish

this by the completion of sub-projects designed to address the root causes of missing instruments.

4.6 Countermeasures

Due to the time constraints of this project, the team chose to focus on several root causes. The assembly of kits with missing instrument was the product of a great many factors, though the team worked with The Academic Medical Center staff to choose from various countermeasures to enact. Standardization or the use of the 5S was the cornerstones of any implemented changes. The role of technicians is key in an SPD, so any initiative that eased the burden of these technicians represented an opportunity to reduce SPD's missing instrument rate. Figures 13, 14 and 15 show the specific root causes identified by the team with a broad plan of action as to how it could be addressed.

Limited Standards	Employees develop their own methods to deal with various situations resulting in confusing losing instruments, misprocessing and wasted time	Develop standard processes all employees should follow in order to eliminate improper instrument placement and processing
Standards are not Posted	The standards that are in place are not universally enforced and hard to remember, therefore kits may be built using nonstandard processes.	Post common processes on easily read, visually understandable sheets
Censitrac	Censitrac is an inventory management system, which is still not complete. Various naming conventions for picklists, leading to incorrect instruments being placed in kits and neccesary instruments not being added	Continue developing the system, though consider using universal instrument names, as opposed to manufacture sepecific names
Kit Variety	Similar surgeries sometimes require vastly different kits, increasing the number of instruments and kit types employees must know and increasing the chance of confusing employees	Continue the transition of kits and instruments to a single, or few manufacturers
Travelers	Travelers and new employees are less familiar with theAcademic Medical Center SPD process and have less experience with the nonstandard utilized by other technicians	Engage in 5s Process Improvement to quickly familiarize them with SPD processes

Figure 13: Human Knowledge Table

Constantly Moving Shelves and Racks	Designated areas for missing instruments, incomplete kits and other inventory moves each day making it difficult to place instruments in the proper containers, and increasing the likelihood that instruments will be lost	Designate permanent homes for various depositories and inventory
Inventory Confusion	It is unclear where certain instruments are to be placed, resulting in sheleves containing a mix of unfinshed kits, instruments to be peel-packed and missing instruments which, due to the clutter, increases the lieklyhood of a neccesary instrument not being found for a later kit	Label all shelves and racks in order to eliminate confusion regarding where instruments and associated inventory must be placed
Instrument Components In Washers	Occasionally small instruments fall out of kits during washing and are not found until the washers are closely inspected which increases the chance a kit will be processed without these instruments	Introduce a quick, visiual inspection of the washers after each kit rack is washed

Figure 14: Facilities Table

Rushing	Due to the urgency forced upon technicians due to the demands of the OR and quotas, technicians often feel rushed which may sacrafice quality and promote pushing problem kits off to another technician	Remove as many nonvalue added steps from SPD processes in order to allow more time for technicians to carefully inspect instruments and take ownership of issues at the point of discovery
Workflow Interuption	Technicians lose focus on their tasks and often waste time and movement in order to address various interruptions such as OR calls to SPD contributing to the need to rush	Streamline work to minimize the number of technicians responsible for answering OR phone calls or other tasks not associated with the current task of assemballing the particular kits they are working on
Multi-Tasking	Similar to workflow interruptions, multi-tasking technicians must divide their focus between different tasks, increasing nonvalue added steps, which creates further need to rush and reduces quality	As a symptom tied into so many other root causes, directly addressing multi-tasking issues may need to take the form of simply establishing a standardized process that explicitly demands a one-piece-flow that is completed in one attempt
Processing Kits With Known Defects	This practice promotes scavenging other kits, increasing the time pressures of SPD by having the OR reject a kit known to be unacceptable and force a rush processing of a replacement kit, and makes replacing truely lost or broken instruments difficult which has clear implications for the defect rate and other SPD metrics	Implement First-Time-Quality and Problem-Ownership in Assembally, so that when a technician sees an issue, they address it through a standard process without fear of being penalized for having a lower production rate as a result of proactively solving this reoccuring issue and if the missing instrument is generally not used, label the kit to alert the OR it is not included

Figure 15: Process Table

4.7 Impact-Effect Matrix

An impact-effect matrix was designed to identify which root causes the team could best address. The goal was to pursue solutions that seemed the easiest to achieve with the greatest effects. The completed matrix is shown in Figure 16.

The diagram in Figure 16 contains a horizontal axis which is labeled as the “effort” required. The diagram also contains a vertical axis which is labeled as the “impact” of the solution. Each quadrant is labeled as:

- Low Effort/High Impact
- High Effort/High Impact
- Low Effort/Low Impact
- High Effort/Low Impact

The quadrant that we focused on the most was the Low Effort/High Impact because if solutions were implemented in the upper-right hand quadrant it would yield the best return on investments and therefore should be considered first. Another reason that it was reasonable to start in this quadrant was because solutions in these area were easier to implement. The categorization of each root cause is briefly discussed in the following sections.

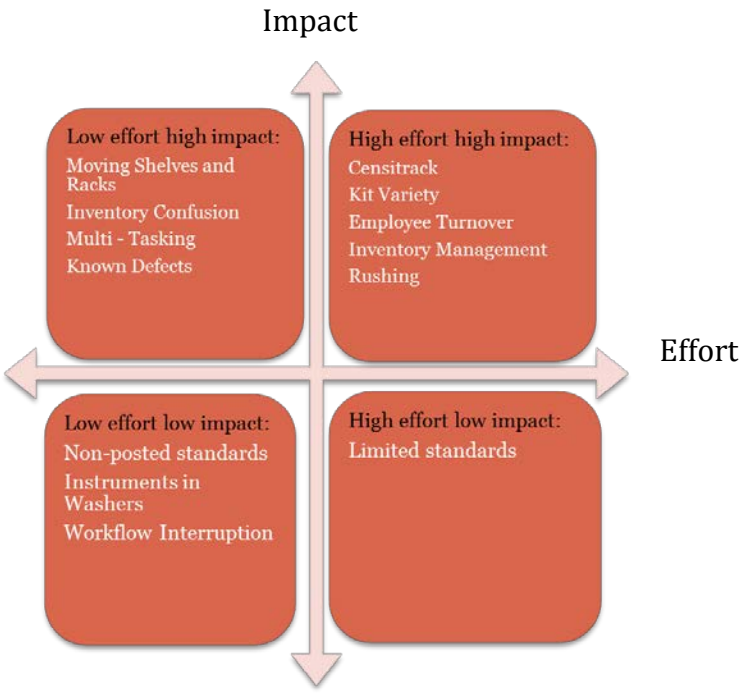

Figure 16: Impact – Effort Matrix

Low Effort/High Impact Opportunities

This section described root causes placed in the upper left quadrant in Figure 16.

Moving Shelves and Racks

We believed that organizing SPD by moving shelves and racks was important because this change would not be costly and that would give the employees a better work space while also motivating them to work more efficiently in a clean area. We believed that by organizing the area and by reducing the non-value space in the SPD assembly area, there would be a reduction in the rate of missing instruments because the process would be smoother. By removing the non-value added space from the different placement of the racks, the technicians would be able to work more easily.

Labeling to Reduce Inventory Confusion

Labeling was also an important step for improving organization because of the variety of instruments. Labeling all shelves and racks was a tedious job but it also remained within one department. We believed it would not be costly to place labels. Also by placing the labels it would make it faster for the technicians to get the instruments they need, further reducing the tendency to rush. Labeling would reduce the percentage of missing instruments as the instruments selected would not be confused with other instruments.

Multi-Tasking

Multi-tasking was an issue that arose due to the roles assigned and variety in process. We believed that having a consistent process in place to reduce multi-tasking would require medium effort because it would require the supervisor and technicians working together to come up with the most efficient way of streamlining the process and therefore making it easier for the technicians to do their jobs. This would have a high impact due to the complex kits in the system.

Known Missing Instruments

Sending kits that were known to contain a missing instrument caused a percentage of missing instruments due to the lack of communication between OR and SPD. Ending this practice would directly reduce the missing instrument rate.

High Effort/High Impact

This section described root causes placed in the upper right quadrant in Figure 16.

Censitrac

We believed improving Censitrac would require high effort because the team did not have access to the system, and it required knowledge of the variety of instruments for

each kit, which we did not have. Improving this system would have a great impact because technicians would be able to have a list that contained all instruments in the system. Having a complete list would make the process more efficient as it would not rely only on technicians' knowledge.

Kit Variety

We believed addressing kit variety required high effort because it would involve multiple departments including the surgeons in the operating rooms, management and SPD. Standardization of instruments would make it easier for the technicians as they would have fewer instruments to worry about. We expected this would reduce the missing instrument rate as there would be less confusion.

Employee Turnover

Employees frequently moved in and out of SPD. New employees struggled to learn the system because of its inherent complexity and because there were few established and posted standards across the department. Reducing turnover would have a high impact on the missing instrument rate because it would reduce the need to train new employees.

Inventory Management

Improved inventory management would be high impact because of the number of instruments in the different kits. This type of management would require high effort because other departments would be involved in creating a system to manage inventory. However, a high impact would be achieved because there would be a well-organized list of instruments that would allow everyone to know what needs to be replaced and also be able to know what they have every day.

Time Pressure

Time Pressure was an issue as most technicians felt pressured to meet certain quotas but they also had multiple problems and needed to redo some kits. We believed changing the process of SPD would require medium effort. If we could reduce non value added time throughout the assembly process, technicians could assemble kits with less time pressure and this would directly reduce the missing instrument rate.

Low Effort/Low Impact

This section described root causes placed in the lower left quadrant in Figure 16.

Instruments in Washers

Occasionally instruments would get lost in the washers. We believed that low effort would be required to deal with this issue because technicians would simply need to look

at the washer for missing instruments. We also thought this would have a low impact because we did not know if this problem happened often and it seemed that this would happen when technicians were being rushed so they did not have the time to inspect the washers.

Workflow Interruption

There were frequent interruptions at SPD due to OR calls which forced the technicians to stop work and answer a call. Low effort would be required to implement a system that would assign specific personnel to deal with the OR calls and therefore technicians working on a kit would not be interrupted. We also believed that it would not have a high impact because technicians who have interruptions would be facing time constraints but it is not a direct effect on missing instruments.

High Effort/Low Impact

The section below refers to the lower right quadrant in Figure 16.

Limited Standards

Employees had a variety of procedures for completing the same tasks. Reinforcing these procedures would require different departments to get involved. However, there would be a low impact because while these standards were usually different between technicians, it did not directly affect missing instruments.

5.0 Sub-Projects Completed

This section details the sub-projects that were completion in pursuit of a reduction in the rate of missing instruments. These sub-projects followed the A-3 Methodology. Section 6 of the report examines the results of each of these sub-projects.

5.1 Assembly Station Project

Background

Most of the work in SPD occurs on the 12 assembly stations as seen in Figure 4. In these assembly stations, kits undergo inspection, cleaning and proper assembly. The stations are set up as stand up workstations, but some technicians use high chairs so that they may sit while they work. Despite the fact that much of the kit assembly process requires the same materials, the assembly stations typically had different sets of supplies and varied from one to another, resulting in a low level of standardization across stations. This frequently led to technicians searching for necessary supplies at assembly stations other than the ones at which they were currently working. Technicians' work was occasionally halted because of needing to find supplies necessary for cleaning instruments and properly assembling kits for sterilization. The trips for supplies made by each technician each shift results in wasted time that increased the time pressure assembly and introduced a point in the process where technicians could become confused or lose their concentration.

Figure 17 shows the arrangement of a typical assembly station prior to the completion of this project. Each station has a computer, mouse, keyboard, and almost all have two shelves. The picture demonstrates how the station is cluttered and materials required for assembly were scattered without labels or not present at all.

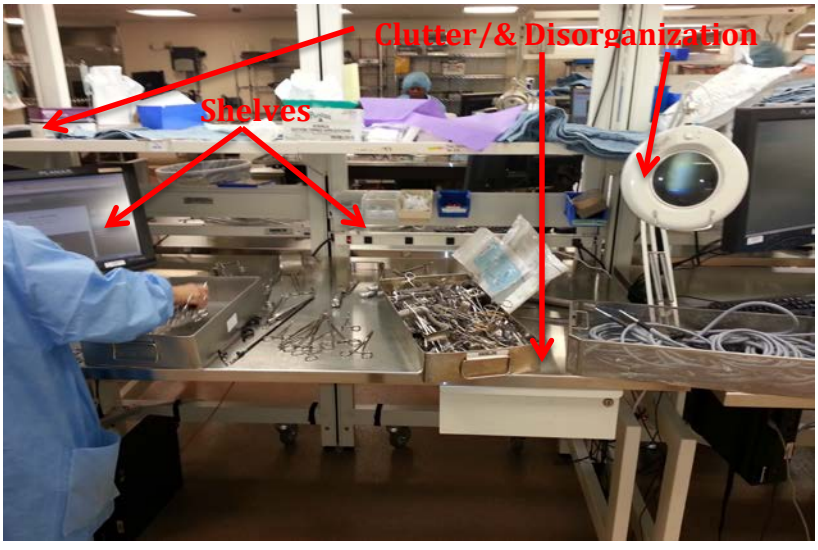

Figure 17: Assembly Station Before

Goal

The goal of the assembly station project was to design standard workspaces for technicians working at stations. We sought to ensure that each station was adequately stocked with materials so that technicians could assemble kits without needing to leave their station. Enabling technicians to work more consistently would reduce distractions due to workflow interruption, which would allow technicians to spend more time actively inspecting individual kits. Organized stations would have a direct impact on the defect rate by curbing a root cause for missing instruments.

Procedure

This project was conducted using the 5S methodology and lasted from November 12th, 2013 – December 12nd 2013. Station 10, as shown in Figure 4, was chosen for a pilot test because it was easily accessible without putting the team in an area where there was a high chance of obstructing the process for a technician.

Sort

Based on responses from SPD management and technicians, various supplies and miscellaneous tools at Station 10 were sorted according to their necessity. Empty containers and unnecessary items were removed from the station table and shelves.

One of the main aspects of the sort step was removing "1x1 kit tags" from the work station bins. We concluded that these cards were repetitive and created opportunity for contamination once the kit came back to SPD for washing. Removing these tags freed up several containers for use by needed supplies that were previously not available at the station. Overcrowded stations also benefited from the removal of such items, as it allowed more workspace and reduced the aesthetically confusing clutter.

Set In order

Our next step was to identify proper locations for supplies and computer placement. We needed all supplies to be in the best location for any technician, of any height, to be able to access them. Reach requirements should be based on the reach of the smallest users, hence we organized supplies in bins that can hang on the shelving units, and allows for easy access to supplies such as indicators, and nail polish remover (Wickens et al., 2004). The inventory for these supplies would be placed on the shelf above their respective bins, while items that are less frequently used would be placed on the higher shelf above the computer. A shelf was placed to sit right above the computer, so that it is at the lowest possible height, so that any supplies on this shelf are easier to reach.

Feedback from the technicians was encouraged and as a result a sheet was left for further improvements. The sheet of paper asked technicians for their feedback on the assembly stations. The feedback obtained was useful as it helped the team determine where each bin should be located. One example of the change can be seen in Figure 19. In the original design, the bins were too far back (see Figure 18) for technicians to be able to reach, and taller people may have had to bend or Lean their bodies forward slightly in order to reach supplies. The blue ovals in Figures 18 and 19 show the specific changes.

At first when considering reach, we considered height, and ignored depth, which is another important consideration when designing for the reach of smallest users (Wickens et al., 2004). With the bins now placed right in front, meaning they were placed in a position with less depth, they were much more accessible to even the technicians with the smallest reach. The new placement of such bins also reduced the need to Lean forward, which is beneficial for both tall and short users (Wickens et al., 2004). Another advantage to the new placement was that the bins were within the normal line of sight, which is 10 to 15 degrees below the horizontal plane. Visually, items and signs placed within 15 degrees above or below the normal line of sight are preferred (Wickens et al., 2004). With bins up front, rather than at the back of the assembly stations, they were now within the acceptable range of visibility. Moreover, the supplies in the bins are frequently used. The frequency of use principle dictates that frequently used items should be placed in the most convenient locations close to the dominant hand, and in optimal viewing locations (Wickens et al., 2004). Based on Figure 18, the basic guidelines of the frequency of use principle have now all been satisfied (since we can assume most people are right handed).

Finally, the fact that the bins were movable offered adjustability, so that if any technician was more comfortable with the bins being placed in a different location they can very easily hang the bin off of a higher or lower shelf or even place the bin on the table (Wickens et al., 2004). Hence, technicians adjusting the bins were a good thing and expected, as it meant they were adjusting the work space to improve their comfort.

Figure 18: Assembly Station after WPI Set in Order

Figure 19: After Technician Set in Order Phase

Shine

Because of the nature of the work in SPD, the shine step is not one we were concerned about. There are frequent trips made by facilities staff to empty trash bins and clean the

floors. Likewise, all the techs take station and instrument cleanliness seriously, and as such SPD does not have an issue of unclean work stations.

Standardize

After considering feedback from the SPD technicians on our sample station (Station 10), we organized the rest of the stations to be as similar as possible. Not every station had the same number of shelves or bins, so we made sure to include the same number of supply bins at each station by freeing up bins where we could during the sort step, and placed shelves at optimal heights, like we did with Station 10.

Sustain

Sustaining this project came from getting buy-in from the technicians and managers. As we received their help and input, the project became valuable to them as they also vested their time and ideas into the project. Realizing that, ultimately, applying 5S to the work stations will only benefit them, SPD technicians seem to want to maintain the stations according to 5S. By labeling the bins and locations of supplies on the work stations as seen in Figure 20, we left the project in a state that is easily sustained so long as technicians continue to be mindful of how they use the station space.

Figure 20: Sustain

We designed a checklist that will be located at each assembly station. The purpose of this checklist is to allow technicians to make sure that their stations are properly organized at the beginning of each shift. The checklist contains a list of supplies that are necessary for the job of a technician. If any supplies are missing, the technician is responsible for restocking their station at the beginning of their shift.

Results

Overall the SPD technicians expressed satisfaction with our help because it allowed them to reduce their supplies inventory to only have what was necessary. For example, they were enthusiastic about removing the name tag/I.D. cards because they never used them and felt that they were a waste of space at each station. While some supplies will still shift placement, as people continue to get used to the standardized stations, all technicians will have a table space with less clutter. Part of our goal was accomplished by having the stations more ergonomically friendly for the technicians, so as to make their jobs easier and more efficient.

5.2 Unsterile Storage Project

Background

A main contributor to the missing instrument rate in SPD was identified as the unsterile storage racks of instruments. These racks store extra inventory of instruments that can be used in the assembly of kits. When an instrument goes missing either due to misplacement or repair needs, technicians should be able to find a replacement instrument in the racks of unsterile storage.

At the outset of this project, the racks contained a variety of instruments, and were often difficult to find. Technicians would search these racks and spend time searching for a particular instrument without finding it. Instruments were difficult to locate because the racks contained many instruments that were no longer used and those used more often were clustered together in large bins without labels. There were 10 racks of unsterile storage. Each rack contained shelves three across and five tall. On each of these individual shelves were usually three or four bins, similar to the one shown in Figure 21. Depending on the size of the instruments located in the bins, an individual bin would contain between approximately 20 and 100 instruments. A rough estimate of the total number of instruments that were located in the racks of unsterile storage area was 20,000, in about 400 bins.

Figures 21 and 22 provide examples of some of the racks within the unsterile storage area of SPD and their visual layout before any changes were made to the process. As shown in Figure 21, some bins contain a wide variety of instruments. There was no clear documentation that would describe what instruments could be found in a bin like the one shown, and technicians would need to search, sometimes for several minutes, in order to

find a particular instrument. Due to frustration and wasted time, many technicians would abandon their search without ever finding the necessary instrument. Figure 22 shows a larger example of a rack that contains a variety of bins. Some of the bins in these photos were labelled. Labelling was common, but the instruments within the bins typically were not reflected by the names on the labels.

Figure 21: Sample Instrument Bin

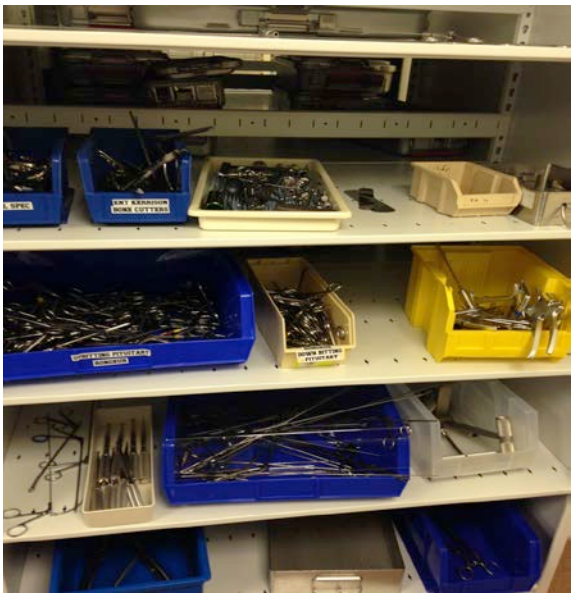

Figure 22: Example of Unorganized Rack

Goal

The goal of the unsterile storage project was to create a sense of order within the unsterile storage racks. Creating specific locations for instruments was intended to reduce the total search time required to find instruments within the racks. More organized racks would also decrease the likelihood that a technician would abandon their search for an instrument before finding it. The gains in time from the reduction in waste and the increased likelihood of finding replacement instruments within the unsterile racks were expected to reduce the overall rate of missing instruments within SPD. The effect of the time saved would be indirect as more time could be spent on value-added work; however, the effect of increasing the likelihood of finding instruments would be direct.

Procedure

The team surmised that the best way to tackle the unsterile storage project would be to utilize a 5S methodology. This project lasted from November 4, 2013 – December 9, 2013.

Sort

The team spent a combined 12 hours over three days between November 4 and November 11 on the sorting step within the unsterile storage racks. The goal of the sorting step was to clear space in the unsterile storage racks so that instruments that were clustered together in single bin could each be given their own bin. The sorting was accomplished by removing unnecessary inventory from the racks. The team worked closely with technicians in order to decide what items were necessary and which were unnecessary. The team and technicians physically separated unnecessary or obsolete instruments from the rest using a “Red Tag” process. There are 10 racks in the unsterile storage area and one was designated as the “Red Tag” area. This rack was labeled with a sign, shown in Figure 23. Instruments that were unnecessary were placed in this rack and as shown in Figure 24, these bins were also filled with labels that indicated that they were “Red Tag” instruments.

Figure 23: Red Tag Area

Figure 24: Red Tag Instruments Bins

Items in the “Red Tag” area were designated to be reviewed for removal by Nurse Line Managers. Once these managers approved the removal of these instruments, they were either donated to other hospitals or destroyed by the environmental team at The Academic Medical Center. Once instruments were reorganized into the “Red Tag” area, 24 extra shelves were made available to proceed to the next step, set in order. Figure 25 shows an example of the extra space created as a result of the sort step.

Figure 25: Extra Storage Room Created

Set In Order

Once “Red Tag” instruments were removed from the unsterile storage area, we began working to separate the bins of instruments that remained. Our goal here was to give each instrument their own bin and label each bin so that it would be easy to locate where an instrument was at any time in order to reduce the amount of time required to find instruments in the racks.

Figures 26 and 27 show the same instruments before and after the set in order process. In Figure 26, it is apparent that there were a variety of similar instruments of different sizes located in one large bin. The team separated these instruments by size and created new bins for each of them with labels in Figure 27. Instead of searching for a specific instrument in one large bin, technicians can now quickly identify which instruments are found in each specific bin.

Figure 28 shows a broader extension of the work performed during the set in order step. Rather than jumbled racks with a variety of mismatched bins of instruments, this rack has been fully organized so that bins are labeled and categorized according to which instruments are contained within them.

Figure 26: Bin before Set in Order

Figure 27: Bins after Set in Order

Figure 28: Fully Set in Order Rack

Shine

The shine component of this project was rather broad. We applied the concept of shine to the specific problem of worn out tools within the unsterile racks. The purpose of the shine step is largely to make sure that everything is ready-to-use and in working order. The specific application was that occasionally, instruments sit in these racks for several years and either become outdated or are used so much that they rust. The shine step involved the continual awareness of the need to remove these items from inventory. This was accomplished by the red tagging of several worn out instruments during the sort step.

Standardize

Due to a lack of supplies readily available within SPD, it was challenging to standardize the unsterile storage racks. Ideally, the team would have wanted to have a uniform binning and labeling system for instruments stored in these racks; however, due to budgetary concerns, this was not feasible for the department. Instead, a variety of different types of bins and labels were used throughout the racks. While this outcome was

less than ideal, we did not expect it to have a large detrimental effect on the quality of the project.

Sustain

The sustain portion of this project began in January and rolled into the next phase of the Unsterile Storage Categorization Project. The goal of the sustain step will be to create an effective system for labeling and tracking the movement of instruments through the unsterile racks which will merge into a larger inventory management initiative.

Results

We created efficiencies in space by reducing the number of racks used to store of instruments from 10 down to 5. In addition, the four most commonly used racks of instruments were reorganized so that technicians can find instruments more easily. At this stage, one more rack still needs to be reorganized and the racks themselves need new labels. In the long term, we hope that SPD will also be able to benefit from the space that has been freed as a result of the sorting of the racks.

Limitations

The main areas of difficulty present during the implementation of this project were a lack of materials and a lack of available technician time. A key aspect of the unsterile storage project was to give each set of instruments its own permanent location in the storage racks. In order to fully accomplish this goal, the team needed bins in which to store all of the instruments. Because many varieties of instruments were stored in single bins, there were not enough bins available at the outset of the project to place all of the instruments.

The other main challenge present during this project related to the knowledge required to physically sort through the instruments in the unsterile storage racks. Because no members of our team are trained sterile processing technicians, we did not always have the appropriate knowledge as to how to sort instruments. Some instruments were easy to separate because they were labeled with engraved numbers; however, many instruments are very similar in appearance but are used for different purposes and need to be separated. To a non-technician, it is very challenging to determine the appropriate way to sort these instruments. In order to successfully sort instruments in the most effective way, the team relied on the knowledge and active assistance of technicians during the separation process.

Recommended Improvements

In order to undergo transformational change, SPD should allocate additional time and resources to support improvements. Within the racks of unsterile storage, SPD should obtain bins of appropriate sizes to store instruments. Additionally, SPD should allocate

time for technicians to continue improving the organization of the racks of unsterile storage. SPD currently has resources to support change, but these additional resources would increase the rate of change.

Continued Progress

As an additional component of the unsterile storage project, the team designed a guidebook, referenced in Appendix B, to further reduce time wasted by technicians and promote putting a visual workplace into practice. Currently in unsterile storage the organization of racks is not consistent and there are no labels in the shelves. Furthermore, the labels on the outside of the unsterile storage racks do not correspond to the placement of the items within the shelves. This set up increases the departments reliance on human knowledge, making it more time consuming than necessary for technicians to find stored instruments if they do not frequently search given sections of the shelves.

The goal of this initiative was to provide The Academic Medical Center technicians with a guidebook to assist them in the implementation of a more effective inventory management system in unsterile storage. By including design considerations and explanations for our suggestions, the guidebook was expected to be useful in any other similar projects, such as a reorganization of the sterile storage area. In order to ensure the long term impact of this initiative, it was designed as an educational tool to promote buy-in for a visual workplace beyond simply storage areas. For this reason the guidebook needed to be short and very precise to guarantee its use, as a long document detailing even small considerations would simply not be read.

First the logic behind the system in place was analyzed by speaking with technicians. Then a list of advantages and disadvantages was generated. Entering a brainstorming session, the team wrote down important considerations that would be used to choose a final design to test. This included discussing tradeoffs such as the one between micromanaging and the work required to implement and maintain such a system. After planning a new system of managing unsterile inventory was conceived, this plan was written down in length, as its implementation became the team's the recommended plan for unsterile storage in SPD. Finally, the guidebook was edited to keep only its core content and refined to provide the most value for the smallest amount of reading. While the team recommends implementing the suggested organization scheme in unsterile storage, it is the team's belief that understanding the procedure that generated this suggestion is even more beneficial. This will synergize with internal efforts within SPD and The Academic Medical Center as a whole to promote Lean thinking and a dedication to continuous improvement. A guidebook that details this progress can be viewed in Appendix B.

5.3 Facility Layout Project

Background

We began our analysis of the Sterile Processing Department after receiving the facilities map (Figure 29) from our sponsor. Congestion within the department was identified by creating different spaghetti diagrams, one which is shown in Figure 30. The distances measured were determined by taking measurements of the main sections of the department (Figure 30). As shown in the facilities map, some tables in the department were undesignated and were used for multiple tasks. As a result, this created a source of confusion that led technicians to spend more time in assembling kits. The peel pack stations and wrapping cloth racks were located in non-ideal locations resulting in unnecessary travel for each technician, and separate wrapping stations did not exist Technicians had to wrap kits at their assembly stations, which often do not provide enough space. For these reasons changes in the layout were seen as important. Figure 31 shows the measured distances of pathways in SPD.

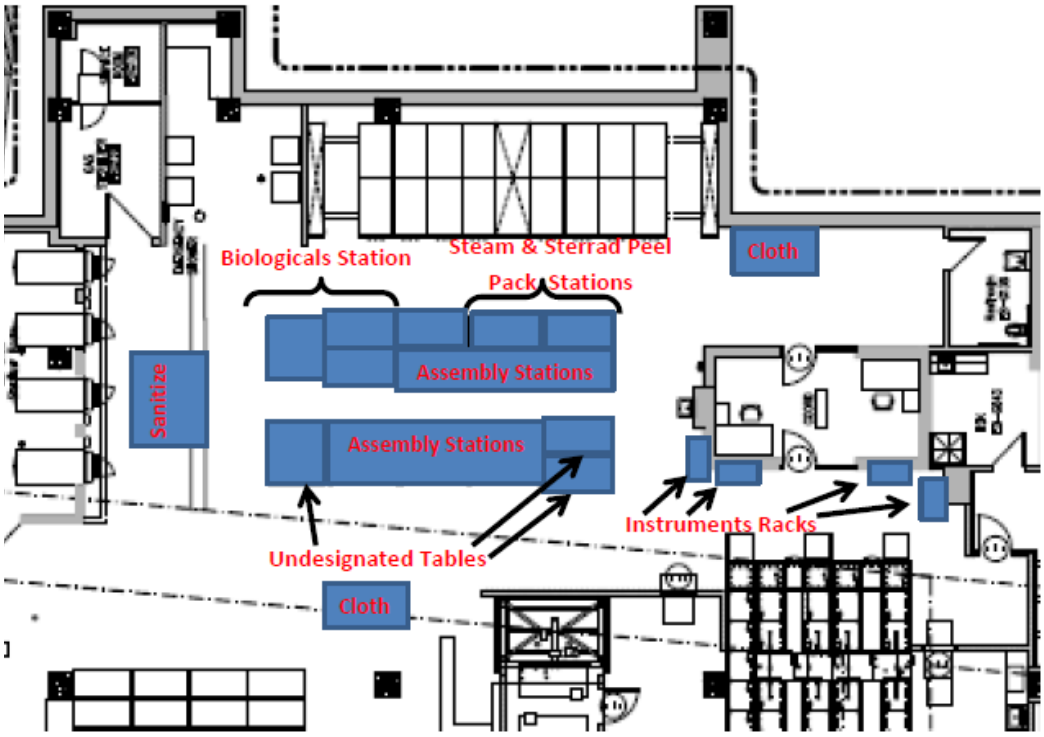

Figure 29: Fully Set in Order Rack

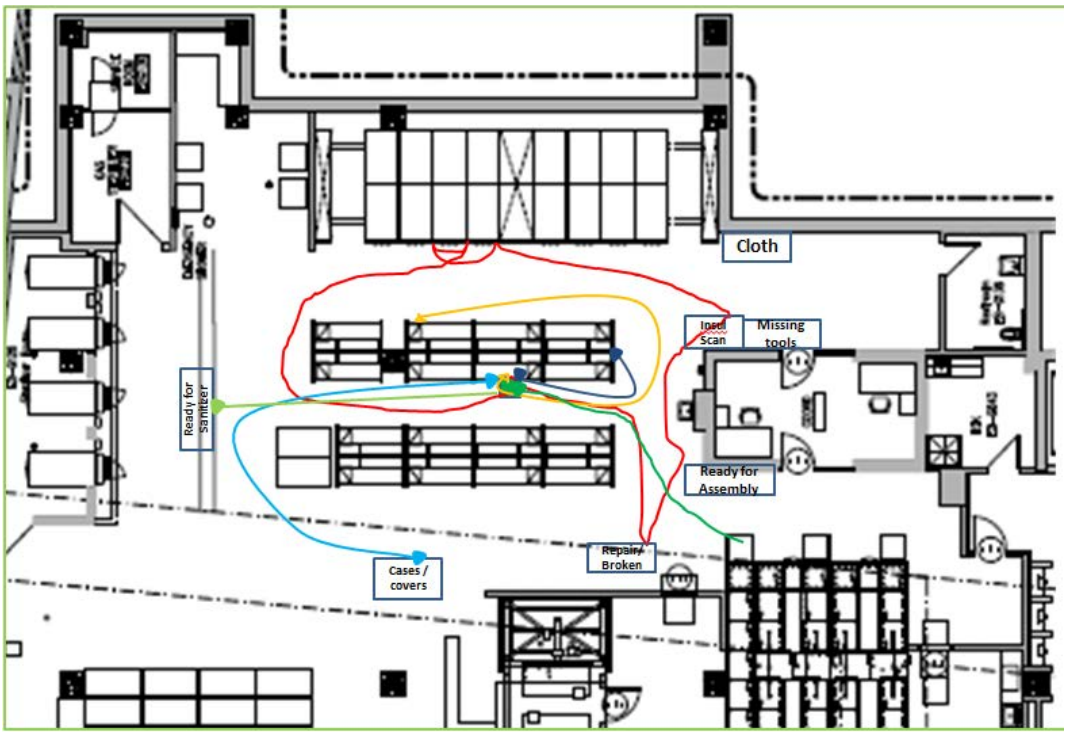

Figure 30: Before changes Spaghetti Diagram

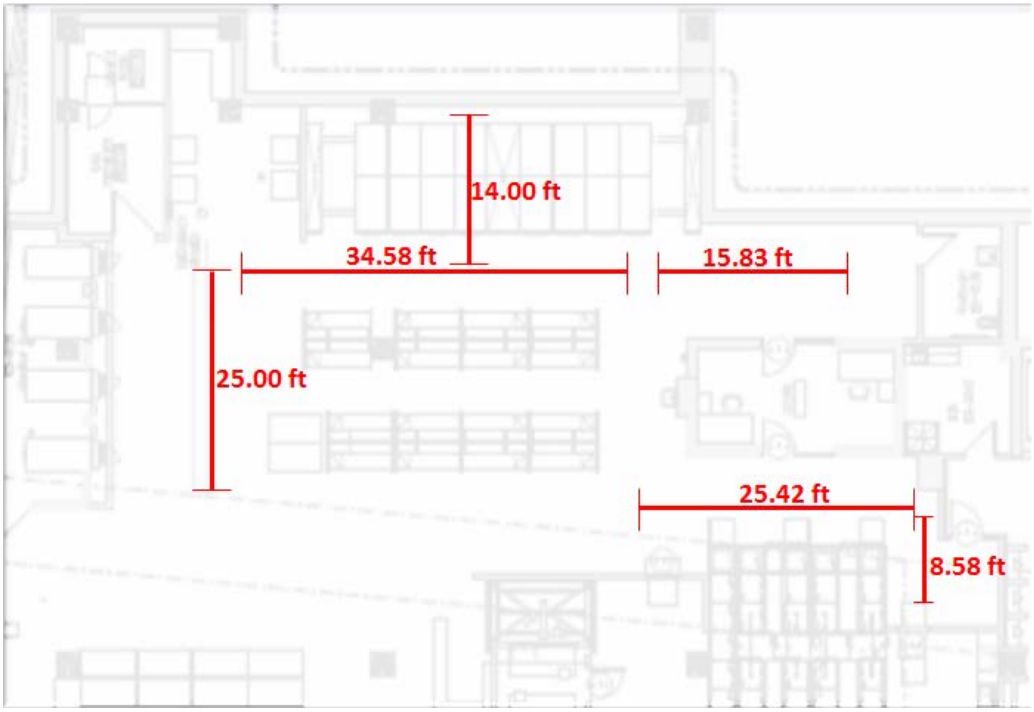

Figure 31: Measured Distances of Pathways

Goal

The goal of the Facilities Layout Project was to make the necessary changes in the placement of the peel pack stations, and wrapping cloth racks and wrapping stations, in order to reduce the congestion and distance that technicians need to travel, ultimately contributing to the goal of reducing the rate of missing instruments.

Procedure

In order to make successful layout changes, we observed the department to find the under-utilized areas. It was necessary to speak with technicians for us to understand the processing of kits and receive suggestions to perform the necessary changes.

Set in Order

After identifying the undesignated space in the department, we were able to use that space to move the peel pack stations and the wrapping cloth racks, to create two wrapping stations and to consolidate the biological station. The stations were physically moved at this time. During this step, as it can be seen in Figures 32 and 33, we labeled and shadowboxed the required materials in their respective tables. In Figure 34 we can see the final layout for the Sterile Processing Department.

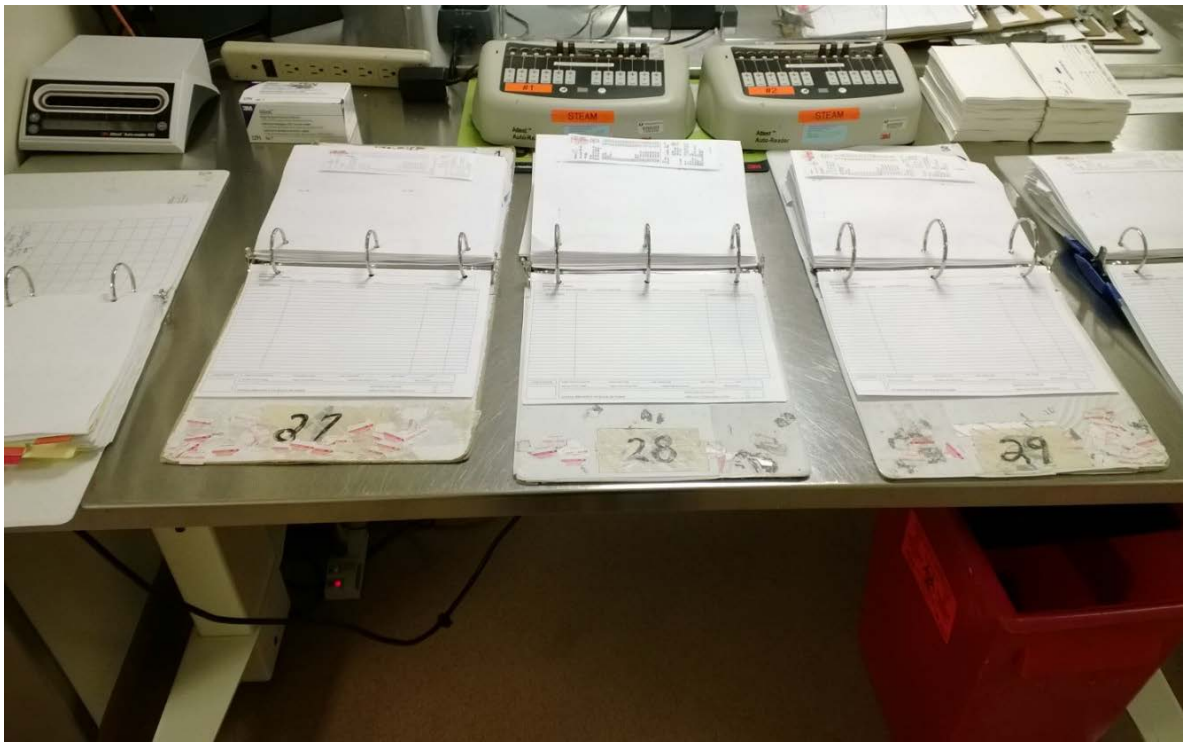

Figure 32: Biological Station

Figure 33: Wrapping Station

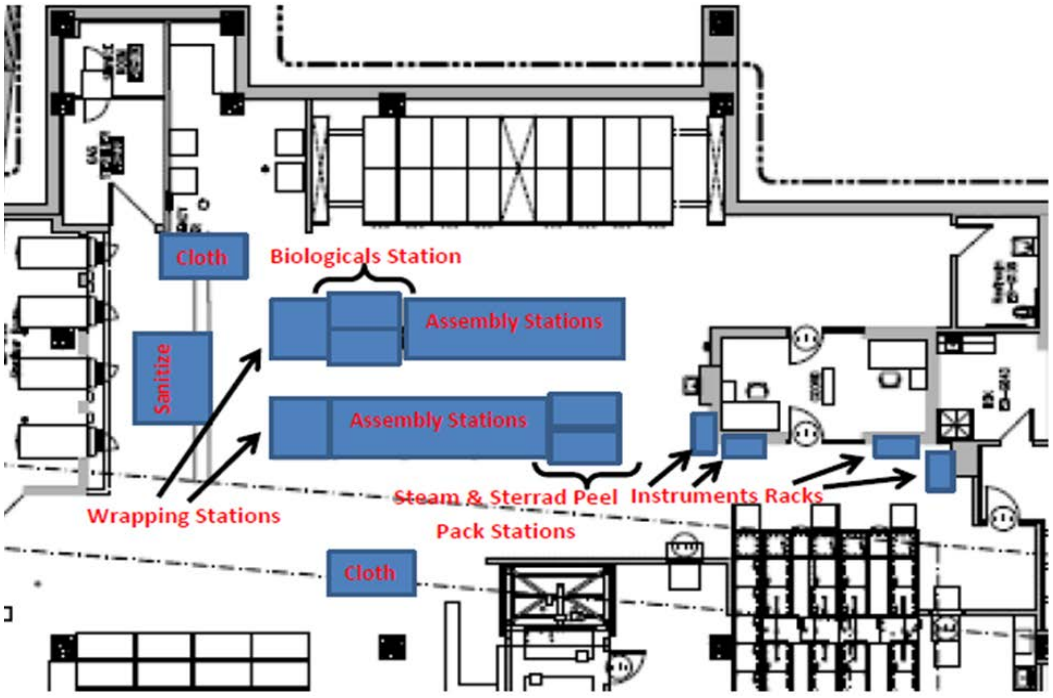

Figure 34: After Facilities Layout Project

Shine

The shine component was mainly part of the set in order step as it allowed us to clean and identify area where it is necessary to maintain a clean area due to the packaging that is involved in the wrapping and peel pack stations.

Standardize

We obtained feedback from the supervisor and the technicians in the department about peel-pack stations and wrapping stations. We attempted to ensure that all parties were adequately satisfied with the new layout.

Sustain

For the sustain aspect of the project, visuals were created for each of the wrapping stations and the biological stations so that technicians know how stations should be organized.

Results

By re-designing the layout of SPD by consolidating the biological station and changing the peel pack stations, cloth racks, and introducing the wrapping stations, there were some significant improvements made in terms of work flow for the technicians. Considering the spaghetti diagrams from before and after the changes, demonstrates how the layout design project significantly improves the SPD workflow. Each diagram models a scenario where a technician working at station 12 is ready to wrap a kit being assembled. Based on the distance measurements of the facility, in the before scenario a technician would be required to walk 72 feet in order to retrieve wrapping cloth, return to the station to wrap the kit, and then bring the kit to the ready for sterilization rack. After the re-design the same technician would only be required to walk 40 feet to complete the same set of tasks. Based on research that shows that the average person walks about 225 feet per minute (Fairfax County, 2006), it was calculated that the reduction in 32 feet of walking saves each technician about 8.53 seconds per kit.

Similarly, re-designing the layout helped to save distance traveled when walking from the instrument racks to the peel pack station and then finally to the ready for sterilization rack. Prior to the re-design, a technician would walk about 65 feet in completing this set of tasks, while after the re-design a technician would only have to walk 40 feet. The reduction in 25 feet of walking saves each technician about 6.67 seconds per kit. The changes made are visualized in figures 35 and 36.

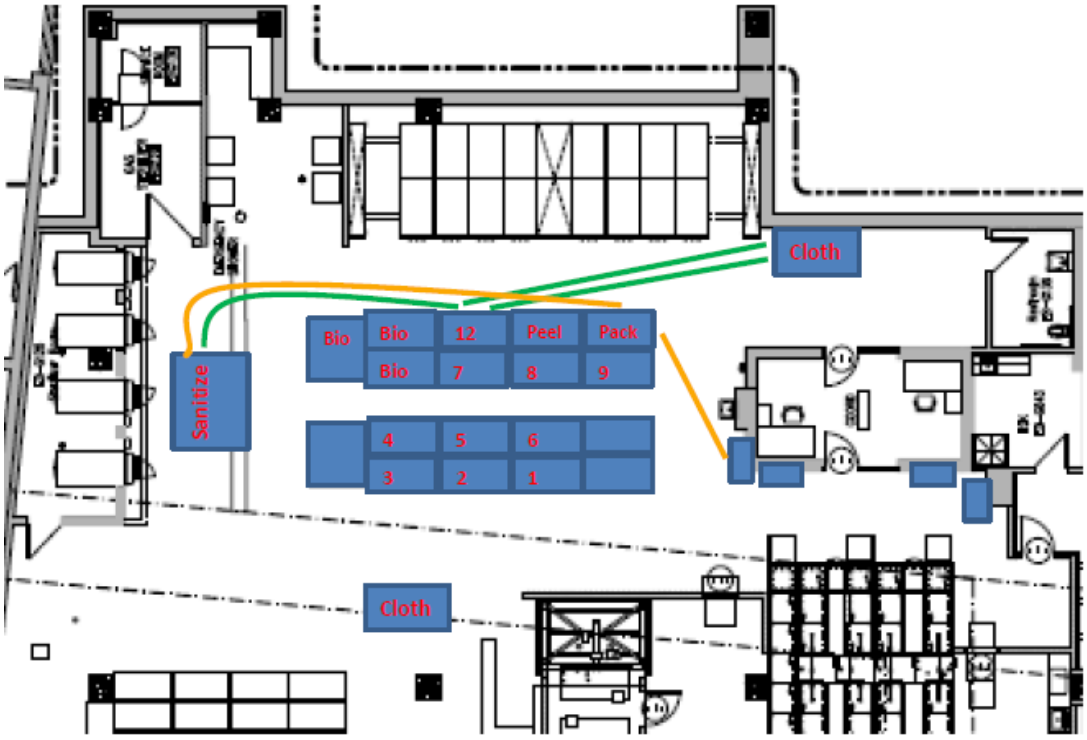

Figure 35: Before Spaghetti Diagram

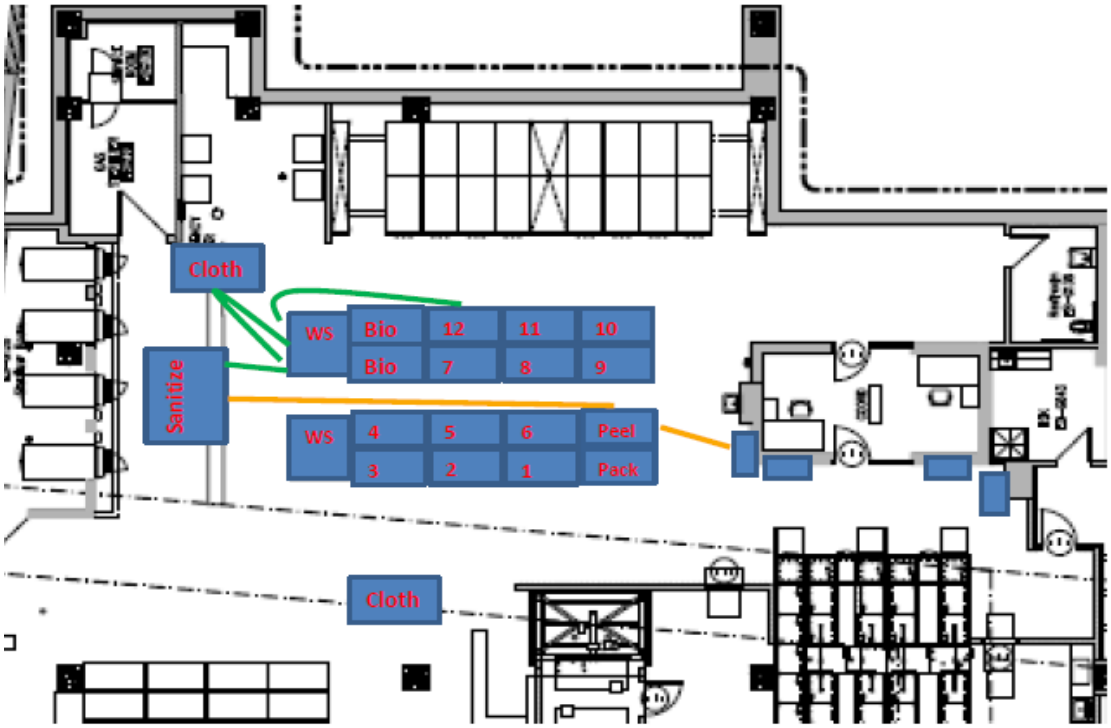

Figure 36: After Spaghetti Diagram

Although 8.53 and 6.67 seconds seem insignificant, when we consider that each technician assembles approximately 15 – 20 kits per shift, there are multiple technicians, and there are three shifts, saving a matter of seconds per person per kit adds up to minutes saved per shift, and per day. Freeing up time allows for technicians to focus on the value-added functions of their job such as inspecting, cleaning, and assembling instruments and kits.

The re-design also reduced congestion of the pathway that ran along the unsterile storage rollaway shelves. Through our observations that particular pathway got congested very easily because supply inventory was kept on the unsterile rollaway shelves. By reducing the need for technicians to have to walk back and forth along the unsterile rollaway pathway to get wrapping cloth, the re-design project helped to create better workflow for the technicians. Based on the before and after spaghetti diagrams, workflow became more linear and direct.

Limitations

The facilities layout project had some limitations because SPD technicians needed time to get accustomed to the new layout. While there were never challenges encountered with the new locations of the peel pack stations, on several occasions wrapping stations became cluttered and were used for tasks other than wrapping instrument kits. Work space is limited in SPD, and because the wrapping station tables were usually void of clutter, as requested in the notes left by our team, they became convenient spaces to use when looking for more available space.

One of the wrapping cloth racks was often moved back to its original location in the back of SPD and other racks would temporarily take its new spot. While our goal was to shadowbox the new location of the wrapping cloth rack and any racks without a permanent location, we were not able to do so due to technical challenges. The floors of SPD have a gloss on them that would make it difficult for floor tape to stick to and even if the tape were to stick, the machines used to clean the floors would scrub away the tape. While gloss could be applied over the floor tape to make it permanent, this option would not give SPD much flexibility if they decided they needed to alter the layout later to address new challenges.

As with any workplace environment, it takes time for employees to become accustomed to new changes. With prompts like clearly visible and defined labels, and notes and visuals for how the new locations should be utilized as left by our team, changes will in time become part of the environment.

Recommended Improvements

Because shadowboxing is challenging within the current environment, SPD should consider the use of laminated overhead signs to promote a visual workspace.

5.4 Instrument Repair, Replace, Recycle Pipeline Management

Background

Since the beginning of the project, both the team and the sponsor understood that the inventory management practices of SPD could be improved in different areas. Time spent searching for instruments and supplies was consistently observed increasing the amount of wasted time in SPD. Informal and inconsistent mechanisms for alerting others to the absence, breaking or wearing down of particular SKU's is also believed to contribute to the difficulties of producing kits efficiently. Figure 37 shows the cart that all instruments that are broken or need repair are placed on. A red tag with some relevant information is tied to the instruments for a supervisor to read when they are able. From there, management determines what to do with each item; either recycling, repairing or returning the instrument. Instruments sent for repair are shipped to a third party each week which will then return the instrument fixed or noted to be beyond repair. At this point it may be informally communicated to the staff what was to become of important SKU's in that position. It becomes increasingly difficult for technicians to quickly determine the status of important SKU's as they are tied up in this repair, replace, recycle pipeline (RRRP).

Figure 37: Repair, Replace, Recycle Pipeline Cart

The RRRP's lack of transparency has been observed to waste time by increasing confusion as technicians search for unavailable instruments or simply assume SKU's are still unavailable. The lack of information regarding a desired SKU's status obtain is believed to reduce awareness of inventory levels, which leads to unexpected stock outs,

time spent waiting or searching for instruments that are not available, and potentially even overstocking units.

Goal

Changes within SPD prevented the team from exploring countermeasures as planned, so the team developed a prototype recommendation as the most viable outcome for this subproject. The goal of this subproject was to provide The Academic Medical Center with a program that will increase the transparency of the RRRP in order to improve SPD's inventory management, without interfering with their pending in-house inventory management improvement project.

Successful completion of this project means that, if adopted by The Academic Medical Center, for a negligible increase in upfront work, technicians would have access to near real-time information regarding the status of SKU's within the RRRP.

Procedure

The team started this project by interviewing SPD management and technicians to understand the system as it was. After analyzing the broad strengths and weaknesses of this system, we began to design potential solutions based on the opportunities and constraints we observed. After eliminating many potential ideas within our group, several were brought to technicians who favored an Excel based solution. Team members with prior experience in coding with Visual Basic for Applications then created a workbook that would act as a program to monitor SKU's in the RRRP. Once developed and tested, the workbook was shown to the technicians the team believed would be the champions of the program's implementation. Based upon their feedback, further refinements were made to enhance ease of use and reduce potential points of confusion. Figures 38 and 39 show screens of the RRRP program.

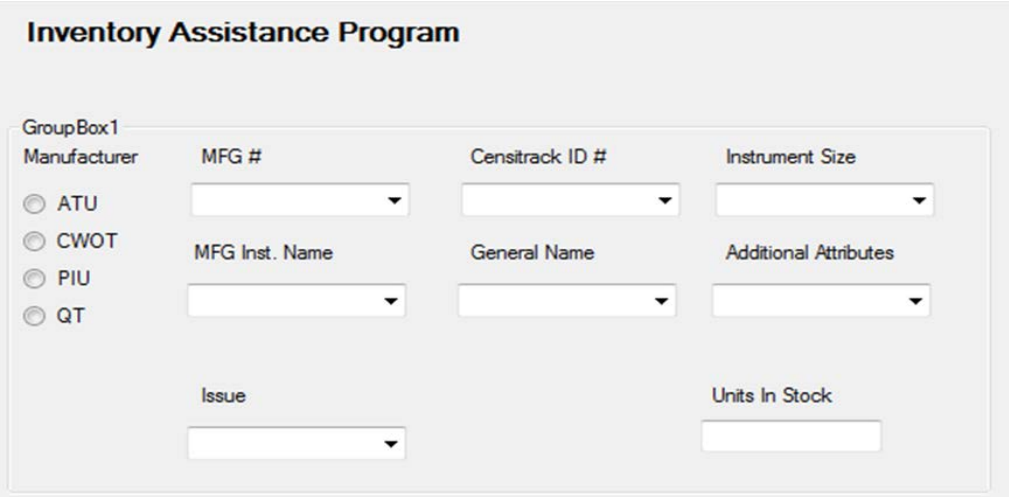

Figure 38: RRRP Program Input Screen

Inventory List												
Date Added	MFG #	MFG Name	MFG By	Censitrack ID	General Name	Size (inches)	Additonal Attributes	Issue	Action Taken	Units In Stock	Est. Return Time (Days)	High Priority
1/12/2014	345-34-54	Alp Bone Saw	QT	848272	Bone Cutter	2.75		Rusted	Sent	0	Restocked	
1/13/2014	654-345-23	Triad Forceps	PIU	721142	Dull Forceps	3.5	Curved	Maintenance Req	Sent		Restocked	
1/16/2014	654-345-24	Triad Forceps	PIU	39532	Dull Forceps	4		Broken	Sent	10	Restocked	
1/16/2014	567-464	Alp B Forceps	QT	1231497	Sharp Forceps	4	Curved	Rusted	Recyled		-	
1/16/2014	235-746-43	Dlp B Forceps	QT	339107	Serrated Forceps	2.75		Rusted	Recyled	9	-	Yes
1/17/2014	324-345-234	Unit Saw	PIU	312940	Bone Cutter	9	Curved	Broken	Recyled	6	-	Yes
1/18/2014	684-34-765	Ctu Bone Vice	QT	1480152	Bone Vice	A		Rusted	Sent		2	
1/19/2014	247-56-745	Clamp 5F	CWOP	1348311	Clamp	5		Maintenance Req	Sent		2	
2/1/2014	345-34-54	Clamp 6F	CWOP	983572	Clamp	6		Maintenance Req	Sent		10	
2/1/2014	654-345-23	345 Liston Knife	ATU	452326	Bone Cutter	3.45		Broken	Awaiting Action	4	-	Yes
2/1/2014	765-54	Alp Full Fleam	QT	1514081	Fleam	-		Broken	Awaiting Action	9	-	
2/4/2014	567-464	Dlp Gigli Saw	CWOP	1893120	Bone Cutter			Broken	Awaiting Action		-	
2/5/2014	235-7546-43	Alp C Forceps	QT	92807	Serrated Forceps	3.5	Slotted	Rusted	Awaiting Action	5	-	

Figure 39: Test Output

Results

While the effects of the program may only be seen if adopted by The Academic Medical Center, the team believes it provides a solution that will increase in effectiveness as more items are placed in the RRRP.

Limitations

The inability of the team to create or support the creation of a more inclusive inventory management improvement limited the potential scope of this project. Despite this, the challenges of creating a program to fit the relatively narrow aspect of inventory management in SPD proved more challenging than expected. Ultimately this limitation may have assisted in the creation of a truly polished final product.

6.0 Analysis of Results

This section summarizes the findings from the sub-projects completed and examines overall impact. The two ways we judged the effectiveness of the overall project were to assess our impact on the missing instrument rate as well as on the organization of workflow within SPD. The analysis concludes with a discussion of data collection and quality within the context of this report.

The initial goal of this project was to reduce the missing instrument rate within SPD. Each project that was completed had the intention of either directly or indirectly supporting this goal. Figure 40, shown below, tracks the number of missing instruments per week from August – December 2013.

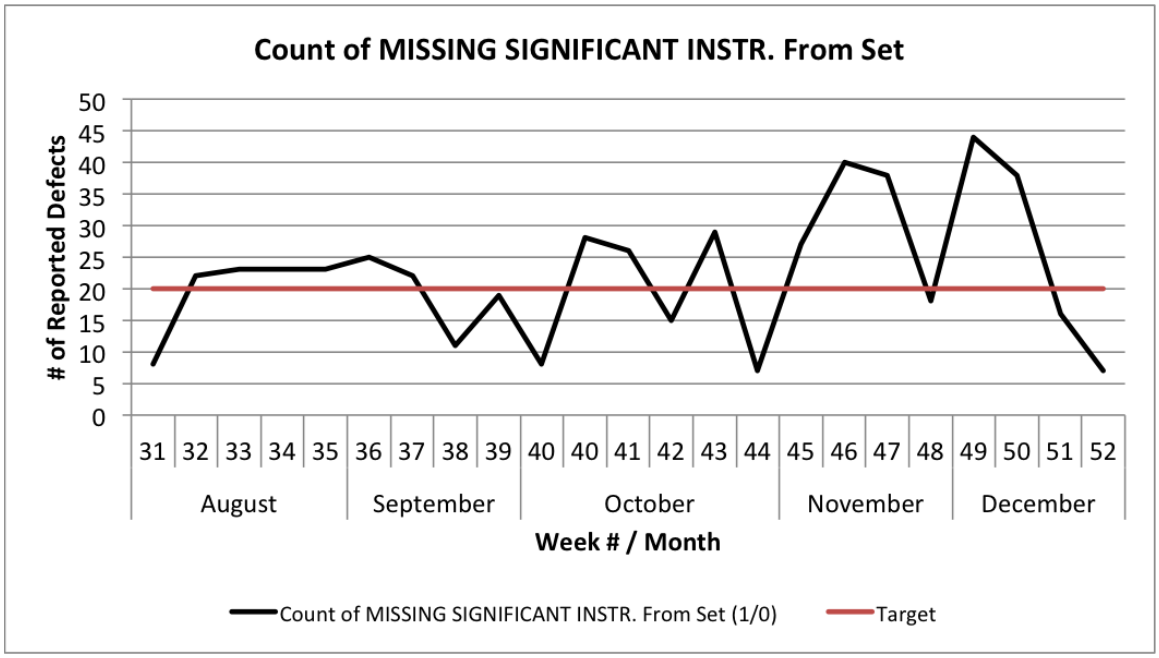

Figure 40: Missing Instruments per Week

These data shows that the number of missing instruments processed each week did not change significantly over time. The variance in the number of missing instruments increased over time. It is important to note that this metric is not a direct representation of the missing instrument rate, which takes into account the number of surgeries. This lessens the impact of this data, as explained in greater detail in Section 6.3.

As shown in the root cause analysis, the missing instrument rate is caused by a great number of factors. The team addressed some of these factors by completing projects, while others were outside of the scope of this team. The next two sections delve deeper into first, how our team was able to support the reduction of the missing instrument rate, and second, what major root causes of missing instruments have yet to be addressed.

6.1 Project Effects on Missing instrument Rate

This section reexamines the root causes for missing instruments and explores how each sub-project addressed the root causes shown in the fishbone diagram in Figure 12.

Assembly Station Project

The goal of the assembly station project was to support a reduction in the missing instrument rate by creating a more efficient and organized workspace. The team believed that the variance among the different assembly stations was causing enough confusion to enable the processing of kits with missing instruments.

This project directly supported three root causes of missing instruments. On the process arm of the root causes, this project addressed rushing and workflow interruptions and on the human knowledge arm, the project addressed limited standards.

Rushing

Rushing was established to be a root cause for missing instruments because it could lead to carelessness. When under time pressure, technicians were forced to spend less time on each individual kit. This allowed room for errors.

Prior to this project, the assembly area contributed to rushing for a variety of reasons. The assembly stations were disorganized so technicians were often required to search for a particular tool or component needed to assemble a kit. This left less time available for the actual kit assembly and increased the pressure to rush. Additionally, not all stations initially contained all required materials. This left technicians needing to leave their stations frequently, which again reduced the time allotted to assemble kits.

As shown in Section 5.1, this project supplied all stations with necessary materials. This reduced or eliminated both causes for delay at the assembly stations and thus mitigated the effects of rushing in this area.

Workflow Interruptions

Workflow interruptions were a root cause for missing instruments within SPD because they contributed to rushing and created confusion. Breaking up a workflow reduced efficiency for technicians assembling kits and caused confusion when returning to a particular task after being interrupted.

Before the completion of this project, workflow interruptions were part of the assembly station area. Technicians would be required to leave their station to search for instruments, answer phone calls or even move to another area because someone else needed their workspace. Upon resuming kit assembly, technicians felt extra time pressure

that contributed to rushing and they may have felt confused and have forgotten exactly what they were doing. Confusion was thought to lead to increased mistakes.

This project made the assembly stations much more specific. Not only did it supply each station with the required materials, but it also designated specific purposes to all of the 10 assembly stations. There are now assembly stations designated for particular purposes, such as peel pack kits, which did not exist before. These advances reduced the need for technicians to leave their stations either to search for something or because their station was needed for another purpose.

Limited Standards

Limited standards were identified as a root cause within SPD for the missing instrument rate. Because standards were not posted or did not exist for technicians to learn, each technician could develop their own way of completing a task. This meant that technicians might not be following best practices and were not able to get clear answers when needing help with a particular task.

The assembly station area was affected by limited standards. There was a lot of variety between assembly stations and there were no clear guidelines on how to actually organize a station.

This project addressed this problem by standardizing stations and creating checklists as guides for technicians. The standardization of the stations was itself the creation of a standard from which technicians could work and the checklists provided a reinforcement of those standards. Now technicians can benefit from this consistency and have a resource to help them prepare for kit assembly.

Unsterile Storage Project

The unsterile storage project was undertaken to impact the missing instrument rate by creating a sense of order in the racks of unsterile storage and saving time in the assembly process. This area within SPD directly contributed to the time pressure root cause on the process arm and the lack of clarity surrounding where things go root cause on the facilities arm.

Time Pressure

Time pressure was a root cause for the missing instrument rate because it led to rushing. The racks of unsterile storage were among the biggest contributing factors to time pressure within SPD. Because the racks contained so many instruments and were not well organized, technicians wasted significant time searching through these racks. This search time was completely non-value added and reduced time available to complete other required tasks, which therefore caused time pressure for the technicians.

This project dealt with this time pressure in two ways. It first removed instruments from the racks of unsterile storage that were unnecessary. This reduced search time because it reduced the total area through which to search. Secondly, it separated instruments based on type, which helped guide technicians to the appropriate area when searching for an instrument and saved time.

Lack of Clarity about Where Things Go

Not understanding where to put things was a large issue within the department at the outset. This contributed to the missing instrument rate because it often led to instruments getting lost. The most common area for instruments to be lost was within the racks of unsterile storage. Instruments were often haphazardly placed within these racks because it was unclear what else to do with them.

This project addressed this concern by creating more organization within the racks of unsterile storage. Bins were labeled and instruments were each given their own bin whenever possible. This did not completely solve the lack of clarity issue, but it certainly brought more clarity to the department surrounding where to place and find the instruments that were categorized during this project.

Facility Layout Project

The goal of the facility layout project was to save time for technicians by reducing congestion and distance travelled within the department. This was intended to directly affect the rushing root cause on the process arm. Technicians spent a lot of extra time walking from place to place, which reduced their time available to work on value-added work.

Rushing

Excess walking from place to place was contributing to rushing and increased time pressure. Reducing rushing would alleviate one of the root causes of the missing instrument rate.

This project specifically addressed rushing by reducing the time needed to travel between areas within the department. It brought areas closer together and ended up saving between 40 and 75 feet of walking distance for the assembly of the average kit. This reduced non-value-added time and freed up more time to work on the assembly of kits. This therefore reduced rushing.

Instrument Repair, Replace, Recycle Pipeline Management

The goal of the inventory-ordering project was to facilitate the reduction of the missing instrument rate by reducing gaps in inventory. When an instrument went missing or sent

out for repair, this project sought to have it replaced. This would support the lack of inventory root cause of the process arm of the Fishbone Diagram in Figure 12.

Lack of Inventory

Lack of inventory was seen to be a problem because kits were sometimes assembled without the full set of instruments. Many times this occurred because a particular instrument either could not be found or did not exist in the inventory of the department. Ensuring that there was enough inventory available to assemble all kits would reduce the missing instrument rate.

This sub-project created a program to help keep track of inventory that is sent out for repair or replacement. The program would allow technicians to see how long it would take for an instrument to be returned once it was sent out for repair.

Unsterile Storage Categorization Project

The goal of the unsterile storage categorization project is to reduce the missing instrument rate by making the racks of unsterile storage more user-friendly. The goal was to label the external faces of the racks to show what was inside and to tie this to the inventory system to display when instruments needed replacement. These improvements would address the root causes of lack of inventory and non-posted standards.

Non-Posted Standards

Non-posted standards within SPD were a contributing factor to the missing instrument rate because when things are not clearly visible and organized, it can create confusion and waste time. The unsterile storage racks, which were not labeled from the outside, provide a good example of this problem because technicians had no way of knowing what was located within any of the racks.

The team suggested labeling the external faces of each of the racks showing what was located inside. This would allow technicians to more quickly locate instruments that they were searching for without having to enter each of the five racks of unsterile storage. This has yet to be implemented, but it is an opportunity for future improvement.

Lack of Inventory

The unsterile storage racks contributed to a lack of inventory because there was no clear organization of the racks. It was very difficult to determine whether or not an instrument existed in the inventory without physically searching through everything to find it. Because the racks were not labeled, it could take a very long time to find any particular instrument.

This project dealt with the lack of inventory as it related to the racks of unsterile storage by first labeling the racks and secondly creating a program to show when an instrument was missing from inventory. A simple signal provides a way for technicians and management to see when a particular piece of inventory really is lacking and it allows the missing instrument to be easily replaced.

6.2 Outstanding Contributors to the Missing Instrument Rate

Despite the fact that our projects attempted to reduce the missing instrument rate, there were many root causes of the missing instrument rate that were outside of the scope of what our team was able to address. Based on the metrics available, the missing instrument rate remains unchanged. In this section we explore some remaining factors that affect the missing instrument rate. The most important root causes to consider in this section are those identified by the impact-effort matrix in Figure 16 as high impact. Those root causes are Censitrac, kit variety and employee turnover. All three of these causes are on the human knowledge arm of Figure 12 and are all interconnected.

Censitrac

Censitrac is the computer system that contains a categorization of all of the instruments needed to assemble kits. This system is being improved, but still contains many errors. In many cases, the system will provide faulty instructions on how to assemble a particular kit, and only the technician's knowledge that Censitrac is incorrect can prevent the error. When employees are unfamiliar with how to assemble a particular kit, Censitrac is designed to help them. But since Censitrac is currently provides faulty information, it is contributing directly to mistakes made by technicians. This raises the missing instrument rate.

Kit Variety

For any given type of operation there are a variety of brands of kits that can be used. These kits are, for any given operation, similar to one another, but contain slightly different instruments. This creates a lot of confusion because not only must technicians be able to differentiate between similar instruments, but also they must know which surgeons prefer which kits. The Academic Medical Center is currently working to reduce kit variety, but until this initiative is completed, it will remain a strong contributing factor to the missing instrument rate.

Employee Turnover

Within SPD, many employees work for only short periods of time before moving to another hospital within the The Academic Medical Center system. Staffing is inconsistent and "Travelers" are often brought into the department for temporary assistance. Because

these Travelers are new to the system and processes within SPD, they are more likely than experienced technicians to make an error. For any job, there is a period of learning; because of the high turnover at The Academic Medical Center, a high percentage of technicians are in a learning phase at any one time. During December for example many Travelers entered the department and the number of missing instruments per week surged during this time. Until staffing becomes more consistent within the department, this is likely to affect the missing instrument rate.

6.3 Measuring Results and Data Quality

The collection of data in a hospital setting is often quite difficult, and was difficult for this project. While the data that we did have access to was helpful, we were not able to obtain the level of detail desired to approach the project from a predominantly quantitative perspective.

In section 6.0, Figure 40 discussed the number of missing instruments per week over time. However, this metric is not actually indicative of the missing instrument rate, defined as the number of surgeries with a missing instrument divided by the total number of surgeries. The number of missing instruments per week does not take into account the number of surgeries per week and thus does not provide information on the missing instrument rate. If we assume that the number of surgeries is constant, we could make more inferences, but this is a broad assumption to make.

At the conclusion of the project, the number of missing instruments has remained largely unchanged. We do not have the information to measure directly the missing instrument rate over time and thus much of the information that we have collected is based on our own measurement of data, rather than on data provided to us from The Academic Medical Center.

Overall, the team was able to quantity impact in SPD by saving time and space. Kit assembly times were reduced between 6 and 8 seconds per kit and storage space for unsterilized instruments was reduced by 50%. Walking distance was reduced by approximately 32 feet on average during the assembly of a kit.

7.0 Conclusion

The conclusion section of the report provides a summary of the team's effort over the duration of the project. The conclusion also includes a design reflection as a graduation requirement for the Industrial Engineering majors who worked on the project. This section ends with recommendations for future improvement.

7.1 Summary

The goal of this project was to reduce the rate of missing instruments within SPD. Initially, the project team focused on the overall defect rate; however, it became clear that it would be more beneficial to The Academic Medical Center to focus on the underlying causes for missing instruments because it was challenging to quantify results based on the defect rate alone. The missing instrument rate proved difficult to measure or to reduce over the duration of this project. With this in mind, the team analyzed several factors that contributed to the missing instrument rate and designed four sub-projects that helped to mitigate these underlying issues.

The first sub-project was the reorganization of the racks of unsterile storage, which contain a variety of instruments that have not been sterilized. We cleaned up the racks by removing unnecessary instruments and began sorting and labeling the instruments that remained within these racks. As a part of the unsterile storage sub-project, the team developed a material storage guidebook to provide recommendations for further improvement of unsterile storage and other storage areas in SPD. Storage space was reduced by approximately 50%.

Two additional sub-projects that the team tackled were the assembly stations and the arrangement of facilities. Initially, each assembly station had a different variety of materials used in kit assembly. The team standardized these stations and created checklists to make it easier for technicians to assemble the kits used in surgeries. Alongside this project, we reorganized the physical facility to reduce the amount of time spent walking from place to place. Together these two projects clarified and improved the overall workflow of SPD. Because 6 to 8 seconds were saved per kit, if we assume that 4 technicians work through 16 kits per day for 40 hours per week, this savings amounts to approximately one hour of work per week.

The team also began assisting The Academic Medical Center in the creation of an inventory management system. This is a wide-reaching issue in SPD and we had previously identified it as requiring a lot of effort. We were able to provide recommendations to the in house team and work with them to design a prototype application to improve information regarding return time for instruments that were sent out for repair or replacement.

Overall, SPD has become more organized and efficient in kit assembly over the past seven months, based in part on the team's efforts. Improvements continue to be made and Section 7.3 discusses some specific recommendations for future improvement.

7.2 Design and Lifelong Learning Reflection

Engineering design encompasses several key principles to which engineers adhere to when conducting projects. Following the set of engineering design principles guides the design process so that it is based on quantitative evidence and improves the chances of a successful outcome ("What Is the Design Process?", 2000). NASA breaks the engineering design process down into eight distinct steps as can be seen in Figure 41 (Dunbar, 2013).

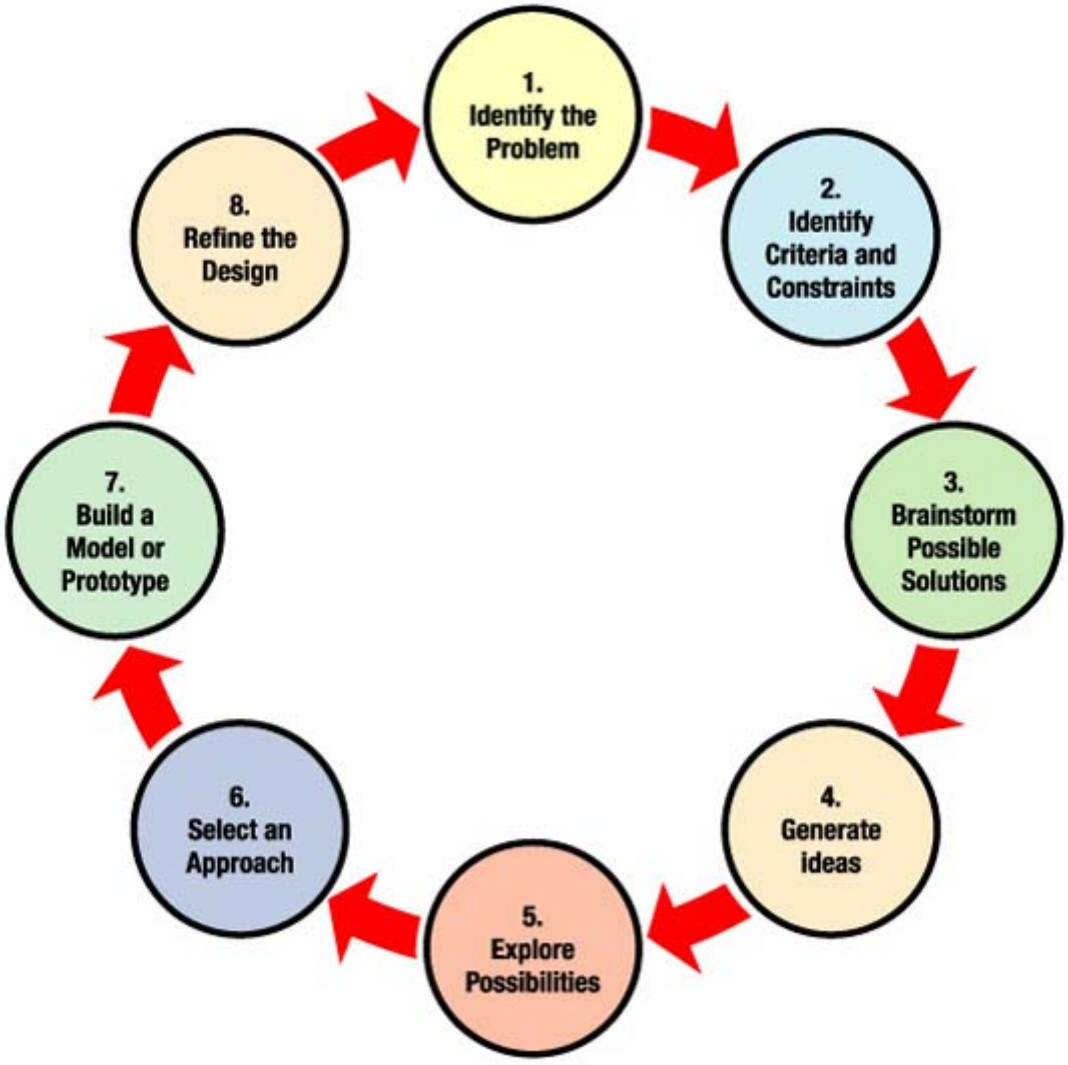

Figure 41: Engineering Design Process

Assembly Station	Improved the design of the assembly stations in accordance with workspace design principles and using 5S procedures, in order to create a more efficient and organized workspace.
Unsterile Storage	Improved the unsterile storage rollaway shelves by adhering to 5S procedures in order to achieve better organization of unsterile tools and by creating visual posted inventory lists on the outside of unsterile storage rollaways, in order to improve user-interaction and retrieval of items.
Facility Layout	Improved the facility layout, after analyzing SPD's process flow, using 5S principles as a guideline for implementing changes to the facilities design.
Instrument Repair, Replace, Recycle Pipeline Management	Designed a computer-based inventory ordering process using Excel and Visual Basic for Applications, so as to better account for tools and inventory in the repair, replace, recycle pipeline (RRRP).

Figure 42: Project Summaries

In this project, the initial effort from August to October 2013 entailed discovering the root causes of SPD's rate of missing instrument production. From October to December 2013, the team focused on the design and implementation of improvements in SPD to address these root causes. As discussed in earlier in this report, many opportunities for improvement were discovered but some were not acted upon. This is because the team and our sponsors recognized the constraints at play in this project.

The projects executed throughout the course of working with SPD, listed in Figure 42, focused on specific areas of the engineering sciences such as facility layout, human factors, and process analysis. The constraints listed in Figure 43 were considered in the design of each countermeasure proposed, recommended or implemented. Although the design process has been summarized in the Methodology and Results section of this report, Figure 44 provides the reader a more explicit look at the design process for the assembly station project based on engineering design principles.

Project Length	The length of this project was not to extend past the early days of March 2013
Time	Individual team members and sponsors could not dedicate full 40+ hour weeks to this project
Financial	The SPD budget is limited and only so many resources could be bought or alloted to the initiatives of the project
Information	Collecting data pertinent to our project was challenging, making it difficult to fully analyze the effectiveness of each project or inform new designs
Facilities	SPD is located in a rather small, awkwardly shaped area of the hopsital resulting in wasted space and limited room for helpful fixtures
Project Scope	Several significant contributors to the defect rate originate in the OR or through interdepartmental activities
Staffing	Key stakeholders in the process such as the technicians themselves and even the department supervisor changed throughout the project

Figure 43: General Project Constraints

Identify the Problem	Through observations, time studies of kit assembly in SPD, and discussions with technicians the team identified areas for improvement in standardization and organization of assembly stations.
Identify Criteria and Constraints	Through observations, time studies, and discussions with technicians the team identified the criteria and constraints for the design. The criteria and constraints consisted of space limitations, ergonomic principles, and technician input due to limited space available within SPD and at assembly stations, which affected technicians' work movement.
Brainstorm Possible Solutions	Through discussions with team members and technicians, possible solutions to standardizing and reorganizing assembly stations were developed.
Generate Ideas	More focused discussion stimulated specific ideas developed around the necessary criteria and constraints.
Explore Possibilities	Discussions around possible designs and mini-tests of change helped to determine the pros and cons of possibilities and allowed for possibilities to be vetted.
Select an Approach	By vetting the possibilities, one solution was selected to be designed. When considering the necessary criteria and constraints, the chosen solution was the most practical.
Build a Model or Prototype	Implementing the solution for standardization and organization was completed with the help of the technicians according to the necessary criteria and within the required constraints.
Refine the Design	After testing the prototype solution, refinements were made to the design, so as to better suit the criteria and constraints of the technicians, ergonomic principles, and space.

Figure 44: Engineering Design Process for Assembly Station Project

The assembly station project closely followed the engineering design process, so as to produce the most effective results. By utilizing engineering design principles, the assembly stations in SPD were sustainably and productively designed, leaving room for refinements and continuous improvement, as is necessary in Lean methodology.

Perhaps what was most interesting about our project in SPD was our ability to apply Industrial Engineering and Lean principles to a process with similarities to, but rather unlike, traditional manufacturing or services based processes. The parts of SPD's work that resemble processes Industrial Engineers are familiar with were used to inform our approach to this project and design solutions. Even aspects where SPD's operations differed from these familiar contexts, the team was able to create solutions according to engineering design principles to make continued improvements in SPD.

Just as SPD will continue efforts to improve after this report is published, the team will continue to enhance and diversify their abilities through lifelong learning. We have learned a great deal about working in the healthcare industry, its conservative attitude toward risk and expenditures, organizational inertia and other concepts that are best learned in the field as opposed to a classroom. We have recognized the importance of posted visual cues and reminders, and that proper information tracking is a crucial part of the success of an organization. Without minimizing the immense impact this work has

had on our knowledge, we feel continued exposure to other industries and continued work in health care would equip us for continued success.

7.3 Recommendations

Based on the work the team completed as well as the initial exploration of root causes, we have several recommendations to offer The Academic Medical Center for ongoing continuous improvement. These recommendations focus on outstanding root causes for the missing instrument rate. The recommendations include establishing clearly written work procedures throughout the department, reducing variety in kits and fully updating Censitrac. Each is briefly described below.

Establish Clearly Written Work Procedures

Our team began creating visual and written standards for work within SPD, but this is an important process that should continue. It is important that employees practice standardized procedures when completing tasks because otherwise the process could become inefficient. For example, the current practice of placing various amounts of sterile indicators in each kit, for example, highlights the risks of limited written standards. When a kit arrives in the operating room, the sterile indicator within the kit is checked to confirm the kit is sterile. Official standards suggest one indicator is sufficient; however, some technicians put two or three indicators in a single kit. Therefore, operating room employees do not necessarily know how many indicators to look for in each kit. While seemingly innocuous, leaving an unseen indicator in a kit introduces risk in the operating room. Looking for other sterile indicators that may or may not be in a given kit is an unnecessary distraction for those who represent one of the final steps of quality control. Establishing and enforcing an official policy of using either 1 or 2 indicators per kit would give operating room personnel an exact number of sterile indicators to look for in each kit.

Reduce Variety in Kits

Currently, kit variety continues to be an issue that directly contributes to the missing instrument rate in SPD. For each type of surgery, SPD generally relies on between three and five manufacturers as suppliers of kits. This means that technicians must work with up to five different brands of the same type of kit per surgery. This is a problem because different brands of the same kits use different names for instruments with the same purpose, which can cause confusion. Having several types of kits available for each surgery greatly increases the amount of inventory stored within the department and increases reliance on individual technicians to be able to know the sometimes subtle differences between the kits.

In order to help technicians become more efficient, The Academic Medical Center should seek to have only one type of kit per surgery. This would eliminate the chance that the correct instrument type but incorrect brand was assembled into a particular kit. This should reduce the missing instrument rate and allow surgeries to occur more efficiently.

In addition, technicians would no longer have to spend extra time differentiating between similar instruments.

Fully Update Censitrac

One of the biggest issues that The Academic Medical Center faces within SPD is their incomplete and often inaccurate computer system Censitrac. Technicians expect to be able to rely on the computerized system as a reference database to help with the assembly of kits. Because the computer system is currently unreliable, technicians must ask one another for information, which can lead to human errors. Since only some of the information contained in Censitrac is incorrect, it is challenging to decipher exactly what is right and what is wrong.

In order to fix this problem, The Academic Medical Center should begin to tag inaccuracies within the system and recode the system to provide correct information. Over time this would increase the accuracy and reliability of Censitrac, which could serve as an extra support mechanism that technicians working on kit assembly are currently missing. Technology is one of the backbones of the modern workplace and the department will not be able to function at the highest possible level without improvement in this area. The healthcare industry relies heavily on information that can be stored in computer systems. Bringing Censitrac fully up to date would help to alleviate some of the pressure that technicians and other employees feel.

8.0 References

AAMI. Top 10 things OR nurses should know about AAMI standards. (2005). *Biomed Instrum Technol*, *39*(4), 326-327. Web. 15 Sept. 2013. http://www.sciencedirect.com/science/article/pii/S0001209206600355

"Basics on Processing & Sterilization." - *Sterile & Materials Processing Department*. University of Rochester, 2012. Web. 15 Sept. 2013. http://www.urmc.rochester.edu/sterile/basics.cfm

Billikopf, Gregorio. "Conducting Effective Meetings." *Conducting Effective Meetings*. University of California, 2003. Web. 15 Sept. 2013. http://www.cnr.berkeley.edu/ucce50/ag-labor/7labor/11.pdf

Blamey, Sue Fuller, Laurence Bayzand, and Janice Penner. "BC Children's Hospital Mistake-Proofing Equipment Assembly" [PowerPoint Slides]. BC Children's Hospital, 26 Feb. 2013. Web. 20 Sept. 2013. http://qualityforum.ca/qf2013/wp-content/uploads/2013/03/A3-Sue-Fuller-Blamey.pdf

Centers for Disease Control and Prevention. (2010). FastStats. Web. 9 Feb. 2014. http://www.cdc.gov/nchs/fastats/insurg.htm

Chobin, Nancy. "The real costs for surgical instrument training in central service" [PDF Document]. Surg Serv Manage. 1998; 4(8):35-39. Web. 2 Feb. 2014. http://sterileprocessing.org/ftp/pub/downloads/misc/nc_paper_2010.pdf

Cranes, W. T. (1980). Effective Meetings for Busy People: Let's Decide It and Go Home (p. 26). New York: McGraw-Hill Inc.

"Defining Value and the 7 Wastes." *Kaizen Training*. Kaizen Training, 2014. Web. 15 Sept. 2013. http://www.kaizen-training.com/tools-techniques/defining-value-and-the-7-wastes

Douglas, Richard K. "Sterilization Technologies." *TechNation*. MD Publishing, Inc., 1 Nov. 2013. Web. 10 Feb. 2014. http://1technation.com/cover-story-sterilization-technologies/

Dunbar, Brian. "Engineering Design Process." *NASA*. NASA Administrator, 3 Nov. 2013. Web. 24 Feb. 2014. http://www.nasa.gov/audience/foreducators/plantgrowth/reference/Eng_Design_5-12.html#.Uwvjj8690mR

Elgin, S. (1983). More on the Gentle Art of Verbal Self Defense. Englewood Cliffs, N. J.: Prentice-Hall Inc.

Fairfax County, Virginia. Planning Commission. TOD Committee. *Walking Distance Research-TOD Committee*. Fairfax County, 7 Sept. 2006. Web. 14 Dec. 2013. http://www.fairfaxcounty.gov/planning/tod_docs/walking_distance_abstracts.pdf

Jacobs, F. Robert., and Richard B. Chase. *Operations and Supply Chain Management, the Core*. New York: McGraw-Hill Irwin, 2013. Print.

Kiff, John S. "Applying PDCA A3 Thinking and Problem Solving" [PowerPoint Slides]. *The Lean Enterprise Academy*. The Lean Enterprise Academy, 2012. Web. 11 Feb. 2014. http://www.Leanuk.org/downloads/LS_2012/day1_kiff.pdf

Kimsey, Diane B. "Lean Methodology in Health Care." AORN Journal 92.1 (2010): 53-60. Print.

Kovach, Stephen. "Sterile Processing Certification: Does It Have Value?" *Infection Control Today*. Virgo Publishing, LLC., 21 May 2012. Web. 11 Feb. 2014. http://www.infectioncontroltoday.com/articles/2012/05/sterile-processing-certification-does-it-have-value.aspx

"Meetings and Huddles | Labor Management Partnership." *Meetings and Huddles | Labor Management Partnership*. Labor Management Partnership, 1 Sept. 2013. Web. 15 Sept. 2013. http://www.lmpartnership.org/ubt/starting-and-running-a-ubt/meetings-and-huddles

Purdy, Kathleen, Louis Kindt, Jim Densmore, and Craig Benson. "Defect Reduction Through Lean Methodology" [PDF Document]. *SPIE Digital Library*. SPIE, 2010. Web. 15 Sept. 2013. http://spiedigitallibrary.org/data/Conferences/SPIEP/1438/78231Y_1.pdf

Rodak, Sabrina. "Respecting Sterile Processing for Their Role in Patient Safety." *Becker's Clinical Quality & Infection Control*. ASC Communications, 31 Aug. 2012. Web. 10 Feb. 2014. http://www.beckershospitalreview.com/quality/respecting-sterile-processing-for-their-role-in-patient-safety.html

Sarkar, Debashis. "The Seven A3 Problem Solving Steps in Detail." *Process Excellence Network.* Process Excellence Network, 17 May 2010. Web. 15 Sept. 2013. http://www.processexcellencenetwork.com/Lean/columns/the-seven-a3-problem-solving-steps-in-detail/

Seavey, R. E. (2010). "Collaboration between perioperative nurses and sterile processing department personnel." *AORN journal, 91*(4), 454-462. Web. 9 Feb. 2013. http://www.sciencedirect.com/science/article/pii/S0001209210000645

"Surgical Instruments and Procedures" [PowerPoint Slides]. *Surgical Instruments and Procedures*. Rozbudd, 2 Dec. 2010. Web. 15 Sept. 2013. http://www.slideshare.net/Rozbudd/surgical-instruments-and-procedures

Swanson, S. C. (2008). "Shifting the sterile processing department paradigm: a mandate for change." *AORN journal*, *88*(2), 241-242,247. Web. 9 Feb. 2013. http://www.sciencedirect.com/science/article/pii/S0001209208000094#

"What Is Lean." *What Is Lean*. Lean Enterprise Institute, 2009. Web. 15 Sept. 2013. http://www.Lean.org/whatsLean/

“What Is the Design Process?” *PBS Learning Media*. PBS & WGBH Educational Foundation, 2000. Web. 24 Feb. 2014. http://www.pbslearningmedia.org/resource/phy03.sci.engin.design.desprocess/what-is-the-design-process/

Wickens, Christopher D., Sallie E. Gordon, and Yili Liu. "Chapter 10: Engineering Anthropometry and Workspace Design." *An Introduction to Human Factors Engineering*. 2nd ed. Upper Saddle River, NJ: Pearson Prentice Hall, 2004. 243-68. Print.

Appendix A: Time Studies

Karl Storz Endoscopic Kit Task	Duration	Value Added?
Get kit	0:10	N
Get towel for cleaning	0:02	N
Find cords	1:15	N
Find clip	0:50	N
Print Report	0:20	N
Find/get Container	0:15	N
Sum	2:52	

Laparoscopic Kit Task	Duration	Value Added?
Searching for instrument	2:25	N
Confusion - Wrong Set	1:30	N
Search for Missing Scissor	7:30	N
Phone Call	0:30	N
Searching for instrument	0:10	N
Gets two new kits	0:20	N
helps other employee	2:10	N
prep for wrapping	1:50	N
Sum	16:25	

Karl Storz Endoscopic Kit Task	Duration	Value Added?
Lean, inspect, Assembly	8:16	Y
Insulation Scan	2:42	Y
Wipe tools	2:00	Y
Wipe cords	4:38	Y
Add Temperature Readers	2:30	Y
Assemble into container	2:52	Y
Bring complete kit to sterilization cart	0:20	Y
Sum	23:18	

Laparoscopic Kit Task	Duration	Value Added?
Set Building	3:25	Y
Set Building	2:40	Y
Set Building	5:00	Y
Finishes Kit		Y
finishes kit	7:30	Y
starts new kit	4:00	Y
kit 2 completed	6:45	Y
kit 3 completed	7:25	Y
Sum	12:45	

Appendix B: Material Storage Guidebook

INSTRUCTIONAL GUIDEBOOK FOR INVENTORY CATEGORIZATION

The goal of the unsterile storage categorization project was to increase the order within the unsterile storage racks. Labeling the current racks with numbers, the sections with letters and each shelf with numbers was intended to provide a more efficient way for technicians to work. Once the new system of categorization is in place, technicians will be able to spend less time searching for instruments and therefore invest more time in working on their respective kits. Part of this goal was also to organize the unsterile storage area into logical configurations based on surgery type and frequency.

STEPS:

1. Label roll-away units numerically

2. Remove old inventory list and place new inventory table on roll-away units.

ROLL-AWAY UNIT

	A Instrument Classification	B Instrument Classification	C Instrument Classification
1	List of instruments	List of instruments	List of instruments
2	List of instruments	List of instruments	List of instruments
3	List of instruments	List of instruments	List of instruments
4	List of instruments	List of instruments	List of instruments
5	List of instruments	List of instruments	List of instruments

3. Label sections of roll-away.

4. Rename shelves numerically from top to bottom

5. Receive feedback from technicians and management and continue to make necessary alterations (Continuous Improvement).