April 2013

VA Laundry and Linen Distribution Optimization

Bill Zhang
Worcester Polytechnic Institute

VA Laundry and Linen Distribution Optimization

A Major Qualifying Project Report submitted to the Faculty of

Worcester Polytechnic Institute

In partial fulfillment of the requirements for the Degree of Bachelor of Science

April 12th, 2013

Submitted by

Xuanya Zhang

Coauthors

Joaqu ń Serrano

Silvia Zamora

Sponsor

New England Veterans Engineering Resource Center VA Boston Healthcare System

Liaisons

Ashley Benedict

Gary McCarthy

Lisa Delaporte

Advisor

Prof. Fredrick Hart

Prof. Sharon Johnson

Acknowledgements

We would first like to thank our sponsors from the New England Veterans Engineering Resource Center (VERC) and the VA Boston Healthcare System, West Roxbury Campus Environmental Management Services (EMS), Brockton Laundry Facility for their support and guidance during our project. They made it possible for us to have this great learning opportunity and accomplish a successful project. In particular, we would like to thank:

Ashley Benedict	Senior Industrial Engineer, New England VERC
Gary McCarthy	Assistant Chief, EMS West Roxbury Division
Lisa Delaporte	Chief of Laundry Services, VA Boston Healthcare System

We would also like to thank our advisors for the insights and direction they provided throughout this project:

Professor Sharon Johnson	Associate Professor, WPI School of Business
Professor Fredrick Hart	Professor, WPI Civil & Environmental Engineering

Lastly, we would like to express our gratitude to the VA staff for the assistance and support they provided during this project. Without the feedback and resources provided by them, we would not have accomplished the project successfully. Specifically, we would like to acknowledge:

Chris Lydon	Head Nurse, CT Scan, VA West Roxbury Campus
Helen Muller	Head Nurse, PCU, VA West Roxbury Campus
Jessica Rizzo	Head Nurse, 3 North, VA West Roxbury Campus
Maryann Miller	Assistant Head Nurse, 3 North, VA West Roxbury Campus

Authorship Statement

This project was accomplished by three students from Worcester Polytechnic Institute majoring in Industrial Engineering: Joaquin Serrano, Silvia Zamora-Palacios and Xuanya "Bill" Zhang. Throughout the project, each student accomplished distinct tasks based on their strengths. Joaquin Serrano led the meetings, designed the specific signals for the project and served as the primary contact for all professional communication between the team and VA staff. Silvia Zamora-Palacios conducted the majority of interviews with hospital staff, photographed current state and new design, and collected data for the project. Xuanya "Bill" Zhang calculated Par Level and safety stock, compiled the notes from meetings and created different diagrams for the project such as the Value Stream Map, SIPOC diagram and Gantt Chart, etc. He also accomplished the environmental analysis aspect of the project to fulfill his degree requirement for Liberal Arts & Engineering. The students worked as a team to conduct time studies, observe the process and identify the undesirable effects in the current system. Together, the team designed the Future State and carried out the trial implementation in pilot areas of the VA Boston Healthcare System, West Roxbury Campus. Finally, this report was completed as a team effort.

Abstract

Linen is a backstage service that is critical for a hospital's functioning. Our team created a refill and distribution system to optimize linen use at the VA Boston Healthcare System-West Roxbury Campus, by applying lean concepts to improve process efficiency and provide the best patient care. The VA-Brockton Laundry facility, which cleans linen for the New England VISN, currently utilizes a steam system for washing, drying and ironing. An investigation of the economic and environmental aspects of replacement equipment options was also covered.

Table of Contents

Table of Figures

Table of Tables

1.0 Introduction

The mission of the Department of Veterans Affairs (VA) is: “To fulfill President Lincoln's promise ‘To care for him who shall have borne the battle, and for his widow, and his orphan’ by serving and honoring the men and women who are America’s Veterans” (Department of Veterans Affairs, 2010). VA has to find the best ways to allocate its resources to provide that care to the veterans of the United States. The Veterans Health Administration (VHA) is one of the three administrations in the VA and is charged with providing medical care to veterans. VHA manages 152 medical centers and numerous outpatient clinics in order to provide the service for veterans across the country. This administration has several divisions based on location, such as the VA New England Healthcare System (VISN 1). VISN 1 covers six New England States and has facilities located in the following cities: Togus, Maine; Manchester, New Hampshire; White River Junction, Vermont; Providence, Rhode Island; New Haven and Newington, Connecticut; and Bedford, Boston and Northampton, Massachusetts. Clinical and support services are required to keep a hospital a float. Linen services are a crucial part of the healthcare system that requires continual monitoring and improvement.

In this project, the larger team focused on linen distribution at the VA Boston-Healthcare System - West Roxbury Campus. Linen distribution is a service that needs to be present for a hospital to function. Limited attention or resources have historically been invested for its proper functioning, which provided the project team with great untapped improvement opportunities. Such improvements could represent cost savings for the VA as well as improved employee productivity and customer satisfaction. Additionally, Xuanya Zhang individually investigated the possible retrofit of the VA Brockton Laundry facility in fulfillment for the Liberal Arts & Engineering major requirement.

1.1 Part 1: Optimization of Linen Distribution

Environmental Management Services (EMS) is in charge of linen distribution for the VA Boston Healthcare System -West Roxbury Campus. EMS charged with linen distribution, and additionally sanitation, waste management, pest control, uniforms, station-level signage, and limited interior design functions (Department of Veterans Affairs VA Boston Healthcare System, 2012). The department used to have 1700 ft^2 linen room but was relocated to a 700 ft^2 room due to a new construction in the hospital. This relocation has presented several challenges for the EMS to continue providing reliable distribution of linen. The nursing staff depends on these to provide their service to the veterans. The space reduction along with various other issues has put the system under stress. A new and more efficient system is needed to help EMS to continue to providing its services to the nurses so that they can deliver the best patient care.

The goal of the linen distribution project was to optimize the system in the VA Boston Healthcare System – West Roxbury Campus by eliminating waste and improving the efficiency of the process, with the primary purpose of standardizing and simplifying the process while meeting quality goals. The team set the scope of the project to be the linen distribution process within West Roxbury VA facilities, focusing on the EMS and nursing staff interaction within the process. The Laundry Service was out of the scop,e even though it can have an impact on the linen distribution process, because the Laundry Service launders the linen for all of VISN 1, which includes 11 medical centers and numerous outpatient clinics, creating a much larger scope and greater variability. Particular areas of the hospital were selected as pilot areas of study for the project, to explore small and large units with different linen needs. A Lean problem-solving approach was employed to accomplish the project. In order to accomplish the project goal, the WPI team established three objectives for this project, as described below.

First, the team decided to understand the Current State of the linen distribution process in the hospital. This included having a complete understanding of the guidelines and policies in place and how closely these are being followed. We strived to understand the linen distribution in all the different depth levers (roles and responsibilities, measures and incentives, skills, structure, and culture) and worked alongside the nurses and EMS staff that directly interact with the process.

Second, the team designed a Future State for the linen distribution process. To accomplish this, we studied the current state of the system, identified the major issues with the system, and understood what changes would have the most impact on the system.

Third, the team implemented the future state and evaluated the outcome of the new design. This was accomplished by identifying the improvements achieved, the areas that needed further work, obtained feedback from the users as well as from the management, and determined the user and customer satisfaction.

The team created three different metrics to evaluate the system. The metrics served as measurements of the system performance and provided an understanding of the system. This understanding demonstrated the progress towards the team's goals.

1.2 Part 2: Environmental and Efficiency Analysis of Laundry Facility

Washing soiled linen is a backstage service that needs to be present for a hospital to function well. Not much attention or resources have historically been invested for its proper functioning, which creates significant untapped improvement opportunities, both operationally and environmentally. These improvements could represent significant cost savings for the laundry facilities as well as a reduced environmental footprint. The European laundry industry has been at the cutting edge of applying new technologies, thanks to the awareness of energy savings and incentives from the government (O'Neill, 2009). Steamless practice has become gradually common, which helps plants in Europe sharply cut down their energy bills. More importantly, it is environmentally friendly and efficient with lower risk. Although the US laundry industry has not experienced such a strong trend, the reduction of steam usage in laundry plants is still evident with several equipment manufacturers shifting their products towards steam-less processes. Many of the VA laundry facilities have a long history of operation, and currently use older equipment. The benefits associated with updating equipment seem to provide great motivation for a retrofit movement.

The Brockton Laundry Facility is the only VA linen processing plant for VISN 1. It is in charge of all the linen washing, drying, ironing and folding for the region. The facility has the responsibility for processing a great variety of linen items ranging from pillowcases and sheets to mops and patient clothing. Each year, Brockton Laundry Facility processes roughly 8 million pounds of linen (Krockta, 2013). The majority are generated from VA facilities. With such a high demand, the outdated machines in the facility are not able to process linen efficiently and energy-effectively. A retrofit and renovation of the facility is necessary, with the replacement of machines the crucial component for such a project

The goal of this part of the project is to provide valid recommendations for improving the renovation plan for the Brockton Laundry Facility, with the primary purpose of reducing the environmental footprint, decreasing the total operation cost and enhancing the capacity as well as the efficiency of the facility. To do this, the following three objectives were established:

1. To acquire a thorough understanding of the current state of the facility and laundry processes. This included having a complete knowledge of the guidelines and policies in place, both within the laundry facility and between the facility and other hospitals, as well as the details of the linen washing process in different dimensions (energy, water usage, and capacity). The student incorporated the interests and requirements from the management of the plant and collected information through interviews and plant visits.

2. To explore alternative equipment for possible renovation and retrofit. The current state of the facility was examined to identify the major issues within the system and understand what improvements would be most beneficial for the facility, both economically and environmentally. Then, research was conducted to collect information about potential suppliers and equipment, which targeted to solving these opportunities for improvement.

3. To conduct a feasibility study of alternatives. For strong recommendations supported by evidence and data, the analysis employed an Analytic Hierarchy Process with a focus on Cost Benefit Analysis. From the analysis, the most favorable option for VA Brockton Laundry Facility was selected by evaluating alternatives against different factors.

Part 1 of the report, on Linen Distribution, and Part 2, on the Laundry Facility, combine together to provide a complete view of the supply chain for hospital linen. Having the entire picture helps greatly to identify issues and create solutions. For the first part of the project, the student was able to acquire the perspective from customer's side while the second part was a great experience from the supplier's point of view. Without an efficient and reliable process in the Brockton Laundry Facility, the Linen Distribution System could not function properly. The relationship between the two parties was a crucial piece for the success of this supply chain. By carrying out the linen distribution optimization and the laundry facility retrofit, the VA Boston Healthcare System would be able to achieve efficiency and environmentally-friendly operations, from upstream to downstream in the supply chain, supporting the sustainability movement of VA.

1.3 Report Organization

The report has been organized into two major parts and twelve sections, as follows. Part 1 of the report addresses Linen Distribution and Part 2, the Laundry Facility. In Section 2, a literature review related to Linen Distribution is provided, including a background study of the tools utilized in the project as well as a case study of a linen improvement process. Section 3 focuses on the Methodology, and c the specific steps taken by the team to accomplish Part 1 of the project are explained; it also clarifies how the information provided in the Literature Review served as guidance. Section 4, the Current State of the System, details the current process in place, the main players of the linen distribution at West Roxbury Campus, and identifies the opportunities for improvement identified. In Section 5, the Future State Design, the system designed by the team to address the existing opportunities for improvement is explained. Section 6, Pilot Area Testing and Trial Implementation, presents the process, outcomes and reflection of a one-week trial implementation of the new design in two pilot areas in the West Roxbury Campus. Section 7, Conclusions, summarizes the results of Part 1 of the project, and includes reflections on the learning experience and how the stated goals of the project were accomplished. Finally Recommendations, Section 8, includes the suggestions provided by the team to the sponsor about the next steps required to truly pursue the optimization of linen use within the West Roxbury Campus. A similar pattern repeats for the second part of the report on the Laundry Facility: a literature review on healthcare laundry and equipment (Section 9), methodology (Section 10), Results and Analysis describing the current state, alternatives, and evaluation

(Section 11). Finally, recommendations were provided for this part of the project to the VA Brockton Laundry Facility (Section 12).

Part 1: Linen Distribution

2.0 Literature Review

In order to start the project, research needed to be conducted in several dimensions. First, there is a description of the data collection methods selected based on the type of research required. This is followed by information regarding the VA culture and policies. Then, there is an explanation of how to determine the linen par levels and cart quotas for different hospital areas. This is continued by a list of the steps to successfully implement Six Sigma in an organization. Finally, a case study is presented as an example for a successful Six Sigma implementation project where linen loss was reduced and the textile resources in the hospital were optimized.

2.1 Data Collection Techniques

In order to conduct a proper scientific analysis, data and information regarding the process and involved personnel needs to be collected. Knowing what information is necessary and how to properly gather it not only saves time and resources but it also prevents "contaminating" or unintentionally altering the data. Data collection should start after determining the focus of the research, the measurable parameters, and the barriers for evaluation.

Selecting what information will be gathered is vital for a successful research. There are two types of information: descriptive and judgmental. Descriptive information is all sorts of data that illustrate objectively the historic or current state of a process. For example: demographic data, reports of project accomplishments, policies, and types of participants. On the other hand, judgmental information is the subjective data provided by people affected in anyway with the process. For example: opinions from experts, consumer preferences, and target audience's beliefs and values. (The Ohio State University, 2010). To acquire a full understanding of the current state of the linen process at the West Roxbury Campus, both types of information were selected for the research. The descriptive information was obtained from several sources, such as: policy documentation, refill request log notebook (area of the hospital, linen item, amount, time, and day), assigned quota for each area, staff schedule, capacity of patients per area and daily linen order to the laundry vendor. The judgmental information was mostly obtained by interviews of the current users; linen distribution staff, nursing staff and management.

The most commonly used methods for data collection are outlined in Table 1, with examples specific to linen distribution:

Table 1: Data Collection Methods

Data Collection Methods	Example for this Project
a) Behavior observation checklist: list of behaviors among participants being observed.	• EMS response to refill requests • Nursing staff's objectivity regarding when a linen item is running "low"
b) Opinion surveys: an assessment of how a person or group feels about a particular issue.	• Most used linen items per area according to the nursing staff
c) Performance test: test the ability to perform a particular skill or task.	• EMS refill request lead time
d) Questionnaire: a group of questions that people respond verbally or in writing	• Linen average and maximum amount for one patient in each area
e) Time series: measuring a single variable consistently over time (daily, weekly, monthly, etc.).	• Daily amount of unused linen returned to the EMS storage room
f) Interviews: individual or group's responses, opinions or points of view.	• Users and management interviews
g) Physical evidence: residues or physical proof observed	• Unused linen in side closets and carts
h) Records: Information from files, records or receipts	• Linen refill requests log notebook

(The Ohio State University, 2010)

Another aspect needed to be taken into consideration when selecting the data collection methods is to avoid any sort of issue or informative conflict. These issues are:

1. Availability: Be certain that the information soon to be collected has not yet been available to the researchers in prior records, interviews, summaries, etc.
2. Pilot testing: Test the data collection instruments or process design before using in the actual research environment.
3. Interruption potential: Avoid methods that can be constantly interrupted by any given reason; this will affect the consistency of the information collected and altered the outcome of the research.
4. Protocol needs: Make sure to have the appropriate permission or clearance before collecting certain information or contacting people.
5. Reactivity: Focus on "how" the question is being asked in order to obtain the most honest answer.
6. Bias: The researcher collecting and analyzing data has to be unbiased; otherwise, the outcome of the research will not be the most "real" one.
7. Reliability: Make sure the evaluation process is consistent; it will always measure the same thing each time it is used.
8. Validity: Make sure the information being collected is relevant and that are actually producing the information planned to be measured.

(The Ohio State University, 2010)

While collecting data, it is important to think simultaneously how the information should be organized, analyzed, interpreted and reported to the interested audience. This will facilitate to future data collection for missing information and the development of the analysis itself, allowing a successful and rich outcome for the research.

2.2 VA Culture and Policy Documents

Due to the different services offered to the veterans and their families, the Department of Veterans Affairs is formed by many divisions and departments. Each division follows a well-defined command chain, where each hierarchy level has established specific responsibilities, work interactions and relationships with other departments. It is important for the project to understand the culture of the VA in order to work with them and not overstep any boundaries.

The work culture at the VA follows the guidelines of the military, because a percentage of the employees at the VA currently work for the U.S. Military or has previously worked there. Military-lingo is common among the employees; however, when interacting with civilians, employees avoid military jargon. Moreover, the authority of higher hierarchy in this entity is stronger and more perceived than in other organizations.

Each VA division has a handbook, where the purpose, policy and responsibilities of each department within the division are detailed. The proper procedures and protocols for each of the different positions are included in the handbook. These handbooks are constantly revised by upper management of each division to guarantee that the best practices are being used to satisfy the needs of the United States veterans.

2.3 Determining Par Level and Safety Stock

In hospitals, the significant unpredictability in the number of patients cared for throughout the day, week, month and year is well known. A regular patient could utilize pajamas, johnnies, pillow cases, fitted and flat sheets, blankets, towels, pink pads, and face cloths. The usage of each individual item fluctuates significantly compared to each other depending on the illness that each patient has. Due to this variability, the linen distribution centers in hospitals must determine a par level that will sustain the maximum amount of linen needed on a daily basis at each area without increasing wastes and costs. A common practice for the hospital Linen Industry is to calculate the par levels of linen (The Laundry Forum, 2012). The coefficient for safety stock varies according to the specific facility it is being used in. The Chief of Laundry Services VISN 1, states that the formula to determine the par level is:

$$Usage = Avg. usage\ of\ each\ linen\ item\ per\ bed$$

$$Changes = Avg. changes\ of\ bed\ per\ day$$

$$Beds = Total\ beds\ in\ unit/ward$$

$$Par\ Level = Usage \times Changes \times Beds \times 1.33 \quad where \quad 0.33\ is\ the\ safety\ factor$$

Even though the quota is a good approximation of the maximum demand of linen in an area, in reality, some items do run out before the end of the day and refills must be requested. Nonetheless, the nursing staff cannot wait to request the linen refill until their area has completely run out of this item. The nursing staff must request the linen refill when they have reached their safety stock. In order to determine the safety stock for each item of linen of a specific area in the hospital, many analysts use the following formula:

$$\bar{L} = average\ lead\ time\ (refill\ delivery\ time)$$

$$\bar{D} = average\ periodic\ sales$$

$$\sigma_L = stardard\ deviation\ of\ lead\ time$$

$$\sigma_D = stardard\ deviation\ of\ periodic\ demand$$

$$z = service\ factor$$

$$Safety\ Stock\ Level = SS = z\sigma_{SS} \quad where \quad \sigma_{SS} = \sqrt{\bar{L}{\sigma_D}^2 + \bar{D}{\sigma_L}^2}$$

(Resources Systems Consulting, 2011)

2.4 Successful Implementation of Lean Six Sigma

Six Sigma has proven to be a successful management strategy focused on improving quality of a product or service by removing defects, minimizing variability in the process and gaining customer satisfaction. Even though this approach has led many organizations to succeed, it has also condemned organizations that failed to implement it correctly. Before implementing Six Sigma, it is important that managers and executives fully understand and support this method. It is equally important they understand their own company or organization. (Gupta, 2001).

A common misconception is that Six Sigma simply improves quality; it actually focuses on improving profitability as well. It is for this reason that one of the first aspects a manager needs to learn about the company is the cost of poor quality (COPQ). The COPQ is the initial financial analysis performed for a Six Sigma project, which seeks to identify the four costs of poor quality in a company: internal failures, external failures, appraisal and prevention (Sharma, Calculating COPQ using weighed risk of potential failures, 2010). By understanding the waste streams in a system, it facilitates the identification of the areas that have direct impact on profitability. After detecting these areas, managers must create a plan to reduce or eliminate the waste streams and variability in the process.

There are several characteristics in an organization that indicate that implementing Six Sigma would not be beneficial, unless there is a drastic change. The most important characteristics are:

a) The quality focus and objectives are not clearly defined and communicated along all the employees.

   Possible solutions:

   - Weekly informative meetings with all staff members
   - End of the month individual goals evaluation

b) There are no measurements to track operation performance (COPQ, reject rate, rolled yield, cycle time, inventory levels, employee skills development, financial performance, design effectiveness, etc.).

   Possible solution:

   - Implement a system to track process cycle time

c) Centralized decision-making; executives are the only ones making the decisions without the input of the employees dealing with the problems on a daily basis.

   Possible solution:

   - Managers request weekly/monthly input of their department staff

d) Employees are afraid of management.

   Possible solutions:

   - Create a “trust” and open environment
   - Incentives program for efficient/outstanding employees

In order to overcome these negative characteristics in an organization, the executives must establish a focus for the organization, a business initiative and implement performance measurements. Moreover, all the employees must understand the direction to where the organization is moving and have passion to achieve improved results (Gupta, 2001).

"Lean" is a widely used term referring to the methodology for process improvement. It consists of a comprehensive set of techniques to eliminate the seven wastes, improve quality, add value for customers, and reduce production time and cost. Taiichi Ohno, the father of Toyota Production System, defined the seven wastes as following: Defects, Overproduction, Transportation, Waiting, Inventory, Motion, and Over Processing. In order to eliminate these wastes and increase the productivity of a system, major tools are utilized such as, Continuous Process Improvement (Kaizen), Root-cause Analysis (Fishbone diagram), and Error-proof Design (Poke-yoke) (Wilson, 2010).

Lean was originally derived from the Toyota Production System (Wilson, 2010). Then it was widely adopted by companies in manufacturing industry as Toyota dominated the automobile market utilizing Lean production practice. In the recent decade, the impact of lean has expanded to service industry as well. Due to its variability, healthcare industry has great opportunities for improvement (Institute for Healthcare Improvement, 2005). Many healthcare organizations have actively implemented Lean approach to conduct process improvement projects, providing better and more cost-effective care to the patients.

A successful implementation of Lean requires a systematic approach to understanding the processes before changes are made. The DMAIC method used in Six Sigma is a common method for guiding Lean implementation, by breaking down the tasks into five major steps: define the goals of the project, measure the performance of the system, analyze the data collected, improve the existing processes, and control the implementation to ensure the sustainability of success (DMAIC Tools - Six Sigma Training Resources, 2013). Other commonly used technique for Lean implementations is the A3-PDSA Problem Solving approach. PDSA stands for Plan-Do-Study-Act. This simple technique not only presents the root cause of the problem, but also analyzes the steps needed to solve the problem and evaluates future improvements for the process (ASSEMBLY Magazine, 2013). Six Sigma and Lean are two strategies focused on continue improvement in a process; however, these two strategies are frequently combined into one single program to enhance the improvement of a system (University of California - Irvine, 2013).

Visualization of the process is helpful for the analysis of the system. One of the most efficient ways is to include all the steps into a map, which also takes into account the value for the customers. Value stream mapping (VSM) is usually utilized by a Lean Implementation team to position process improvement strategically. A Current State Map provides an effective visual representation of the existing system (VHA Office of System Redesign, 2011). Within the map, the opportunities for improvement, also known as undesirable effects (UDEs) are specifically marked; their solutions represent the major design parameters for the next step, the Future State Map. The Future State Map depicts the ideal system. An implementation is created as the guideline to transition from Current State to Future State. An example of a Value Stream Map is found in Figure 1.

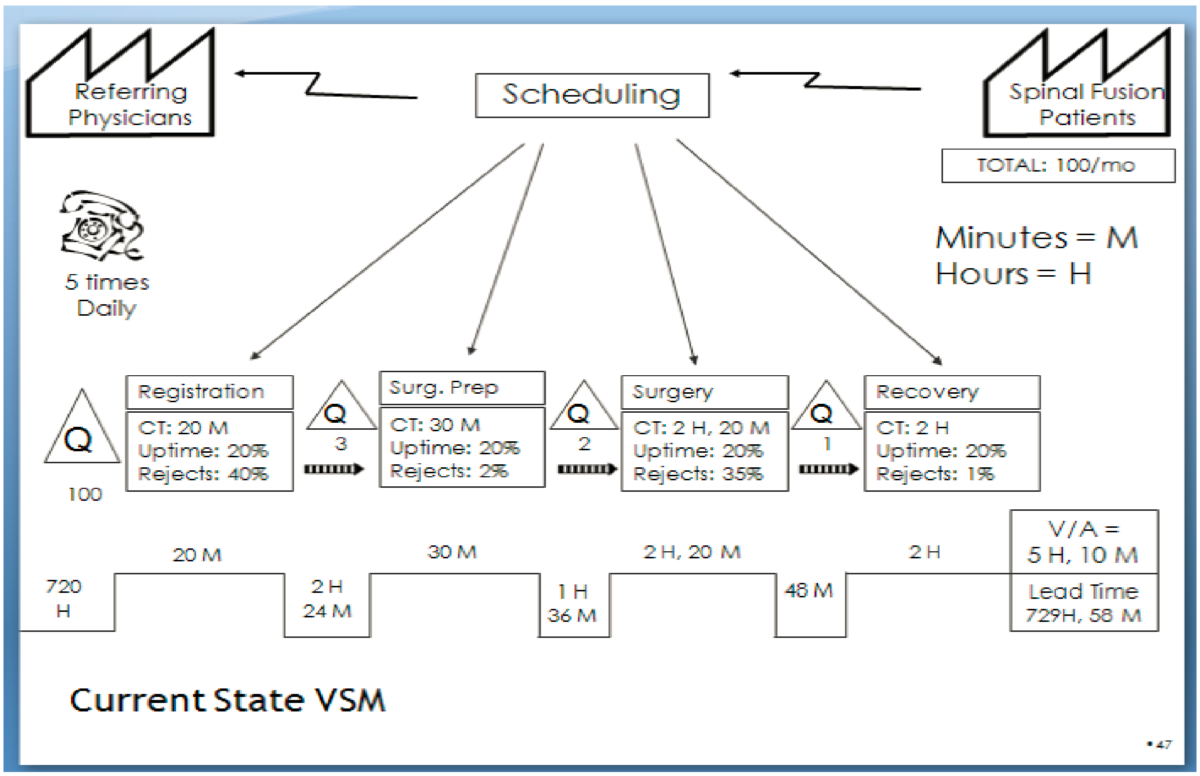


Figure 1: Value Stream Map Example

Besides a systematic approach, process owners and champions are crucial to the success of a Lean Implementation. The process owner is in charge of the designing, measuring, guiding and advocating for the Lean Implementation (Hammer, 2011). This role is commonly played by the functional manager of the process in place. The champion plays a supportive role that ensures the proper resources and management commitment (Process Excellence Network, 2013). This person is a senior manager that is invested in making the process change happen in the organization.

2.5 5S/6S Application

In a workplace, much of the time is lost due to lack of organization. According to an estimate from VA Healthcare, nurses spend more than 40% of their time trying to locate information, equipment or materials required for patient treatment (VA TAMMCS, 2011). Finding necessary documents, important inventory or tools could be a time consuming process which does not add any value to the product/services. 5S is one of the Lean tools specifically aimed at eliminating waste and variability by better organization of the workspace. The scope of the 5S projects is typically small and the duration short. However, such a simple and practical approach could greatly improve the performance.

The 5S are respectively: Sort, Set in Order/Straighten, Shine/Scrub, Standardize, and Sustain (VHA Office of System Redesign, 2011). These could be applied to implementation in linen distribution as follows:

- Sort: Nursing and EMS staff in the workspaces (EMS storage rooms, clean linen room, soiled linen room and linen closet) needs to categorize all items and place them into appropriate locations.
- Straighten: Nursing and EMS staff define designated and convenient locations near point of use for regular used items (linen, linen related tools), and move these items to these locations. Visual Controls are created for these locations. Potential tools could be: labels, signage, dashboard, or tape.
- Shine: Staff cleans the workspace and clears all the trash, dirt, scraps, leaks, dust, etc. A schedule of cleaning needs to be created considering the priority of the areas. (Waste baskets should be emptied regularly.)
- Standardize: Nursing and EMS staff define and agree on the standard work instructions together for the tasks related to linen usage. Regular reporting will be required to monitor the implementation of the standard work. Staff should also be trained in order to start the implementation of standards.

- Sustain: Head Nurses and EMS Directors will be engaged in the implementation and maintain of the 5S projects. Incentives for the employees will be provided and audit of certain frequency will be conducted.

The 6th "S" is Safety. It is originally not included in the 5S technique but the awareness of employee and customer safety is raised. In a healthcare organization, such matter is extremely important since the services are closely related to the health of patients. Therefore, including safety as part of 6S is necessary and appropriate for our project. Additionally, this also aligns with VA's goal of building a robust health care system (Department of Veterans Affairs VA Boston Healthcare System, 2012). During the 5S projects, safety was a major consideration in every step. After the implementation of 5S, all the changes in the workspace were evaluated against safety standards.

2.6 Case Study: Applying Lean Six Sigma to reduce Linen Loss in an Acute Care Hospital

As mentioned previously in this chapter, linen loss is very common problem in hospitals. For this reason, a case study was developed by a student of the Southern Polytechnic State University focused on reducing the linen loss of a hospital by implementing Lean Six Sigma practices into the system (Furturer, 2011). The study was conducted in 2011 at the Holy Cross Hospital, in Ft. Lauderdale, FL, USA. explained the current state and strategy development along the five different phases of the DMAIC (Define-Measure-Analyze-Improve-Control) methodology and other key lean concepts.

In the *Define* phase of the problem statement, the goals and the SIPOC (Supplier-Inputs-Processes-Outputs-Customers) diagram are established. In the problem statement, the two main problems are mentioned: the baseline soil to clean linen ratio is 3.86% and the goal is 5%, and in a period of 6 weeks in 2010, the hospital lost $18,101 in linen. Therefore, goals were focused into solving these two major problems. The SIPOC diagram (Figure 2) developed in the case explains in great detail who is involved in handling the linen and how the process works.

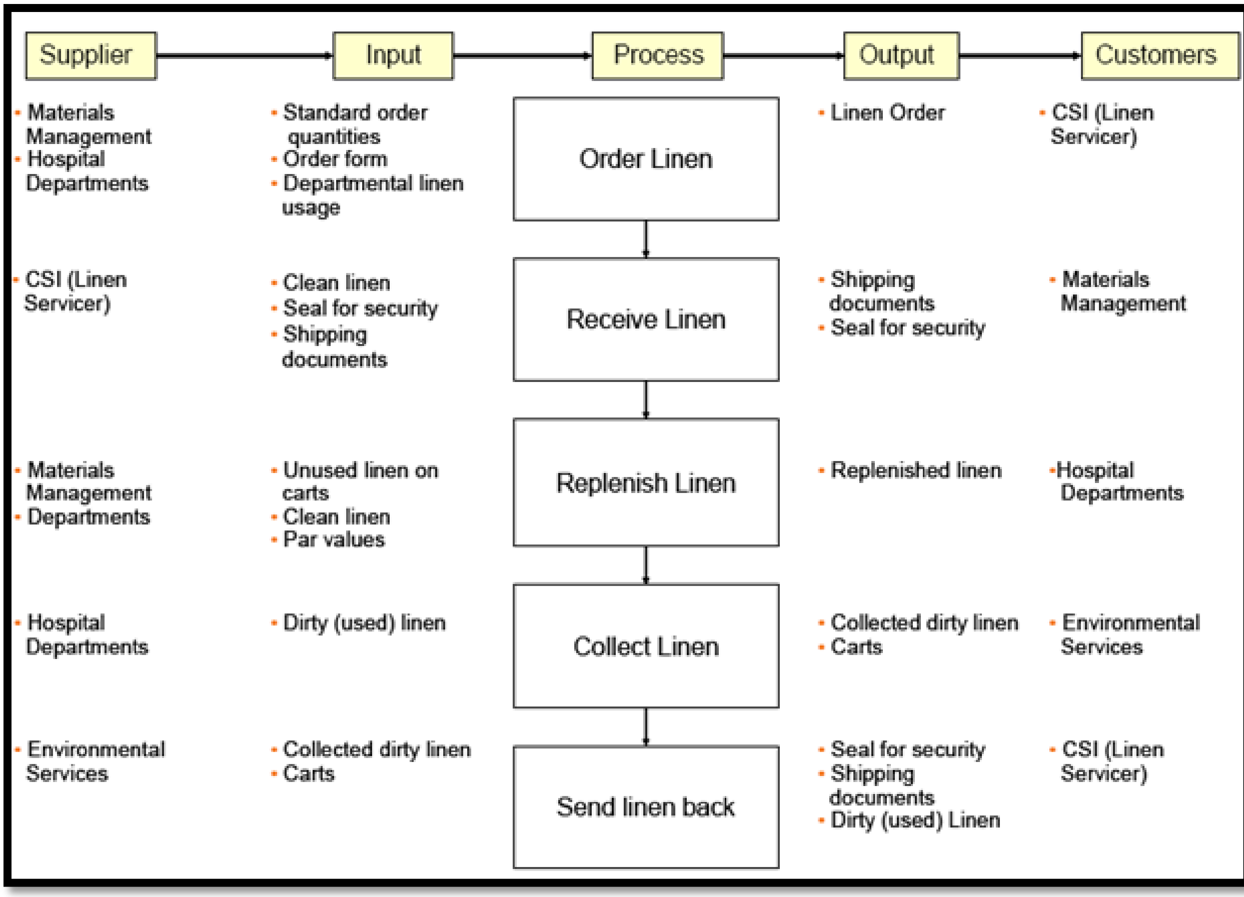


Figure 2: SIPOC Diagram (Furturer, 2011)

The *Measure* phase, Further defined the current process, the detailed voice of customer (VOC), the voice of process (VOP), the current performance, and validated the measurement system to make sure it was accurate. Figure 3 illustrates the current state for a part of the process and Table 2 displays the data collection plan.

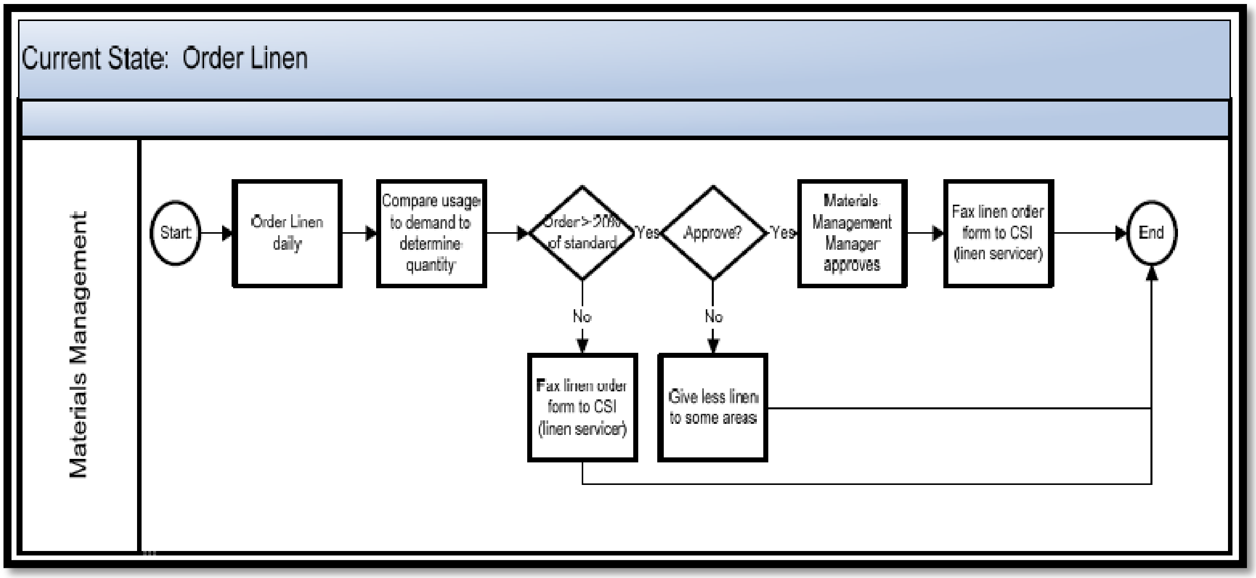


Figure 3: Current State Chart (Furturer, 2011)

Table 2: Data Collection Plan (Furturer, 2011)

Critical to Satisfaction	Metric	Data collection mechanism	Analysis mechanism	Sampling plan	Baseline
Linen loss	Soil to Clean Ratio: (1 – (Clean / Soiled)) * 100%	CSI linen service provides these numbers	Basic statistics	1st quarter 2010	(1 – (434,737/452,183)) = 3.86%
Linen usage: appropriate use of linen	Pound per adjusted patient days: Pounds linen delivered / adjusted patient days * 100%	CSI linen service provides these numbers	Basic statistics	April 2010	10.46%
Annual linen replacement cost	Annual cost of replacing linen	CSI linen service provides these numbers	Basic statistics	Q1 and Q2, 2010	Scrubs: $27,271 Linen (not scrubs): $347,750 **Total: $375,462**
Annual linen processing cost	Cost of processing linen	CSI linen service provides these numbers	Basic statistics	Q1 and Q2, 2010	Scrubs: $17,004 Linen: $600,674 **Total: $616,677**

For the *Analyze* phase, further explained the different formulas to calculate the soil to clean linen ratio as well as cause and effect relationships were developed. An interesting diagram in this phase is the "Why-Why Diagram". In this diagram (Figure 4), the paper presents the different possible scenarios that explain why linen is lost in the hospital.

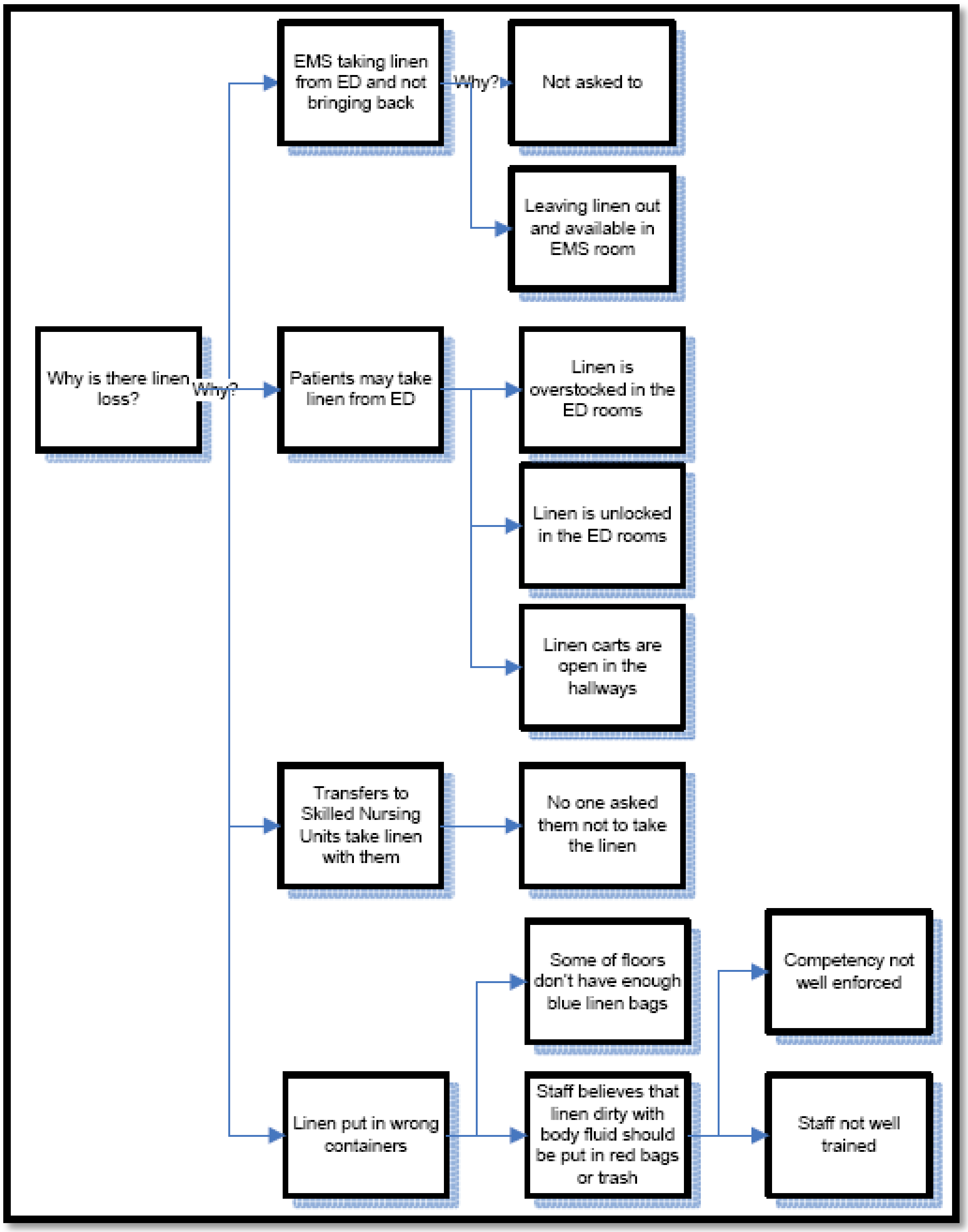


Figure 4: Why-Why Diagram (Furturer, 2011)

After concluding with the *Analyze* phase and identifying the root causes of linen loss and low soil to clean linen ratio, the *Improve* phase was set in motion. In this fourth phase, different improvement opportunities and plans were identified, a cost/benefit analysis was conducted, a future state was designed, performance targets and project scorecards were established, and pilot improvements were implemented.

In the fifth and last phase, the *Control* phase, the outcomes of the implemented pilot activities were measured. Moreover, a control plan was developed to monitor the system throughout time and avoid the previous situation from happening again. The control plan is shown in Table 3.

Table 3: Control Plan (Furturer, 2011)

Metric	Control Mechanisms	Actions to be taken if problems occur	Responsibility
Soil to Clean Ratio	Measure soil to clean ratio quarterly	Linen Committee implements further improvements	Linen Committee
Pounds per Adjusted Patient Day	Measure pounds per adjusted patient day		
Annual Linen Replacement Cost	Measure linen replacement cost quarterly		
Annual Linen Processing Cost	Measure linen processing cost quarterly		

One year after implementing Lean Six Sigma into the linen process, the hospital saved $77,480 and reduced the soil to clean linen ratio by 16%. This case exemplifies how successful an organization can become by properly implementing Lean Six Sigma in their process. By carefully analyzing the given data and understanding the performance of the organization, root causes for problems will be identified and an appropriate improvement plan can be developed. This case study provided us with many key ideas and steps to follow in order to accomplish a similar outcome.

3.0 Methodology

The goal of this project was to improve the linen distribution system of the VA Boston Healthcare System - West Roxbury Campus. We accomplished this goal through the following objectives:

1. Understand the current state of the linen distribution process
2. Design a future state linen distribution process, and
3. Work towards the implementation of the future state process and evaluate possible outcomes

These objectives were met using three Lean tools: Value Stream Mapping, 5S techniques and a SIPOC chart. Multiple Value Stream Maps were created for both Current State and Future State conditions of the system. 5S projects were conducted in pilot areas to help organize the Linen Storage locations. The SIPOC approach was utilized to have a high level understanding of the entire process. In addition to these three tools, we also conducted data collection (time study), process observation and personal interviews to incorporate the input as well as feedback from VA nursing and EMS staff.

The team recognized that it was not practical to study the whole hospital due to the size of the hospital and the 21-week duration of the project. In order to address this, we strategically selected three focus areas based on the data collected and the guidance of the EMS Assistant Chief. After careful analysis we selected the following areas: CT Scan, PCU and 3 North. These areas were recommended because the nursing staff was interested in collaborating towards improvement. Moreover, each area represents one of the three types of areas in the hospital: a small area, a unit, and a ward. Focusing on these areas allowed us to learn and obtain a general idea of the current linen distribution process in the entire hospital. The team sought to test and implement aspects of the future state design in two of these pilot units.

The project group identified the major stakeholders to be the nursing staff, linen staff, housekeeping, and patients. Attitudes of major stakeholders were taken into account through the Value Stream Mapping sessions, with the exception of the patients and housekeeping. Due to the time constraint for the project, the team was capable of interacting mostly with head nurses and the staff from the EMS morning shift. A weekly timeline can be found in Appendix A detailing the schedule followed to implement the following methodology.

3.1 Determining the Current State

The first step of our plan was to understand the current state of the linen distribution process at West Roxbury Hospital. A Value Stream Map (VSM) was created to understand the detailed steps of the linen distribution as well as to identify existing improvement opportunities in the system. The VSMs can be found in the Appendix section. In order to create the VSM, we first shadowed the EMS linen staff during their distribution rounds and linen cart preparation during the first two visits, while interviewing them about the process and current problems in the system. Based on the linen staff's and EMS Assistant Chief's input, the EMS VSM was created. Then, the team did group interviews with the nursing staff of each selected area. During the group interviews, we created the VSM using their input from post-it on a white cardboard. This method was also an effective communication tool between the project team and the staff. It demonstrated our understanding of the current process and collected knowledge about the existing system from the hospital's employees. We completed the Current State Value Stream Map at the end of the 14th week of the project.

3.1.1 Data Collection, Observation, and Metrics

A valid VSM should have the input from the front-line staff but it should be based on observations and data to support it. Some may argue that these measurements of the system may slow down improvement projects. However, many studies have shown that a systematic improvement plan generated from accurate data analysis is much more effective and efficient than "fire-fighting" problems without a well-structured approach (VHA Office of System Redesign, 2011). Additionally, basing our decisions for the improvement areas on data analysis helped us focus on the problems that are more urgent and have a greater impact on the system.

The team determined what data was necessary to understand and improve the process. For the linen distribution process, we were interested in understanding the following:

- Linen inventory amount for each area
- Real linen demand by area
- Linen usage by area
- Delivery time of the process
- Linen refills lead time
- Linen refill request frequency by area
- Linen refill request process
- Linen distribution staff working hours and capacity
- Quality information about linen
    - Stock-out frequency for linen in different areas
    - On-time delivery rate of the linen

Data collection in the project focused primarily on the process. Each individual team member followed one of the linen distribution staff through their morning delivery trips. During the shadowing, times were recorded when they picked up the clean linen from EMS Storage Room, delivered to the linen closet, and the time they spent in the linen closet before returning to EMS. The same time studies were used during the morning clean-up process where the linen staff brought container carts for soiled linen.

Observation of the process was also utilized to understand the current system. During the shadowing trips with the linen staff, team members took notes about potential opportunities for improvement. Without interrupting the process, these direct observations served as the first hand information about the system. They were compiled and compared to the results from meetings and interviews.

The refill of the linen closets was taken into consideration as another focus of the project. Based on the interviews with the nursing staff and EMS linen staff, we determined this was the most important problem in the distribution system. This part of the process reflected the lack of trust in the system as well as a lack of standardization in the refill process.

The team established three metrics for evaluating the system throughout the project. These metrics are Linen Order/Delivery Ratio, Linen Usage per Area, and Linen Refill Lead Time. The Order/Delivery Ratio provides insights on the supply of linen received from Brockton Laundry Facility. The Usage per Area indicates what the demand for linen is in each area. Finally, the Refill Lead Time demonstrates the capacity of the EMS Linen staff for the refill process. Table 4 below contains details for each of the three metrics explained in this section.

Table 4: Project Metrics

Metric	Formula	Control Mechanisms	Actions to be taken if Problems occur	Responsibility
Linen Order/Delivery Ratio	Ordered / Delivered	Inventory reception of linen from delivery	Contact Brockton immediately and implement further improvements with Linen Committee	**Immediately:** EMS Supervisor **Future:** Linen Committee
Linen Usage Per Area	Morning Delivery + Refill + Afternoon Delivery - Returned	EMS data collection and counting	Contact Linen Committees	**Immediately:** EMS and Head Nurse **Future:** Linen Committee
Linen Refill lead time	Time of Delivery - Time of call = Hotline time to pass message + EMS Staff time to deliver	Data collection point throughout refill process	Help Desk and EMS Supervisor	**Immediately:** EMS and Head Nurse **Future:** Linen Committee

3.1.2 Interviews and Focus Groups

The data and observation results provided the team with a general idea about the linen distribution system. However, visiting the hospital several times was not enough to give us the entire picture of the system. By incorporating the knowledge of the staff into the data, value was added to the Current and Future State Value Stream Maps created by the team. For this reason, informal interviews were conducted during the visits with the EMS staff and nursing staff. A pool of questions was prepared before the visits and team members asked them during the visit. Further questions were added during the conversations when the team members found it necessary.

3.1.3 Mapping of the Current State

After collecting process data information and completing the current state VSM, several meetings were held with focus groups of the different stakeholders in the system to investigate the accuracy of the map and its details. In these meetings, we showed our current state VSM to both the EMS staff and the nursing staff and requested for their feedback and any missing data points. This ensured the real system was well reflected on the VSM. With both value-added and non-value-added steps, the team was able to streamline and simplify the linen distribution process to increase its efficiency. Our goal was to eliminate non-value-added steps as much as possible without impacting the robustness of the system. It was a crucial section of the project since all downstream designs were based on this Current State as the foundation.

3.2 Designing the Future State

With the Current State VSM, we were able to identify several improvement opportunities and unnecessary steps in the system. The Future State VSM was created by examining the opportunities for improvement and considering the constraints of the system to create feasible solutions to address these opportunities. We completed the future state value stream map at the end of the 15th week of the project.

3.2.1 Identifying Opportunities for Improvement

The Current State VSM as well as the input from the process owners was utilized as the main source for identifying opportunities for improvement. The potential solutions were created based on the opportunities for improvement. To determine the potential solutions, the team conducted several brainstorming sessions amongst the group as well as with the process owners and stakeholders at the VA.

3.2.2 SIPOC Approach

After coming up with potential solutions, the team used a SIPOC approach next. SIPOC stands for: Supplier, Input, Process, Output, and Customer; the five important components of a system. This process-oriented tool is a systematic way to investigate a system and map its flow. A high-level view of the process was created by dividing the system into these five significant elements. Suppliers to the process are those who provide the materials, services and information. Inputs are the actual materials, services and information provided by suppliers which go into the process. Process steps are how the system adds value to the inputs and yields outputs. Outputs are the final product/service of the process. Finally, Customers of the process are the ones benefiting from or receiving the outputs. The process steps are where the greatest potential for improvement lies. For this project, the VSM and SIPOC were combined and utilized for the analysis. The SIPOC approach helped the team in creating a more detailed future state that would take into account all the parts of the system. This approach helped the team create the key elements of the process such as the refill process, the par levels, and cart quota. Figure 5 illustrates the SIPOC chart for our study.

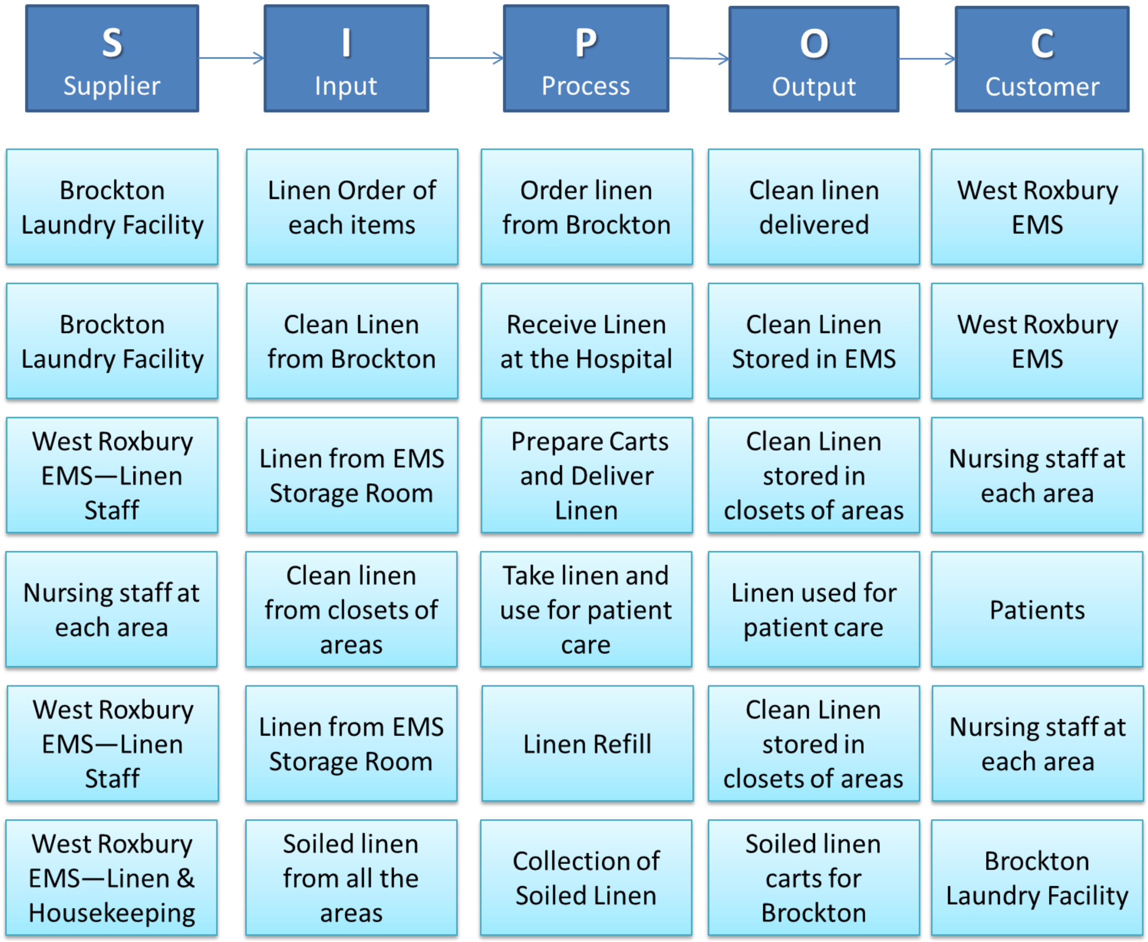


Figure 5: SIPOC Chart

3.2.3 Determining the Par Level and Cart Quota

Accounting for the variability of the linen demand in a hospital was a challenging part in the design of the Future State. The SIPOC analysis helped the team look at the system in a holistic manner and understand how everything was interconnected. Determining the Par Level was a vital step that helps understand the demand for linen in each area enabling the team to determine a Cart Quota for each area. In order to determine the new par and cart quota for the three pilot areas, the team used the following data:

- Number of beds per area
- Amount of each linen item used per patient in average and in outstanding situations that required a larger use of linen (maximum amount), and
- Average changes per day per area

The second and third data points were given to the team by the nursing staff of each area.

The par levels were calculated using a formula provided by the Chief of Laundry Services for VISN1. This formula is:

$$Par\ level = daily\ consumption\ \times number\ of\ beds \times avg.changes\ per\ day \times 1.33$$

$$where$$

$$1.33 = safety\ stock$$

As previously mentioned, the daily consumption of linen varies per item and area. The average changes per day can fluctuate between 1-3 changes per day depending of the type of area in the hospital: wards, units, or small areas. In case of 3 North, the selected pilot area representing the wards, the value used was 2. For PCU, the pilot area representing the units, the value used was 1.5. For CT Scan, the pilot area representing small areas, the value used was 1.

To calculate the cart quota, we divided the par level by half and evaluated if this amount would fit in the current linen carts. After running this test, we estimated a preliminary quota. We then took into consideration the amount of linen found in each bundle of linen (e.g. a bundle of towels has 24 towels). By working with sets of bundles, the linen cart preparation process will be faster, easier and more accurate. By taking these factors into consideration, the team was able to determine an accurate and efficient cart quota for each pilot area to be used in the Future State.

3.3 Testing and Implementing Aspects of the Future State

After developing the Future State VSM, the team chose particular elements to test and implement. For the trial implementation phase of the project, we utilized 5S lean techniques. Carrying out all proposed changes at the same time may not be most favorable strategy since each change has an impact in the system and affect its results. Due to the time constraints, the team decided to work towards preparing the environment to successfully implement the future state, and tested the trial implementation in pilot areas. This process was started during the 18th week of the project and continued until the end of the project in week 21.

4.0 Current State of the System and identification of Improvement Opportunities

The current state of the linen distribution system when we started the project was convoluted and confusing. People knew how it worked because they used it on a daily basis, but the system as a whole had never really been looked at and understood. Several revisions of the current state map were required in order to get a full understanding and representation of what was actually going on and how things were done. In this chapter, we describe the general process of the linen distribution system and then break down the general process into the detailed processes that happen within the different areas involved in the system. We conclude by identifying the opportunities for improvement within each specific area that were discovered as a consequence of describing the current state.

4.1 General Process

In order for each bed at the hospital to be prepared with a clean set of linen, three different departments work together to make it happen. These three departments are the Laundry Service, the Environmental Management Service (EMS), and the nursing staff. VISN 1 shares many resources and laundry is one of them. All linen for the VISN is washed at Brockton and then transported back to the respective medical centers. EMS at West Roxbury places a daily order every weekday to the Laundry Services in Brockton, ordering the linen for the next day. These orders could include up to sixteen different linen items. A truck arrives from Brockton on the following day with the clean linen that was ordered. This linen is used by the linen staff to fill up the carts for each unit and ward with their respective quotas that same afternoon. The carts with the clean linen are then delivered by the linen staff the next morning, and the linen is used by the nurses and housekeepers as needed. The lead time from when the linen is ordered until the time it could get to the nurses for usage is at least three days. Whenever the nurses see that the linen levels are running low, they call EMS staff to request a refill. Finally, when the linen is used and becomes soiled, it is disposed of and sent back to Brockton for washing, completing the linen cycle. The locations where linen is stored throughout the system are the following: EMS Storage Room (located in the ground floor of the West Roxbury Campus), linen carts, and linen closets and side closets. The general outline of this process is shown in Figure 6.

Figure 6: Process Outline

4.2 Specific Process Divided by Area

As mentioned before, three different departments work together throughout the linen distribution system; these departments are the Laundry Services, the EMS, and the nursing staff. After careful consideration, we decided to set the scope of our study to be the EMS and the nursing staff interactions within the linen distribution process. The Laundry Services are out of the scope of our study because they process the linen for all of VISN 1 which includes the 11 medical centers in New England. The focus of our project was to understand and optimize the linen distribution within the West Roxbury Campus, so we determined Laundry Services was out of the project scope because it worked within a much larger area. The EMS and nursing staff interact constantly throughout the process in order to get clean linen to every bed and patient in the hospital. Each department has several internal processes involving linen, and several processes related to interactions between each other as well. These can be broken down into the reception of linen from Brockton and the delivery to each area of the hospital by EMS, the usage of that linen by the Nursing staff, and finally, the refill and collection of the soiled linen by the EMS to send back to Brockton again. These interactions are depicted in Figure 7.

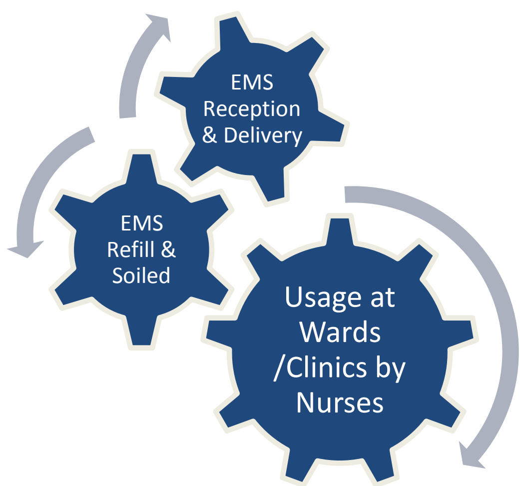


Figure 7: System's interactions

4.2.1 EMS Linen Reception

In order for the linen to be delivered every weekday, the EMS Linen Supervisor places a daily order by phone to Brockton requesting the linen to be delivered the following day. The order for Tuesday is placed on Monday, the order for Wednesday is placed for Tuesday, the order for Thursday is placed on Wednesday, the order for Friday, Saturday, and Sunday is placed on Thursday, and finally, the order for Monday is placed on Friday. Clean linen arrives by truck to West Roxbury from Brockton in big tubs with transparent plastic covers to protect the linen inside from possible contamination during transportation. The EMS staff receives the linen at the docking area and transports it to the Linen Storage Room, where it is sorted into the respective shelves or left in the tubs if the shelves are full. This process is depicted in the process flowchart in Figure 8.

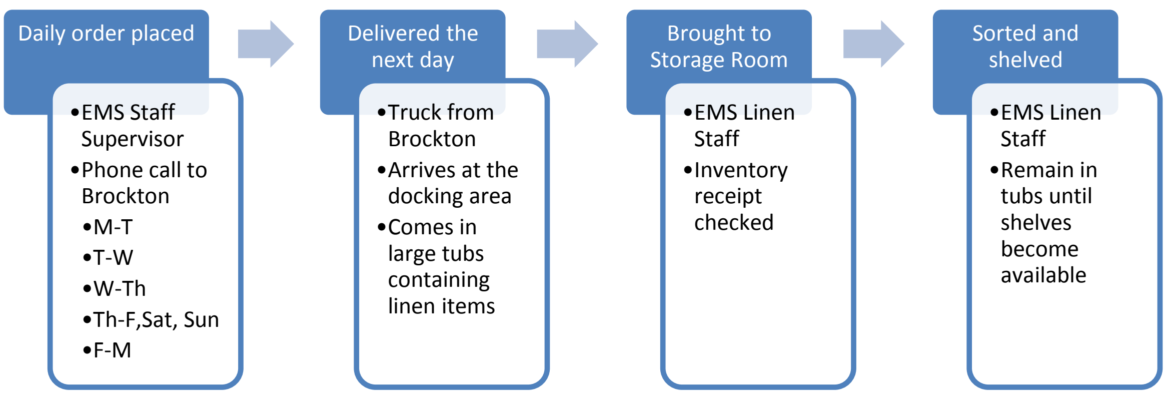


Figure 8: EMS Reception Process Flowchart

4.2.2 EMS Linen Delivery

Once the linen that was delivered from Brockton is brought down to the Linen Storage Room, it is ready to be distributed to areas of the hospital. The linen staff on first shift fills up the carts for each area with their respective quotas and leaves those carts ready to be distributed the next morning. The linen carts are delivered to each area between 6 am – 9 am each weekday morning. There are two carts for every area, one that is always in the linen closet of that area, and one that is in the Linen Storage Room. In the morning, when the carts are delivered, the ones with clean linen are swapped with the cart that was delivered the previous day. The used cart in the closet is then brought down to the Storage Room to be refilled so that it can be exchanged the next day. The linen staff then goes out to all areas and refills the isolation gown tubs between 7 am – 9 am every weekday morning. A process flowchart of this can be found in Figure 9.

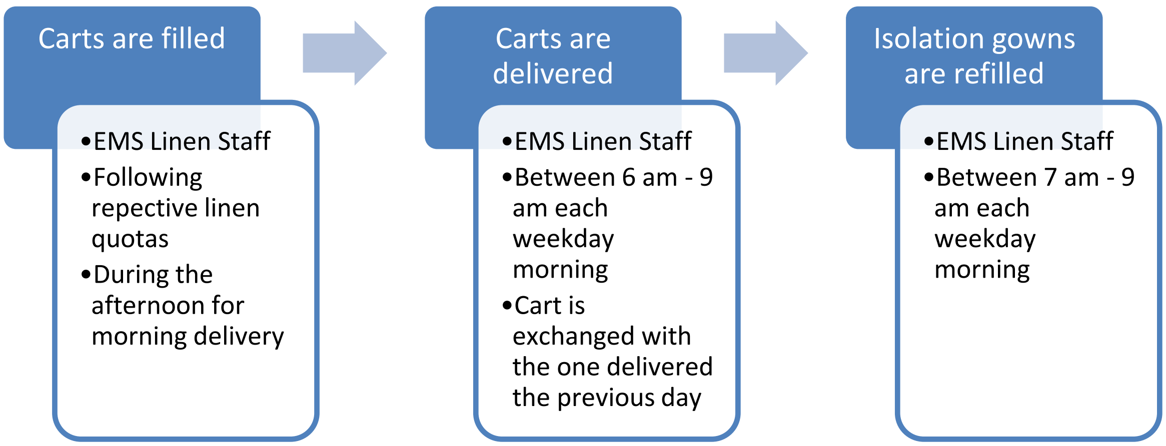


Figure 9: EMS Morning Linen Delivery Process Flowchart

4.2.3 Linen Usage by the Nursing Staff

Once the clean linen is delivered at each area's closet, it is ready for use by the nursing staff when needed. The nursing staff refills the side carts and side closets after the clean linen is delivered. The nurses and nursing assistants refill drawers outside each room with yellow prevention gowns after the large tubs are refilled. Nurses, nursing assistants, and housekeepers then utilize the linen as needed throughout the day by taking it from the side carts or closets, and bringing it to the patient who needs it. When the linen gets soiled, the nursing staff or Housekeeping disposes of it in the soiled linen bags located in each individual room. Housekeeping is responsible for taking the soiled linen bags every day to the soiled linen closet and placing them inside the empty tubs located there. Finally, whenever the nurses believe that the linen is running low, they call EMS to request a linen refill. A process flowchart of this can be found in Figure 10.

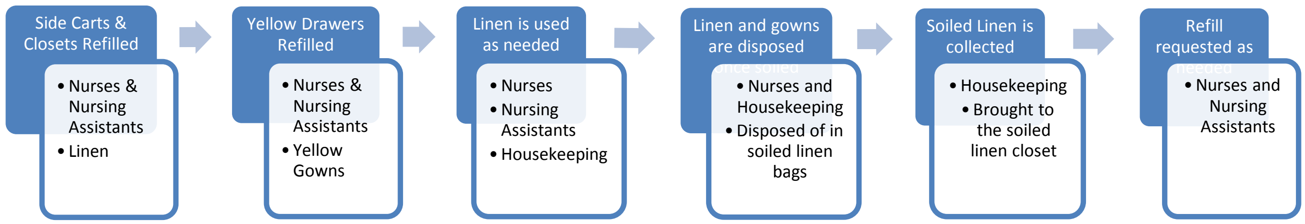


Figure 10: Linen Usage Flowchart on Nursing Unit

4.2.4 EMS Soiled Linen Process

Once the linen is utilized, becomes soiled, and is deposited in the soiled linen closet in every area by housekeeping, the linen staff collects it in the afternoon. The soiled linen bags should be placed inside the empty tub left in the closet, but currently there are not enough tubs to have one in every area. The linen staff brings the tubs filled with soiled linen to the entrance of the EMS Storage Room, and the tubs are brought to the docking area before the truck from Brockton is due to arrive. At the docking area, a green cover is placed on top of each tub to help identify that they all come from West Roxbury. When the truck arrives with clean linen tubs, these are exchanged with the soiled linen tubs and taken back to Brockton for washing. A process flowchart of this can be found in Figure 11.

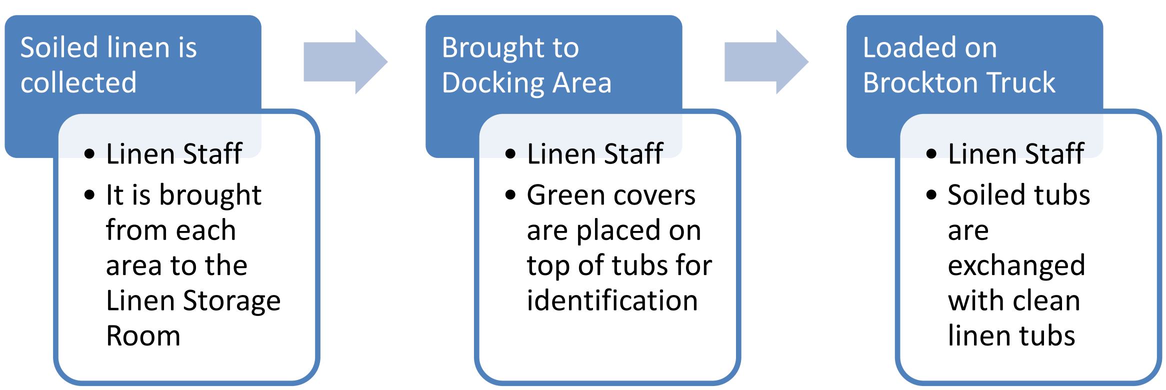


Figure 11: Soiled Linen Process Flowchart

4.2.5 EMS Linen Refill Process

In the processes described so far, there is no direct interaction between the nurses and the EMS. Each of them rely on the other's work to be able to perform their daily duties; nurses depend on EMS being able to deliver clean linen in order to provide adequate care for veterans, and EMS depends on the nurses utilizing the linen so they would need to restock it again. However, the linen refills require a direct interaction between the two departments. When the nurses deem that the linen levels are running low, they call the EMS to request a refill. The call could be made to the EMS Help Desk for all the facilities in VISN 1 or to the EMS Storage Room if the request is in the West Roxbury facility. If the call is made to the EMS Help Desk, the person in charge creates a ticket for each call and contacts the Linen Staff personnel to inform them about the request. This contact could be made by the following seven methods:

- Stopping the EMS Linen Staff as they walk in front of the EMS Help Desk
- Walking down to the Storage Room
- Calling the phone in the Storage Room
- Contacting a supervisor
- Paging the linen staff
- Leaving a note hanging on the EMS Storage Room.

Once the linen staff is contacted, they proceed to collect the linen that was requested, record the linen item and the area it is going to, and bring it up to the respective area. If the call goes to the Storage Room, then the linen staff will log the same information in the linen log notebook located in the EMS Storage Room and take it up to the respective area. The afternoon linen shift will check the linen levels only for the hospital's wards and refills them as necessary. A process flowchart of this can be is shown in Figure 12.

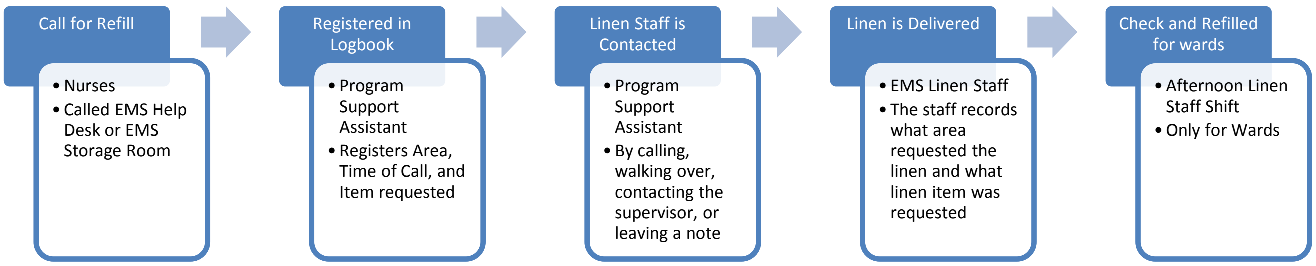


Figure 12: EMS Linen Refill Process Flowchart

4.3 Data Collection

The system has very little to no data collection in place, which created difficulties when trying to understand the process. In order to understand the system, the team attempted to create a data collection plan. One of the major components of this plan was conducting time studies to understand the lead time of the morning delivery of linen. After three sessions of data collection and shadowing of the EMS Staff, it became clear that the lead time for the morning delivery of linen was not critical to the project so the team stopped the data collection efforts. Valuable data was provided by the EMS log notebook, where all the linen refills are documented. This provided the team with a better understanding of the amount, time, and frequency of the refill orders in the pilot areas.

4.4 Opportunities for Improvement

The process maps of each sub process helped the team to understand the current state of the linen distribution process. At the same time that we were studying the process and understanding exactly what happened to make it function, we were able to discover opportunities for improvement within the system. These opportunities could be categorized into undesirable items in the system, poor practices by the different departments, constraints within the system, and miscommunication throughout the system. In the following section, we will detail the opportunities for improvement found in each specific step of the process explained in the previous section. The EMS delivery and soiled linen sections are not mentioned below since they did not show any substantial opportunities for improvement.

For receiving linen, there is no standard or metric by which to validate or indicate how much linen should be ordered in the daily phone call to Brockton. The EMS supervisor places the order every day based on some set standards in some cases, personal observations, and experience of the fluctuation of linen that day in the Storage Room. There is an opportunity for improvement here by creating a systematic way of ordering the linen that will reflect the actual inventory and current usage of the linen. There is no specific system to bring down the tubes and to organize them in the Storage Room. Even though the EMS's space is limited, having an organized and systematic way of placing the tubs and rotating them to fill in the shelves with clean linen would be beneficial in many ways. By having an organized system for the tubs, the supervisors will clearly know how much linen they have on inventory and could place more accurate daily orders to reflect the demand and usage of the linen. The shelves that are located in the EMS typically have an assigned item, but this practice is not followed at all times and shelves are not labeled.

There are several opportunities for improvement in the linen usage by the nursing staff. To begin with, there is no standard as to how much linen should be taken from the linen closet for every bed change-over. Since it is left for personal interpretation, it inevitably varies from nurse to nurse. This allows for situations where nurses take extra linen into the rooms that is not used and has to be rewashed unnecessarily. There is also high fluctuation in the demand for linen in two dimensions: from one area to another and within each area from day to day. This affects the usage of the linen and makes the system even more complex and harder to serve. It was also discovered that some of the items delivered in the carts do not reflect the actual need of the specific wards or areas, indicating that the quotas have not been updated recently. Finally, the linen inside the carts was cluttered and unorganized when delivered. This lack of organization makes it hard for the nurses to extract the linen items from the carts as well a makes it harder to predict how much linen is actually in the carts at any given moment.

For the linen refills there were several opportunities for improvement since it involved the most complex part of the system where both departments directly interacted. The nurses call for a refill whenever they feel that the linen levels are running low. There are no parameters to measure this or a standard of what "low" indicates. It was also not established who was responsible for calling and to whom they should be calling. There was very limited communication throughout the system making it impossible for the nurses to know whether the EMS had already been contacted, resulting in multiple calls made for the same request, wasting nurses' and EMS's time. Ultimately there was a lack of trust in the system as a whole. The consequences of this lack of trust are that nurses hoard linen when they fear certain items are running low as well as borrow linen items from other wards or units. Sometimes housekeepers would be asked to go directly to the Linen Storage Room to obtain the required linen from the Storage Room instead of calling the EMS Help Desk for linen refill. Please refer to the Appendix section to find the Value Stream Map referred to in this section.

5.0 Future State Design

After a careful study of the opportunities for improvement described in the Current State chapter, we designed a Future State for the linen distribution system that would address each opportunity. The Future State describes the way the new system ideally is conducted within the following four areas: Quota, Organization, and Signal System for the Refill Process, and Standard Practices. This section first explains the tools implemented in the future state, and then an explanation of how these tools are used by the different stakeholders in the process is given. The Future State Value Stream Map can be found in the Appendix section of the report.

5.1 Modified Quota

As mentioned in the Methodology, the par level is the maximum daily usage of linen in a certain area and is calculated utilizing a formula based on demand and safety stock. The baseline calculations for each area's quota are determined based on the input of the experienced nursing staff, the calculated quota, the capacity of the linen carts, and the previous working quota. The quota is revised as needed at the quarterly meetings between EMS and nursing heads to ensure that the nurses are able to provide the best care for the veterans.

5.2 Environment Organization (5S/6S)

To facilitate the standardization processes, it is important to have a clean, organized, and efficient working environment. The different areas that are encompassed in the material flow of the system are the EMS Linen Storage Room, the linen carts, and the linen closets located in each unit. In the following section, we describe how each of these areas is organized following a 5S approach. In order to sustain the organization throughout all the different areas, the EMS supervisors conduct a bi-yearly audit to each of the areas.

5.2.1 EMS Linen Storage Room

The EMS Storage room has a designated area for each different linen item stored in tubs as well as a rotation system. The designated areas are clearly marked on the floor so that each tub is easily located in its corresponding location. A rotation system is in place to ensure a First In First Out (FIFO) movement of the tubs through the system. FIFO is a practice that guarantees the proper rotation of items in a system where the first item to go into the system will be the first one to be extracted. Moreover, there is designated shelf space for each type of linen item, which is clearly labeled and clearly visible. Once shelf space becomes available, the linen items are moved from the tubs to the shelves so that they can later be utilized to fill the carts or for refill requests. Having a systematic rotation system and an organized EMS Storage Room facilitates the ordering process for linen from Brockton by providing the supervisor with a clear picture of the inventory levels in the Storage Room.

5.2.2 Linen Carts

The linen carts are customized to reflect the quota for each area. Each linen item has a separate, labeled compartment that contains enough space to store the assigned amount. The cart only contains the linen items that are utilized in its area and no more. The cart also has the flexibility to be customized to adjust for any changes in the quota. The orientation of the linen items is taken into consideration when placing them inside the cart. The folded part of the linen is facing outwards so that it is easier to access and extract. The fitted sheets, as was mentioned in the current state, are the most problematic item because of its irregular shape. They way that they were stored could also lead to infection control issues. By wrapping them around themselves into a round shape, they become easily accessible, organized, and more compact. In the areas where a side closet exists, the distribution of linen is decided with the input of the respective head nurse. The amount of linen to be distributed is marked on the carts so that it is easily identifiable by the nursing staff and the side closets are consistently restocked. An example of this is found below in Figure 13.

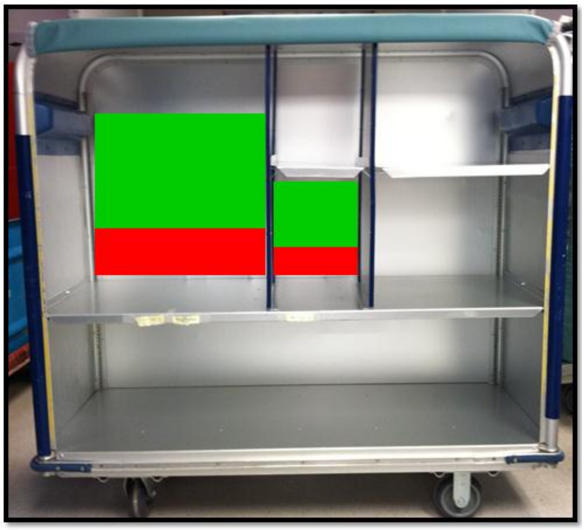


Figure 13: Sample of Linen Level Indicators in Linen Cart

5.2.3 Linen Closets

The linen closets are cleared of all clutter and organized to the greatest extent possible. All extra shelves and storage locations are eliminated or locked so that the only location where linen could be found or placed is in the linen cart. The linen cart also has a designated area inside the linen closet so that it is always found and placed in the same location.

5.3 Refill Process Signal System

To foster communication throughout the different departments involved and provide an accurate representation of the linen levels available, a color coded signal system is implemented to aid the refill process. The color coded signal system is utilized in the linen closets in every ward and unit of the hospital as well as in the EMS Storage Room. This section explains how a color coded signal system is implemented in each area of the hospital and it also explains how the whole refill process works and how the signal system is utilized within the refill process. The design of these elements as they were implemented in the pilot areas is described in the next section about the implementation of the process.

The color coded signal system consists of the colors green and red. Green represents adequate conditions, where no action is required from the staff. Red represents inadequate conditions, where the refill process is initiated; an action needs to be made by the staff. This color coded system is utilized in the linen carts, the linen closets, and the EMS Storage Room.

Each separate compartment of the linen cart has a linen level indicator divided in green and red portions. The length of the whole indicator represents the height of the linen item corresponding to the quota for that area. The height of the red indicator represents the safety stock calculated for each item. The space from the safety stock to the top of the level is colored in green

The signal system in the linen closets consists of a laminated poster hung at a visible spot. The laminated poster has a green side and a red side. The green side indicates that there is an adequate amount of linen in the cart. The red side indicates that the linen levels of at least one item are running low; this side has a table to record the information of the refill request. Figure 14 shows an example of the laminated poster.

Figure 14: Laminated Poster

The color coded signal system is also implemented in the EMS Storage Room with a laminated poster hanging at a visible spot directly above each of the linen carts. The green side of the poster indicates that the cart is filled with the assigned quota. The red side of the poster indicates that there are missing items in the cart to fulfill the required quota.

To guarantee effective communication between EMS and nursing staff regarding the refill request, an EMS contact schedule is located next to each telephone in the area. The schedule specifies what time the EMS should be contacted by calling the EMS Help Desk or by utilizing the pager.

The refill request process is initiated when a nurse takes an item from the linen cart and the linen level reaches the red indicator. This immediately triggers the refill process to start. The nurse flips the laminated poster in the linen closet from green to red, writes down the required information in the red side of the poster (nurse's name, item(s), time) and proceeds to contact the EMS. Depending on the time of the day, the nurse contacts the EMS Help Desk or pager accordingly. EMS proceeds to obtain the linen from the cart that requested the refill. The amount of linen taken is the equivalent of the green level. Before the linen is taken, the laminated sign is flipped from green to red. The EMS staff delivers the requested linen, go back to the Storage Room and restock the cart back to its full quota. The sign is flipped back to green after it is restocked. If there is not enough linen on the shelves or in the tubs to refill the cart, the EMS staff records the missing items on the red side of the laminated sign. Having the laminated poster with the information about when the refill was placed and by what nurse helps inform the other nurses of what the state of the refill request is. A process lead time is established and the EMS commits to delivering within that time frame. This system eliminates having multiple refill requests for the same item and also gives the nurses a peace of mind knowing that if the linen is running low and there is a request placed, the linen will be on its way. Ultimately, this creates trust in the nurses for the linen distribution and refill system. A graphical respresntation of the refill process and signal system can be found in Figure 15.

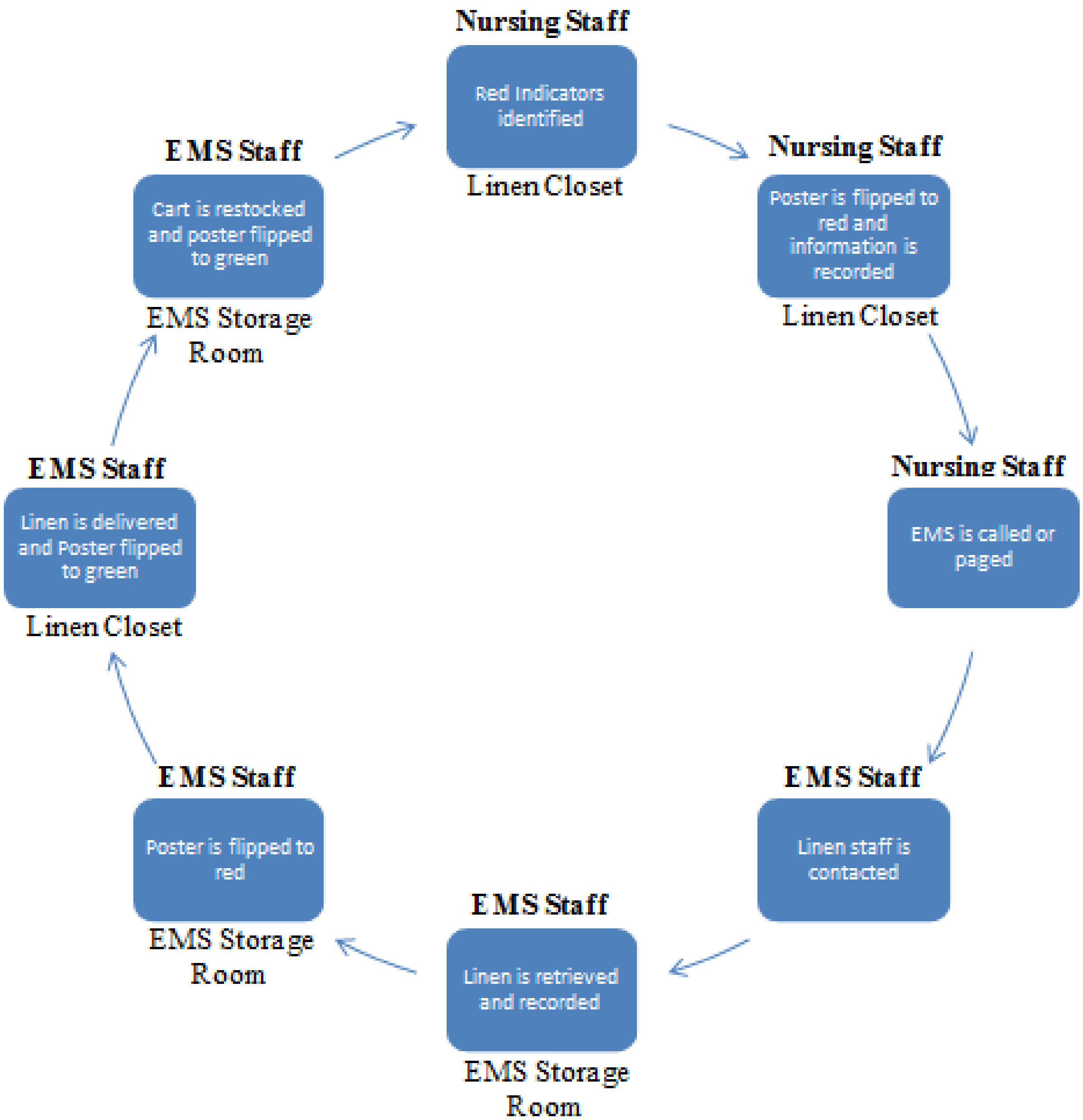


Figure 15: Refill Process Signal System Cycle

5.4 Standard Practices

The linen distribution system follows standardized work and standardized practices within each area that is involved with the process as well as with every supporting process in the system. By having standard work and standard practices in place, the system does not depend on any individual worker's experience to function, and new workers can easily be trained when needed. Standard practices have been created for the nursing staff, linen staff, EMS Help Desk, linen supervisors, and EMS Assistant Chief, as described in the following subsections.

5.4.1Nursing Staff

The standard linen usage is determined by the head nurse for every area based upon the specific needs of the area. The exact number of each different linen item required for a whole bed change is specified by the head nurse in order to assure consistency in the usage of the linen. Similar standards are set for the rest of situations where linen is required for each area in order to maintain consistency for the uses of all linen.

Nurses are reminded of nursing best practices for linen every month by the head nurse. In these meetings, the proper usage of the linen refill system as well as the correct refill request calling process is reviewed. The correct usage of the refill system includes only calling when the linen level of the item(s) is red and the side closets are empty and recording the necessary information for each refill request. The correct refilling process for the side closets are followed by only taking the established amount of linen from the main cart to the side closet. Other best practices are reviewed in the monthly meetings to eliminate issues such as extra storage of linen in the patient rooms. Nurses have a space to communicate any concerns or further opportunities for improvement with the linen distribution to the head nurse.

5.4.2 EMS Linen Staff

The EMS Staff conducts refills of linen following First In First Out (FIFO) practices and provides the required documentation. FIFO is implemented to ensure the timely rotation of linen through the system to minimize infection control of the linen. The required documentation includes:

- Recording the amount of linen each cart was provided with.
- Recording the linen that is taken out from the EMS Storage Room for refills in the linen log notebook, and
- Recording the required information in the linen closet room control tables.

Every morning, after the carts are delivered to the storage room and the staff is filling up the empty carts to be delivered the next day, they record if each cart received the full quota. If the full quota was not matched, they record the area, and items that are missing. The information for the linen log notebook includes:

- The area that requested linen
- The items of linen that were requested
- The time of recording, and
- The name of the linen staff.

The information that is required for the linen closet room control charts includes: copying the linen refill request information from the nurses (name, item, time) as well as their name, time of delivery, and report of nurse compliance. The compliance is just a Yes/No checkbox that indicates if the linen level for the requested item was actually in red. The purpose of this is to make sure the nurses are following the system and are only calling when they should. An example of this table can be found below at Table 5.

Table 5: Linen Closet Table

Linen Delivery Record Sheet				
Time of Call (Date, Hour, Minute)	Time of Delivery (Date, Hour, Minute)	Items Requested	Name of Linen Staff	Request Compliance (Yes/No)

5.4.3 EMS Help Desk

The Program Support Assistant, who is the person in charge of the EMS Help Desk, documents the refill requests and communicates the requests to the EMS linen staff following a standard procedure, The documentation for the refill requests includes the time the request was made from nursing, the area it came from, the linen item(s) requested, and the time the linen staff was contacted. The standard procedure utilized to contact the staff consists of the following:

- 0 – 5 minutes: Waiting for the linen staff to walk by the office to contact them.

- 5 – 10 minutes: Page the linen staff to inform them about the refill request.
- Greater than 10 minutes: Contact the EMS shift supervisor to inform him/her about the refill request.

The times displayed above represent the time elapsed from the moment the refill request was received. These measures standardize the way the linen staff is informed of the refill requests and provide data to understand the capability of the process and measure the effectiveness of the system.

In case there is a complete stock-out of any linen item(s), the Program Support Assistant informs the head nurses of affected areas.

5.4.4 EMS Supervisors

EMS supervisors are in charge of collecting all the documentation from EMS staff and analyzing it. They collect the following documentation:

- Linen refill request tickets from the Program Support Assistant with the refill order documentation.
- Linen refill log notebook.
- The closet room refill control table information.
- Quota completion for morning delivery information.
- Daily linen delivery inventory from Brockton

Based on the information collected, the supervisors monitor the process and the performance of the linen staff and refill process. The Supervisors are in charge of analyzing the metrics mentioned in the Methodology section 3.1.1, to provide them with the tools to evaluate the performance of the system. The information collected is utilized for the monthly meetings with the EMS Assistant Chief.

5.4.5 EMS Assistant Chief

The EMS Assistant Chief is in charge of conducting monthly meetings with the EMS supervisors as well as quarterly meetings with the head nurses of the hospital. For the monthly meetings with the supervisors, these are some topics that should be evaluated and discussed:

- Lead time for the refill process by shift.
    - Time it takes for the Program Support Assistant to inform the EMS linen staff from the time the request was made.
    - Time it takes for the EMS linen staff to deliver the request.
- Control and Run charts for frequency of item request by area.
- Nurse compliance with the refill system.
- Revise and adjust the linen order placed to Brockton according to the demand.

For the quarterly meetings with the head nurses, all the information discussed in the monthly meetings with the supervisors is presented. The EMS Assistant Chief presents the major issues and the greatest accomplishments of the EMS linen performance. The head nurses provide any feedback for the system as well as the quota they are being delivered. Revisions and adjustments of the quotas are considered in the discussion.

6.0 Pilot Area Testing and Trial Implementation

After acquiring a clear understanding of the Current State and constructing a more efficient and robust Future State, we focused on testing and implementing proposed solutions from the Future State. As explained in the Section 4 (Current State), the trial implementation was focused only in PCU and 3 North at the VA Boston Healthcare System West Roxbury Campus. CT Scan, the small area that the team studied showed that it did not have any linen supply issues. The variability of the demand was very low and the usage of linen is low as well, compared to the wards and units. For these reasons, the team did not dedicate further time to CT Scan. Due to time and capacity constraints, we unfortunately could not test all proposed solutions. In order to create a significant impact on the system, we implemented the most influential solutions with the fewest obstacles. All the solutions were ranked by their impact and ease of implementation. The matrix and the explanation for each solution ranked are provided in Figure 16.

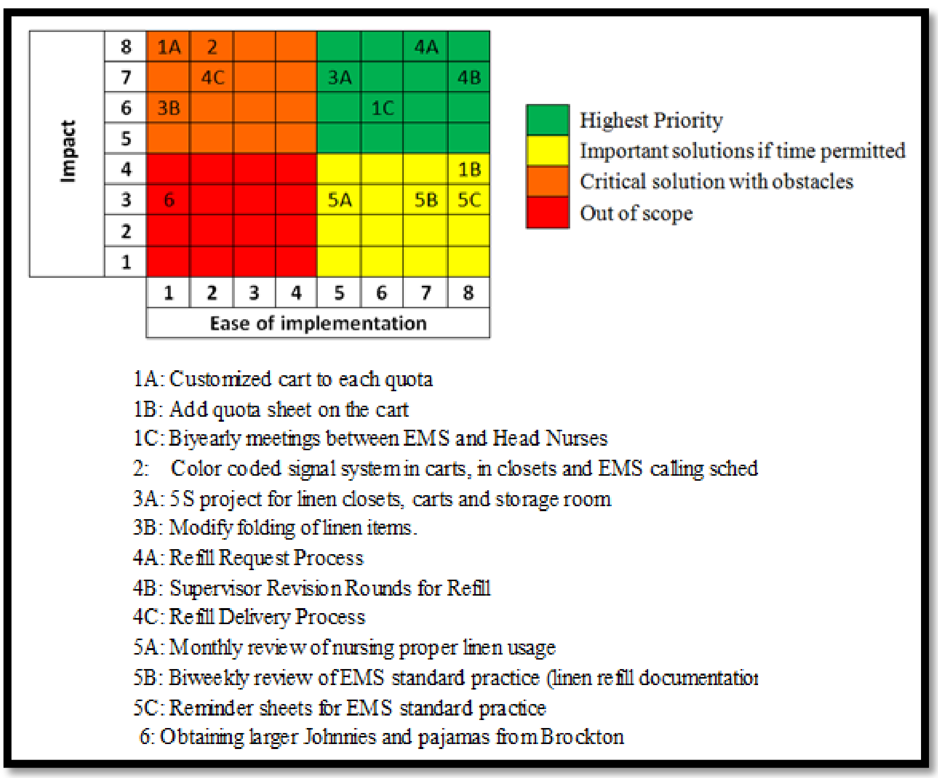


Figure 16: Impact Analysis Matrix

The numbers and letters symbolize the different solutions considered. There were six general solutions specifically targeting the existing system. Taking into consideration the ranking matrix above and the time span of the project, we tested and implemented the following measures to address the most urgent existing opportunities for improvement:

- Par levels and cart quota were updated utilizing the knowledge of the frontline nursing staff. The updated par levels and quota reflected the actual usage of each unit or ward more accurately.
- The revised refill request process was tested, by creating and implementing the three tools of the signal system; the laminated posters, the linen level indicators, and the EMS contact schedule. The system was streamlined and documented at multiple points for data collection purposes.
- The layout of the linen cart was modified by creating a separate, labeled and color coded compartment for each linen item. The method of stocking items into the carts was also changed.
- 5S projects were conducted for both the linen carts and linen closets to ensure that they are well organized.

6.1 Goals for the Trial Implementation

The team designed the Trial Implementation with the following three goals in mind.

1. Find any design errors and determine the feasibility of the designed system.
2. Obtain feedback from the stakeholders of the process.
3. Understand the challenges to implementing the system in order to develop recommendations for the actual implementation of the system.

The trial implementation is judged against these goals in the final subsection to evaluate its success.

6.2 Updated Par Level and Cart Quota

As discussed in section 5.1 of the Future State, we decided to collect further detailed information about the daily usage for 3 North and PCU. Such information is the collective knowledge of the entire nursing staff in both areas. We interviewed and discussed with the nurses possible scenarios for linen usage in their assigned areas. With that information, we recorded the daily usage of each linen item per bed. This information is found in the Table 6.

Table 6: Linen Item per Bed

Linen Type	3 North Daily Usage per Bed	PCU Daily Usage per Bed
Blankets	1	1
Flat Sheets	2	1
Pillow cases	4	1
Towels	2	4
Facial Towels	1	1
Pajamas	1	1
Snap Johnnies	1	1
Pink Pads	1	2
Fitted Sheet	1	1

Using the formula described in methodology, we calculated the Par Level for both areas. The results are shown in Table 7.

The par level for 3 North is much higher than that of PCU. This is because 3 North has 24 patient beds while PCU only has nine. 3 North has two bed changes per day on average whereas PCU only has 1.5 bed changes on a daily basis. These differences were generated from the different patient turnover rates of the two areas. In addition, the previous table does not specify the exact pajama types/sizes to use. We considered the total demand and divided the par level between four types/sizes of pajamas evenly to accommodate possible variation of demand for pajama sizes. The EMS and nursing staff agreed on meeting biannually to review the par level and cart quota together.

Table 7: New Par Levels

Linen Type	3 North Final Par Level	PCU Final Par Level
Blankets	64	18
Flat Sheets	128	18
Pillow cases	255	18
Towels	128	72
Facial Towels	64	18
Brown Pajamas	16	4
Yellow Pajamas	16	4
Blue Pajamas	16	4
Red Pajamas	16	4
Snap Johnnies	64	18
Pink Pads	64	36
Fitted Sheet	64	18

With the par level updated, we attempted to optimize the cart quota for each area based on this data. The maximum capacity of a linen cart was the major constraint to be taken into consideration. The space constraint was not as serious for the PCU linen cart; on the other hand, it was considerable for 3 North due to its greater demand for linen. Ideally, a larger linen cart may be more appropriate for wards as we mentioned previously. It would also be beneficial to have extra division panels for the linen carts so that they could be easily modified. During the implementation phase of our project we attempted to purchase the division panels from the original manufacturer of the linen carts. We were not able to do this due to the time required for purchasing within the VA as well as the supplier's delivery time frame. As a consequence, we utilized alternative materials to accomplish similar solution. The quotas for 3 North and PCU were adjusted to fit the size of the linen cart. The cart quota results are presented in Table 8. After implementing the calculated quota and carts, the team discovered three additional issues that were not addressed in the new quota implementation. These issues are discussed below and the solutions or actions taken to address them are described.

Table 8: New Cart Quotas

Linen Type	3 North Cart Quota	PCU Cart Quota
Blankets	18	12
Flat Sheets	30	24
Pillow cases	60	24
Towels	40	24
Facial Towels	30	12
Brown Pajamas	6	4
Yellow Pajamas	6	4
Blue Pajamas	6	4
Red Pajamas	6	4
Snap Johnnies	20	12
Pink Pads	18	24
Fitted Sheet	27	12

The first issue involved the lifting pads used for transportation of certain patients, which are provided by Brockton Laundry Facility on a daily basis along with other linen items. The usage of the lifting pads is very limited. The lifting pads were not included in the calculated quota, and no space was created for them in the carts. Furthermore, the lifting pads present a separate issue since they are not allowed to stay in the EMS Storage Room so the linen staff distributes them throughout the hospital in the linen carts. In the two areas we studied, these green lifting pads were barely used and occupied precious space for linen. Therefore, further communication with Brockton facility is necessary and a revision of their usage and distribution should be examined.

The second issue involved female pajamas. Although there is a limited demand for this item, the demand still exists. The team was not able to gather enough information to propose a solution to this issue.

The third and final issue found involved the johnnies' size and type. The team decided to utilize snap johnnies for the demand in PCU and 3 North as it is one of the most utilized items according to the nursing staff. The snap johnnies are strongly preferred over tie johnnies in our two areas of study because they facilitate the nursing job when treating patients. The snap and tie johnnies are delivered separately from Brockton making it easy for the linen staff to deliver either of them. The team requested that only snap johnnies be delivered in the areas for the implementation phase.

6.2 Refill Process—Lead Time

In the newly designed system, the goal is have the EMS linen staff be able to consistently deliver the requested linen within a certain timeframe. In order to understand what that time frame might be, we identified all the steps that are involved in the refill process. These steps are as follows:

- As soon as the linen levels hit red either a call is placed to the EMS Help Desk (from 8:00 am to 4:30 pm during weekdays) or the pager is reached (afternoons, nights, and weekends)
- The linen staff is contacted from the EMS Help Desk or the pager
- Linen is retrieved from the linen storage room, and finally
- Linen is delivered at the area that requested it

It is important to understand what the lead time of the refill process is in order to establish the safety stock level marked by the red level indicators and to inform the nursing staff so that they know when to expect the delivery.

The refill system depends on information transfer in order to notify the staff to transfer the material from the Linen Storage Room to the requested area. The team established three control points to measure the performance of the system. These points were located at the EMS Help Desk, the EMS Storage Room, and the linen closet at each area. The information collected at each of these three locations would demonstrate the time required for the EMS Help Desk/Pager to contact the linen staff after the request was made and for the linen staff to deliver the linen after they were contacted by the EMS Help Desk/Pager. The information that would be obtained from each of the control points is the following:

- EMS Help Desk:
    - Time linen request received
    - Item requested
    - Area requested
    - Time linen staff was contacted
    - Name of linen staff
- EMS Storage Room:
    - Time of request

    - Item requested
    - Unit/ward requested
    - Linen staff responded
- Linen Closet:
    - Time of call
    - Time of delivery
    - Item Requested
    - Name of linen staff

The Program Support Assistant and the linen staff were briefed about the project goals and objectives and were requested to record the information outlined above during the 18th week of the project. The plan was to collect the data for a period of a week in order to get a general understanding of the process lead time before implementing the whole refill process. The collected information would provide the team with an estimate of the baseline lead time for refill, which would be communicated to the nurses. Then, when the refill process was fully implemented in week 19, data would be collected for an additional week to gain a more accurate measure of the system lead time.

Unfortunately, the requested data was not collected by the EMS Help Desk or the EMS staff. For this reason, the team was not able to estimate a baseline for the process lead time, and recommends that this is an important early step as implementation proceeds.

6.3 Refill Process—Cart Signal

The greatest issue in the Current State regarding the linen refill process is the absence of standards for when to order linen. The system utilized is completely subjective and up to the personal interpretation of each nurse, resulting in great variation of when the refill is requested. The team created a system with clear standards emphasized by color coded signals to standardize when the refill process should be initiated.

For the implementation of the color coded signal system in the cart, due to monetary constraints for the project, the team was only able to modify one cart out of the two carts for each pilot area. In order to accommodate the signal system implementation in one cart per area, the linen staff was requested to conduct an extra step. The step is filling the unchanged cart in the

EMS Storage Room, bringing it to the area and transferring the linen to the modified cart. The carts were divided in separate, labeled and color coded compartments as shown in Figure 17.

Figure 17: Linen Level Indicators

The safety stock was calculated using the method discussed in the Methodology section. The results of such calculation were compiled in the Table 9.

While implementing the signal system, a new concern regarding the lack of communication between the three different EMS shifts was brought to the team's attention. Inconsistencies in practices between the shifts constrained the system and limited the successful test of the new system.

Table 9: Safety Stock

Linen Type	Red Level for 3 North	Red Level for PCU
Blankets	2	1
Flat Sheets	4	1
Pillow cases	8	2
Towels	4	4
Facial Towels	2	1
Brown Pajamas	1	2
Yellow Pajamas	1	
Blue Pajamas	1	
Red Pajamas	1	
Johnnies (snap)	2	1
Pink Pads	2	2
Fitted Sheet	2	1

The linen closets at PCU and 3 North have side shelves for extra storage room for linen items. These side shelves were removed from the linen rooms in order to guarantee that the new signal system, quota, and refill process would be utilized. During the visit on the 20th week, the team found that 3 North had brought in one of the extra shelves that had been removed from the room and was storing the linen on the shelf and flat surfaces in the closet. The process was not well understood overall, and the signal system and cart quota were not utilized. PCU did not use the side cart for the weekly trial period, having the linen cart as the only source of linen as specified in the future state. However, there were complaints about the system and they requested their Housekeeping staff to borrow linen from other areas or pick it up from the storage room. It was clear that the team needed additional time to work with the nursing staff training them in what the system was and how it worked.

6.4 Refill Process—Laminated Posters

The refill process relies both on the color coded levels in the linen carts as well as the laminated posters in the linen closets. The laminated sign was originally placed inside the linen closet immediately next to the linen cart. When the team presented the implemented signs to the head nurses, PCU's head nurse suggested that the laminated posters be relocated on the outside of the door of the linen closet where they would be more visible. This suggestion was incorporated in 3 North as well due to its greater effectiveness and visibility. Figure 18 shows the laminated posters in the pilot areas. During the trial implementation, they were not used, likely because of the overall lack of understanding and use of the carts and new process.

Figure 18: Laminated posters on pilot areas

6.5 Refill Process – Calling Schedule

The EMS contact schedule was created and placed by every phone in the two pilot areas for nursing staff. As mentioned in the Future State, the schedule will streamline contacting process by the nurses to the EMS. The schedule was originally printed on plain white paper. When the team implemented them, the schedule got lost in between all the other signs that were pasted around the phones. In order to increase the visibility of the schedule, the schedules were printed on blue paper instead. Figure 19 shows the difference between the white and blue papers utilized. After visiting the hospital on the 20^{th} week of the project, one out of the six schedules that were implemented had been removed from their place and none were properly utilized.

Figure 19: EMS Contact Schedule

6.6 Linen Cart Design & 5S

As mentioned in the Future State, the linen carts need to be redesigned to utilize all the space available and facilitate the extraction of the linen. Division panels were used to create individual compartments for each linen item. These division panels were improvised for a two-week period for an implementation trial with office supplies that served the required function. The required division panels and their locations were the following and this division can be seen in Figure 20, arrows point towards the major changes in the organization of the cart, as well as an image of the current linen cart layout:

- Vertical panels between different colors of pajamas, top right compartment.
- Vertical panels between pink pads, flat sheets and towels, bottom compartment.
- Horizontal panels between facial towels and pillow cases, middle top compartment.

Figure 20: Current and Modified Cart Design

Besides the separation of linen items, we also took the user-friendliness of the linen placement into consideration in Future State. The linen items will be placed into the cart with the folded side facing outwards and the seams facing inwards. The linen staff was consulted about the feasibility of this practice in their daily operation, and they stated that it was only a minor change that could be easily implemented. Figure 21 shows an example of this practice with blankets.

Figure 21: User-friendly Linen Placing

The folding of fitted sheets was also examined due to its irregular shape. As noted in section 5.2.2 of the Future State, the fitted sheets were rolled into a spherical shape and tucked at the end so that they would remain rolled up. By folding the fitted sheets this way, the capacity of the fitted sheet compartment of the cart was increased by 58 %, from 17 fitted sheets to 27. This folding method was presented to the EMS Assistant Chief and gained his approval. The team proceeded to teach the linen staff the folding technique and the Assistant Chief requested that this folding practice become a standard practice in West Roxbury during the 17th week of the project. The team revisited this subject during the 18th week of the project and encountered issues since the fitted sheets were becoming unfolded during transportation. The issue was due to the linen staff failing to tuck the sheets in after rolling them up. This was emphasized to the staff during the 18th and 19th week visits, however, the fitted sheets were found unfolded during the visit on the 20th week. Figure 22 shows the folded fitted sheets utilizing this new folding practice.

Figure 22: Fitted Sheets Folding

6.7 Assumptions for Trial Implementation

In moving forward with the implementation of the selected solutions in the two pilot areas, the team made a series of assumptions about the system. The assumptions were an important part of the implementation phase because they provided direction and reduced attention to the variability in the system that the team was unable to control or unaware of. These assumptions were made based on the knowledge we had of the system at the time of implementation. Some of these assumptions turned out to be true, and others did not. The assumptions that the team made are listed below.

Correct assumptions:

- The delivery of linen from Brockton would not be any more sporadic than the usual.
- Both EMS and nursing staff would be willing to actively adopt the new system. There would be no major staff changes for the key players in the system.

Incorrect assumptions:

- Because head nurses had bought into the system, they would be successful in championing it to the nursing staff. However, due dedication to patient care and lack of time, the head nurses were not able to successfully communicate the new system to their staff.
- The average number of patients and the demand for linen would not fluctuate dramatically.
- Nurses would properly communicate with the EMS following the schedule provided.
- The weekend and weekday shifts for nursing would have the same attitude and understanding of the system.
- The morning, afternoon, and night EMS staff shifts understood the system, and would work as a team and cooperate to achieve the established goals.

The team's lack of experience with implementing such projects, the limited control the team had over the system, as well as the limited presence the team had at the hospital were the main reasons for the team to have incorrect assumptions.

6.8 Final Outcomes of Testing and Trial Implementation

After implementing the system, and testing it for a week, it was clear that the environment was not ready for such a change. The main obstacle encountered in the trial implementation was the inability of the team to devote the required time for training of the EMS and nursing staff in the newly implemented system. As a consequence of this lack of training, a number of obstacles were encountered in the trail.

In one nursing unit, the head nurse was only able to communicate the system to the nursing staff via email and had no opportunity to explain it in person or dedicate more time to it. As a consequence, the nursing staff did not understand the system and so did not use it. The other unit invested effort into the system on the first day; however, when linen reached red levels at night, nursing failed to follow the schedule calling the EMS Help Desk for a refill As the schedule shows, no one is available to answer the phone at night and that is why the pager is used. Since the nursing staff got no response, they returned to the old habits of borrowing linen from other areas or sending their housekeeper to obtain linen. This unit also experienced unprecedented demand during the trial implementation week. The morning shift of the EMS linen staff did make an effort to utilize the system. However, they encountered problems when the afternoon and night shifts did not follow the new practices of the system. This resulted in extra work for the morning shift that would try to remediate the previous night's alterations of the newly implemented system. The issues with the afternoon and night shifts were a consequence of a lack of the team's presence and effective communication with these shifts. The team learned valuable lessons that can be utilized in the future implementation of the system, to guarantee its success. The main learning outcomes from this trial implementation include:

- Ensuring a stable input of linen from Brockton before changing the internal processes of West Roxbury Campus will significantly reduce system uncertainty and create the conditions for an effective internal linen distribution process
- Before implementing the system, it is vital to train the involved personnel and get their buy in to the system.
    - Details of the system have to be thoroughly explained to everyone involved in the system, with additional explanation and help as questions arise.
    - There should be a practice run through of the system with involved parties to assure everyone understands the changes required.

    - Feedback from the users of the system should be considered and incorporated into ongoing implementation.
    - Acquiescence of the staff should be looked out for.

- A process champion and a process owner are imperative for pushing the system forward to successful implementation. The project team's role should be clearly defined, and changes as the project proceeds. Particularly as implementation nears, the role shifts to that of facilitators. The team acted on certain occasions as process owners and process champions. This negatively affected the adoption of the new system during the trial phase from the real process owners, and made it harder to find a process champion within the system.

The team's trial implementation successfully accomplished the three goals identified. Design errors were pinpointed, such as the location of the laminated poster in the linen closet. The location was initially inside the closet by the cart where it was not the most visible. The location of the laminated poster was changed to the outside of the door of the linen closet based on the feedback from the nurses. The feedback from EMS staff and nurses confirmed that the designed system is feasible for implementation, with additional training and explanation of the system. Many challenges for implementation of the system were understood and are incorporated in the next section as recommendations.

7.0 Conclusions

The goal of the project was to optimize the linen distribution system in the VA Boston Healthcare System – West Roxbury Campus by eliminating waste and improving the efficiency of the process, standardizing and simplifying the process while meeting quality goals. In order to accomplish the goal, the team used a lean approach throughout the project. To understand the current state of the system, the team conducted interviews and observed the system. Through these interviews and observations, the team was able to create a Current State Value Stream Map identifying opportunities for improvement. Features in the Future State such as the Signal System and Standard Practices will solve the main undesirable effects: miscommunication among the EMS and nursing staff, and the lack of standardization in the procedures regarding linen and its distribution. Finally, the team carried out a trial implementation in pilot areas, of to test the most influential parts of the proposed Future State solutions and identify obstacles for implementation.

After completing implementation, the proposed Future State solution can be measured and evaluated using three metrics, as described in Section 3 - Methodology. The stability of the system can be tracked by the linen order/delivery ratio to guarantee that the linen being delivered accurately reflects what is being ordered. The linen usage per area can illustrate the real usage of the system and can be used to more accurately understand the linen demand in the hospital. The linen refill lead time can be used to demonstrate the responsiveness of the refill process to help understand the efficiency of the refills. The proposed solution and recommendations have been created to improve the system's performance in terms of stability, real usage and responsiveness which can be measured with the defined metrics.

The designed Future State successfully addressed the undesirable effects identified in the Current State, ultimately helping both EMS and nursing staffs interacting with the linen distribution system. The EMS benefits from the system by having a more responsive, reliable and standardized system. With the organization of all the linen-related locations, EMS will count with a greater inventory of linen in the EMS Storage Room improving the effectiveness of their linen service. This system will also give them a better understanding of the demand for linen in each area of the hospital. The nursing staff wills also benefit from a more reliable, responsive, and user friendly linen distributions system. The standard practices of the stakeholders, along with the refill request system, will ensure the reliability of the linen distribution. The color coded Signal System, the reorganization of the carts, and the modification for the folding of the items will provide for greater responsiveness and user friendliness of the system to the nurses. Finally, the entire Future State facilitates better communication throughout the linen distribution system and lays the foundation for the stakeholders to start trusting the system again.

7.1 Team Reflection

During the time span of the project, the team invested significant time and effort to see the project successfully completed. The 21 weeks of the project were filled with site visits to the hospital, interactions with the linen and nursing staff, meetings with our project liaison and advisors, and extended discussions amongst the team members. Throughout the process, we always encountered strong support from the VA Staff at West Roxbury, as well as counseling and guidance from our project liaison and advisor. The project provided us with the opportunity to apply the knowledge we have gained throughout our four years at WPI to a real world problem. Reflecting on these 21 weeks of project work, there were many valuable lessons learned from this experience. This section contains an explanation of these lessons.

One of the most important takeaways from this experience was learning that a systematic approach is vital to obtaining successful outcomes throughout the project. Having a systematic approach provides a team with a clear goal and lays out the necessary steps to accomplish it. Real life is very unpredictable, and this holds true in the functioning of a health care provider. A systematic approach provides the team with an overarching direction to follow to guide the project through the unpredictable and uncontrollable situations encountered.

The project provided the team with the opportunity to apply a variety of the Lean and Six Sigma tools learned in our Industrial Engineering classes. Being able to implement them in a real world setting and observing their impact in the process was a rewarding experience. The team encountered several obstacles during the application of these tools and working to resolve these obstacles was a challenging task. This experience provided the team with new insight for understanding what the tools were and how they could be applied.

The project trial implementation phase provided the team with an understanding of what is required to have a successful implementation. It is important to understand the role that a process improvement team should take for a project of this nature. The team has to act as a facilitator throughout the whole process, which involves empowering the process owners to get invested in the project and make sure their concerns are considered, and their ideas are implemented. The team should also work to find and support a process champion, and obtain the support from top management for the project.

The group development cycle (Tuckman, 1965), which explains the stages every team encounters in the process of formation, was experienced both within the project team as well as within the hospital's staff. The project team experienced the four stages of group development: forming, storming, norming, and performing. Having to work through each of the group development stages was a great growth experience for the team. Being able to reach the performing stage was extremely gratifying and helped the team become extremely productive. On the other hand, we were able to observe how our project created the need for to form a group consisting nursing and EMS staff. Unfortunately, due to the time span of the project, which limited the time and scope of implementation, the team, was not able to see this group develop past the forming stage.

Another important lesson is to understand the people and culture in which the process improvement project will be implemented. At the VA, there is a hierarchical culture that maintains some military structures and procedures. Learning what these structures are and being able to follow the procedures facilitates interaction with the people and the implementation of the project. Being able to understand who the workers are, and how they fall into the hierarchies in place can also help a project precede smoothly. It is vital to gain the trust and cooperation across the entire system in order for any progress to be made. The team experienced what it was to interact with people from different backgrounds and responsibilities within the organization, and what it took to gain their trust and cooperation.

7.2 Design Reflection

In order to improve the linen distribution system, the team created a Future State Design that would make the material and information flow of the system more efficient and effective. The team created the new linen distribution system following the Engineering Design principles. Engineering Design considers the following four parameters in the design process: requirements of the design, constraints for the design, alternative solutions for the design, and an evaluation of the alternatives. This section contains a reflection on how the team approached each of the four steps in the Engineering Design process.

The team determined five requirements for the design of the linen distribution system which are listed below:

- Robustness
- Effectiveness
- Standardization
- User friendliness
- Feasibility

The created system fulfills all these requirements. The standardization of tasks performed by each stakeholder of the process explained in section 5.4 Standard Practices. The 5S projects explained in Section 5.2, Environment Organization, ensure the effectiveness and robustness of the system. User friendliness was accomplished by the modified folding and placement of the linen items as well as the responsive color coded signal system created. Finally, the feasibility of the design was tested and confirmed in the trial implementation of the project.

There were five constraints considered in the development of the linen distribution system design, which is listed below:

- Scope
- Infection Control
- Cost
- Time
- Social

The design of the system was completed within the context of the constraints. The scope of the project was bounded within West Roxbury Campus and the design of the system was considered accordingly. The design addresses Infection Control by modifying the folding of the fitted sheets as well as incorporating FIFO practices for the refill process. Cost was considered for the design and we incorporated a retrofitting of the current carts instead of suggesting purchasing new ones. Similarly, the signal system was developed utilizing low cost and readily available materials. Time was always present in the development of the new system because the team was aware of the importance for the timely delivery of linen to the nurses. This was incorporated in the design of the refill system, where by streamlining the communication of the refill requests; the system strives to make the deliveries as fast and efficiently as possible. The social constraints of the system were addressed by taking into account the role of each stakeholder and designing the system not to overstep current organizational structure boundaries.

The following paragraphs describe alternative solutions considered for the various aspects of the system and how the team evaluated these to select the optimal alternative that was incorporated in the Future State.

For the reorganization of the linen carts, the team determined that retrofitting the existing carts by purchasing the division panels from the cart manufacturer was the best option. In order to come to this decision, the team also considered purchasing new carts with greater flexibility and larger size. Cost was the major decision factor. The team evaluated the cost-effectiveness of the two options and determined it was not worth investing in the new carts.

When considering the organization of linen in the carts, the team decided that changing the orientation of the linen as well as modifying the folding of the fitted sheets was an optimal solution. The factors that were taken into consideration for this decision included: the additional operational time required from the EMS linen staff, the user friendliness of the system, infection control of the linen, and the ergonomics of the linen retrieval. The team found that the EMS linen staff's additional operational time added greater value to the system by addressing the three other considerations mentioned above.

The team considered different options to guarantee the proper rotation of the linen in the refill process. Physical solutions as well as alternative practices by the EMS linen staff were considered. The physical solution involved removable compartments that could be rotated after the refill. The alternative practice by the EMS linen staff consists of putting the remaining linen items on top of the refill pile before placing the whole pile in the assigned compartment. The alternative practice was chosen over the physical solution for its greater reliability and because it could utilize the current carts in place, without having to inquire additional purchasing costs.

The color coding of the signal system was created to be objective, intuitive, and responsive. The system was incorporated in the laminated posters, in the linen closets, in the EMS Storage Room, as well as in the linen level indicators. The initial consideration for the color coding system was based upon a traffic light signal. The team considered utilizing the three colors (green, yellow, and red). The team eliminated the yellow color because it allowed for the subjectivity that we were trying to eliminate in the first place.

Once the color coding system was in place, the team evaluated the different tools to communicate and record the initiation of the refill process. The team assessed the following alternatives for the communication tool: a white board, a laminated poster, an item checklist, and a magnetic or Velcro symbol representation of the linen items. The parameters that were considered were effectiveness, ease, and robustness of the communication system. The laminated poster was the alternative that complied with the selected parameters the best and was also the cheapest to implement.

8.0 Recommendations

This section presents final recommendations for this project, after reflecting on the Future State Design and analyzing the results and feedback from the trial implementation in the pilot areas. Four specific recommendations were identified by the team to successfully modify the linen distribution system at the VA Boston Healthcare System - West Roxbury Campus in order to make it more effective, efficient, and reliable.

In order to establish a smoothly functioning linen distribution system within the VA West Roxbury Hospital, decreasing variability and uncertainty in the input to create more stability is imperative. The linen distribution system at the VA Boston Healthcare System - West Roxbury Campus depends on Brockton, the laundry service facility, to deliver the linen to West Roxbury. There is no control and only broad knowledge of the input to the system, which is the amount of linen being delivered from Brockton every day. If the input to a system is not stable, modifications made within the system make the system more efficient but not effective. It is for these reasons the team concluded that the next step that should be taken is stabilizing and understanding the input to the system. The team recommends that the VA Boston Healthcare System - West Roxbury Campus works with Brockton to ensure that the daily linen order is accurately delivered.

A second step to be taken is to work to implement engaged work teams with the involved departments so that they are more receptive and proactive about the improvements in the system and working together. The experience the team had during the implementation phase, working with both EMS and nursing staff, demonstrated that there are miscommunications between each department and also within the departments between each shift. It is vital to foster a cooperative and trusting working environment to successfully implement changes in a system.

After the process has been stabilized and engaged work teams have formed, the team recommends implementing the described Future State of the system. Identifying the process owner and the champion must be the first step taken towards implementation. The team recommends the Future State be implemented in phases, first focusing exclusively within the EMS. Before the new system is implemented, the refill process lead time has to be measured and established through data collection by the EMS staff. Once the refill lead time has been established, the EMS can begin to fully implement the Future State, involving the nursing staff only to seek their input on each area's linen par level. After the par level has been determined, the linen quota for each area should be calculated and the modifications to the linen carts can be made, including the separate compartments as well as the linen level indicators. This process allows glitches in the system to be identified and addressed, and acquaints the EMS staff with the system. This phase includes performing 5S in the EMS Storage Room, incorporating the laminated posters in the Storage Room, and training the staff in the system.

After the process has been successfully implemented within EMS, the next step should be to incorporate the nursing staff into the implementation. The team recommends initially implementing the system in the areas of the hospital where the nursing staff is interested and willing to test the new system. After completing the implementation in the early adopter areas, the implementation should be spread to the rest of the hospital. Differences in each area should be taken into consideration for the implementation. Factors in the system that vary depending on the size and functioning of the area are the amount of linen and the type of linen items required, as well as the existence of side closets. For the implementation with the nursing staff, thorough training should be provided to all those who use the system.

Full implementation of the linen distribution Future State then has the potential to significantly improve the system, creating the following benefits:

- The robustness and flexibility of the system will be increased, better accommodating variability in the demand for linen.
- The nursing staff will have a reliable supply of linen to perform their duties.
- The EMS staff's time will be better utilized and their tasks will be simplified.
- Trust and transparency will be established within the different departments of the hospital.
- The system will better account for safety and infection control of the linen.
- Linen waste will be reduced by eliminating poor practices using linen.

- Cost reduction throughout the whole system will be attained.
- An understanding of the demand and costs for linen in the system will be achieved.

Through these implementation activities, the team hopes that West Roxbury becomes the flagship for an effective and efficient linen distribution system, which leads other hospitals within the VA to follow in its steps.

Part 2: Laundry Facility

9.0 Literature Review

The second part of the project looked into the current process and equipment in the Laundry Facility, to propose better solutions and then evaluate them to recommend the most favorable option. To start, information needed to be collected with respect to several aspects of the project. First, extended research was conducted in steam heating. Then the student collected information regarding laundry services within the healthcare industry. After that, VA policies regarding laundry services for soiled linen from hospitals were examined. Then, the research targeted Cost Benefit Analysis methods, as a means of thoroughly comparing the alternatives and weighing their benefits and disadvantages. Finally, a case study was explored as an example for a successful steam-less laundry facility retrofit project where energy consumption was reduced and the capacity of the facility was increased.

9.1 Steam Heating

The history of steam heating dated back to the years of the Industrial Revolution. In 1830s, the central heating system was first installed using steam to artificially warm up residential communities. The steam generated from the steam engine found its new function powering machines in factories (Spratt, 2013). After years of development, steam heating technology has largely improved. Currently, steam boilers are used to produce steam solely for heating purpose. Boilers used to be constructed on site by the manufacturer of the boiler at the customer’s location. However, packaged boiler solutions have become the standard practice in recent decades. Boilers are delivered to a customer finished (Spratt, 2013). They only require limited steps to be installed at customer’s facility.

Two major technologies are mainstays of steam boilers: water tube and fire tube. As its name suggests, fire tube boilers heat the water to steam by submerging the pipe containing combustion heat under a pool of water. On the other hand, water tube boilers place tubes of water within the combustion chamber (Spratt, 2013). Both of technologies are widely used and efficient. Boilers also contain baffles to decrease the combustion rate and tabulators to increase contact time, harnessing more heat for heat exchange of water.

Before the water is heated, it is stored in a pond. The water is heated to over its boiling point, and then the steam is transported in insulated pipes to all the locations requiring heating and finally comes back as water after the condensation process. Two kinds of distribution systems are available: branch or loop. Branch systems directly send steam to individual locations and then back to the plant. A loop system forms a large loop going through all the necessary locations and then comes back to the plant (Grudzinski, 2013). The selection of distribution system generally depends on the geographical location of the heating locations as well as the engineering approach. Currently, most steam heating systems are high pressure, presenting certain risk for pipes. Low pressure steam system is available. Nevertheless, its need for extra satellite boilers at different locations reduces its popularity among engineers.

The steam heating system is not perfect. In fact, the efficiency of such systems hardly reaches 90%. There is also 15% to 20% steam loss on average due to pipe leaks and direct use of steam (Grudzinski, 2013). To monitor the system, multiple chemicals are added to the steam and analyzed constantly by the operator of the boiler. NaOH is used to test the PH value of incoming water; polymers are added to protect the boilers and keep the solids from water in suspension; and sulfite is used to take out residual oxygen. All the testing values are electronically monitored in the plants built recent years (Spratt, 2013).

Potential problems are pipe leaks, insulation of the pipes and the effectiveness of steam trap. Pipes transporting steam need to be strong and tough as well as creep-resistant. With a constant high temperature, materials used for steam pipes tend to age faster. Therefore, piping systems require frequent tests to eliminate any possible leakage. Even if the pipe is well sealed, the heat exchange between steam and outside substances could lead to tremendous heat loss. Thus, the insulation of steam pipes is directly related to the effectiveness of the system (Baldwin, 1890). The steam trap serves as the separator between water and condensate water reaches a certain level, it is discharged. This helps maintain the steam temperature since the condensate water within steam could sharply decrease the temperature in a short period of time (Grudzinski, 2013).

9.2 Laundry Services for the Healthcare Industry

Hospitals, due to the number of patients they care for on a daily basis, produce a large volume of dirty linen, which needs to be cleaned in a short period of time. Hospitals change the bed linen and staff clothing at least once a day, depending on the patients requirements as well as doctors' and nurses' tasks. This need for an efficient laundry system created the market for a new industry that focuses on laundry service specialized for hospitals, which is called hospital linen cleaning services.

The costs and usage of inventory and hospitals' utilities are being monitored more strictly at hospitals all around United States. The objective is to reduce operating costs to become more efficient and utilize their resources to offer better healthcare services to the patients (Julian, 2011). Outsourcing of the laundry service is a popular trend seen in the healthcare industry. Linda Burgman, General Manager at CleanCare, a hospital linen cleaning company, states that "a hospital or nursing home's capital expenses are zero when it chooses to use outside linen supply company. They do not make initial investments in linens, nor do they have operational expenses like utilities and employees. They can redirect these savings and focus their management on patient care". It is for this main reason that hospitals have chosen to outsource their linen cleaning to companies in nearby locations. This action taken by hospitals has created the need in the field for a linen cleaning industry: the hospital linen cleaning service. Nevertheless, VISN 1 does not outsource the linen cleaning services because of adequate capacity from existing laundry facilities owned and operated by VA.

Hospital linen cleaning services is a fast paced, growing industry across the nation. These companies focus entirely on fulfilling their customers' needs when it comes to linen cleaning. The basic tasks performed by these companies are: sorting, washing, extracting, drying, ironing, folding, mending and delivering a hospital's linen while complying with the cleaning standards set by the government's health department. Specifically, sluicing is the practice of cleaning attached objects from linen items using running water while calendaring is the activity of drying the linen while hanging. Figure 23 illustrates the basic laundry and cleaning procedure for the linen cleaning companies.

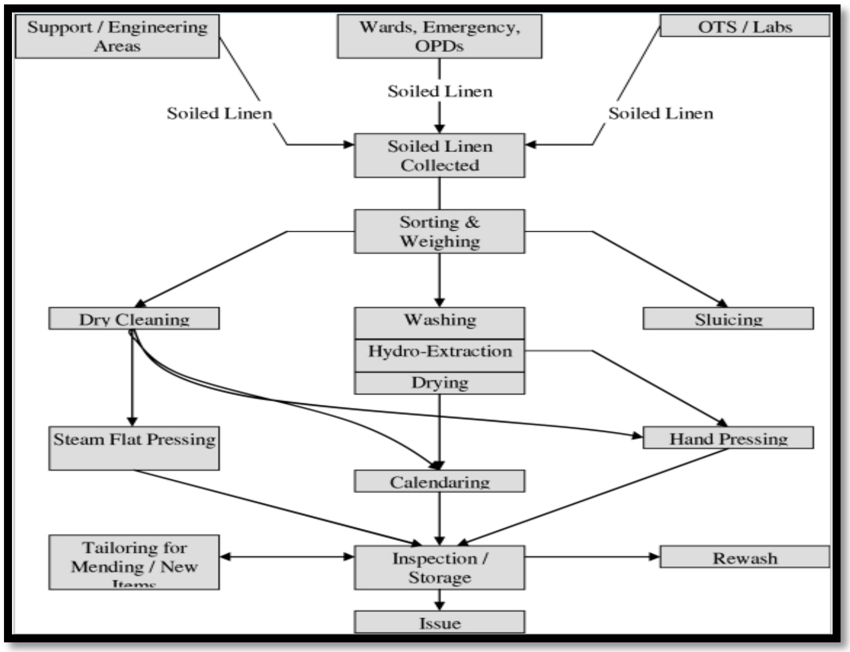


Figure 23-Linen and Laundry Service Flowchart (Occupational Safety & Health Administration)

Krishna Veni, Laundry & Linen Manager at Laico Eye Care Medical Center states that cleaning contractors, with the purpose of fulfilling their tasks satisfactory, comply with some basic requirements that any cleaning company must follow. Some of the principal requirements are: the location of the laundry facility must be in an area that has abundant daylight and natural air ventilation, with enough space for the washing and drying machines and working area for the employees. Moreover, it has to maintain a level of cleanliness in the work area and by employees in order to avoid any contamination of the clean linen and risk the health of the hospitals patients. The Occupational Safety & Health Administration (OSHA) has set several regulations in order to prevent disease transmission through poorly cleaned linen. It is for this reason that all hospital linen cleaning companies need to be certified by OSHA, confirming that they do comply with the minimum cleaning standards of health (Occupational Safety & Health Administration , 2012).

Many hospitals, such as the VA also have textile control and security policies to prevent contamination of clean linen as well as misplacement and loss of linen Some of these policies are:

a) Textile storage areas and vehicles are to be under locked and controlled access
b) Only one 24-hour supply is to be kept in storage for each using unit
c) All clean textile delivery carts must be clearly labeled as to their destination including quota
d) The textile carts must only be attended by designated employees (Department of Veterans Affair, 2010)

The hospital linen cleaning industry plays a key role in maintaining good health and high hygiene at hospitals, not only safeguarding the health of the patients, but also the health of the medical staff. The quality of this service contributes to the overall quality of any health care system, making this new industry a vital component for any hospital and medical center.

9.3 Methods for Comparing Alternatives

A common method for evaluating alternatives is cost benefit analysis (CBA). The starting point of cost benefit analysis is also its most crucial step—determining what information to include in the analysis. This process requires highly subjective judgments using certain underlying principles, including incremental cost and benefits, opportunity cost, technical benefits and societal cost for all stakeholders. Stakeholders are all the individuals influenced by the project itself. Opportunity cost is the value lost for all options not chosen. Technical benefits are the advantage provided by better and more advanced technology, besides the monetary value provided. The analysis should not include sunk cost, which is the cost after the project terminated. Individual preferences aggregate to the general societal cost of the relevant population. The next step is to apply certain discount rates to transfer the monetary value to present worth.

How is the entire collection of costs and benefits calculated? Williams (2008) argued that a market price should be assigned to certain costs to unify all the units to monetary measure. Although economists strive to do this, costs and benefits of some projects may not have market value since they will not be sold in any market. Facing this situation, researchers utilize four major valuation approaches to solve the problem:

1. The *averted costs* method transfers indirect cost or benefits to the items in the analysis to estimate their market price if such a value is not available. It is widely used in various areas and industries due to its simplicity. Its drawbacks include incomplete measurement and subjective to imperfect market price.
2. *Human capital* focuses on time benefits through the implementation of the potential project. By saving or gaining time, each individual could use that time for other activities, thus bringing benefits to the entire society.
3. *Explicit valuation* relies heavily on experimental survey and contingent valuation methods to measure required concepts. Despite its meticulousness, users of explicit valuation have to conduct it in an unbiased way to capture the real results from the population.
4. *Implicit valuation* takes an observation perspective to record the behaviors of the target population. In this way, it can eliminate inaccurate estimation when individuals state their opinions. Historically, housing and labor markets apply such methods most frequently (Williams, 2008).

The analytic hierarchy process (AHP), developed by Thomas L. Saatym is designed to solve complex multi-criteria decision problems (Zhu, 2012). This method was utilized specifically for this project thanks to its functionality even without detailed data. AHP requires the decision maker to provide judgments about the relative importance of each criterion and then specify a preference for each decision alternative based on the overall preferences expressed by the decision maker. The first step in AHP is to develop a graphical representation of the problem in terms of the overall goal, the criteria to be used, and the decision alternatives; such a graph depicts the hierarchy for the problem. Pairwise comparisons form the fundamental building blocks of AHP. In establishing the priorities for the criteria, AHP requires users to state how important each criterion is relative to each other criterion, when the criteria are compared two at a time (pairwise). Using the pairwise comparison matrix, the priority of each criterion can then be calculated in terms of its contribution to the overall goal of selecting the best option. This aspect of AHP is referred to as synthesization (Zhu, 2012). A key step in AHP is the making of several pairwise comparisons as previously described. An important consideration in this process is the consistency of the pairwise judgments provided by the decision maker. With numerous pairwise companions, perfect consistency is very difficult to achieve. In fact, some degree of inconsistency can be expected to exist in almost any set of pairwise comparisons. To handle the consistency issue, AHP provides a method for measuring the degree of consistency among the pairwise comparisons provided by the decision maker. If the degree of consistency is unacceptable, the decision maker should review and revise the pairwise comparison before proceeding to AHP analysis. A sensitivity analysis about the weighting factors would be suitable for such a situation since the criterion for evaluation have a heavy influence on the final decision. By changing the weight of each criterion for a certain percentage, scenarios were created. Then the comparison of the scenarios would help determine the influence of the criteria.

9 .4 Case Study: WMSHL Steam-less Plant

West Michigan Shared Hospital Laundry Services (WMSHL) was in trouble. As a facility processing 28 million pounds of linen annually, the WMSHL had limited space and outdated equipment in the facility. The problem only got worse when the 31 acute care or long-term care facilities and other 200 clinics sent increasing amount of soiled linen to the laundry facility (American Laundry Systems, 2010). As the demand grew, the plant could not expand at all due to the lack of room and capacity. This serves as strong motivation for a retrofit project. Therefore, the management decided to upgrade and renovate the plant to enlarge its capacity and cut down the environmental footprint. They were determined to go over and beyond the industry average. Instead, they would like to be at the cutting edge of the technology. Thus, the first fully "steamless" healthcare laundry plant was constructed based on the original plant.

Figure 24-WMSHL Washer (Jensen USA, 2010)

To accomplish such an ambitious goal, the plant uses direct-fired water heaters by natural gas instead of steam boiler. These two heaters could fully satisfy the total demand of the entire facility without using any steam. Although the idea of steamless is not common in US, it has been a strong trend in Europe. Compared to its steam counterpart, the natural gas-fired equipment has a dominant advantage in energy efficiency, which is at 95% or better compared to 75-80% of steam system. From the start of the process to the end, state-of-the-art machines are utilized. Jensen USA provided the solution for integrated sorting system; two tunnel systems (displayed in Figure 24 and 25), two conventional washers and two industrial dryers from Chicago Dryer Co. were in place for the wash room; four gas-fired self-contained thermal flatwork ironers, four folders (Figure 26) and stackers were installed and there is still extra room for expansion. A water-recycling system from Thermal Engineering of Arizona helps minimize waste of heated water, utilizing the technology of ceramic microfiltration. The renovation plan also expanded the plant from 45,000 square foot to 75,000 square foot to accommodate the addition of equipment and storage (Beggs, 2010). This system with no steam input is the direction Brockton facility is striving for. The Steamless Tunnel Washer in Figure 24 has comparable capacity with that of Brockton, and has proven to be a great option for facilities targeting at high-energy efficiency goal.

Figure 25-WMSHL Conveyer (Jensen USA, 2010)

All of these changes would naturally lead to high cost. However, by evaluating the options, this retrofit project is actually half of the cost compared to building a new facility for $25 million. Capacity of the renovated plant doubled from 30 million pounds to 60 million pounds per year while the environmental impact was sharply reduced: natural gas consumption dropped by 40%; carbon dioxide emission decreased 2.8 million pounds; water consumption reduced 28.7 million gallons, only half of the original amount (Beggs, 2010). This successful example the “steamless” laundry facility suggests the promising future of the technology. And it is clear that the reduction of the environmental impact, as well as an increase in cost-effective and energy-efficient equipment will be the major trend for the US healthcare laundry industry soon.

Figure 26-WMSHL Folder (Jensen USA, 2010)

10.0 Methodology

The goal of this project is to provide valid recommendations for the renovation plan of the VA Brockton Laundry Facility, focusing on environmental impact, cost reduction and efficiency improvement. This goal was accomplished through the following objectives:

1. Understand the current state of the laundry process
2. Research and compile alternatives for equipment
3. Conduct cost benefit analysis to evaluate options

These objectives were met using three major tools: interviews, Value Stream Mapping (VSM), and Analytic Hierarchy Process (AHP) analysis. To collect direct information about the system, personal interviews were conducted with the Facility Manager, Engineering staff and front line workers to incorporate their knowledge about the system. Value stream mapping and process maps were created for both the Current State and proposed alternative conditions of the system.

The student recognized it is practically impossible to provide recommendations for the entire plant due to the size of the facility and the time constraints of the project. In order to best utilize the limited time and energy, the equipment and energy consumption aspects of the retrofit plan were considered. These two areas not only have the highest possibility for operational cost reduction, but also possess the most environmental impact reduction potential.

The major stakeholders of this project are the laundry facility staff, related engineering staff, all the EMS staff in VISN 1, nursing staff in VISN 1, and patients in VA facilities. Attitudes of major stakeholders were taken into account through the interview sessions. A weekly timeline can be found in the Appendix, detailing the strategy for implementing the methodology described in this chapter.

10.1 Interviews

The research on the healthcare laundry industry provided a general idea about laundry processes. However, a basic idea was not enough to acquire an understanding of the current system. Therefore, incorporating the knowledge of the staff into the information pool added more details to the current state VSM. For this reason, informal interviews were conducted during the visit and shadowing with the Brockton Laundry staff. A pool of questions was prepared before the initial visit and the student asked them during the visit through casual conversations. Further questions were added during the conversations if the student deemed it necessary.

Considering the large number of the employees in facility, it was not feasible to conduct a large meeting, which included everyone. Instead, it was effective to have a focus group which consisted of several key individuals: Washer and Dryer Operator, Lead Plant Engineer, and Plant Manager. They represented different stakeholders in this project. This way, I obtained a full spectrum of ideas from different aspects of the facility. I also interviewed key persons individually such as the Laundry Facility Plant Manager, Boiler Plant Manager from a local college and WPI's Facility. The list of questions guiding interviews is found in Table 10.

Table 10--Interview Questions

What temperature units will be used during the conversation F or C?
How many machines for each type (washers, dryers, ironers, etc.)? And what are their capacity, water usage and energy consumption?
What are the specific power sources for the Washer (water processing), Dryer, Ironer, and Folders?
What are used in the boiler to produce steam: oil or electricity?
What specific type of Geothermal System are you interested in?
For the current steam system, is it possible to switch to use hot water instead of steam?
What do you feel the problems are in the current system? How is the efficiency & utilization?

10.2 Current State Mapping

Visualization of the process is helpful for the analysis of the system. One of the most efficient visualization methods is to combine all of the steps into a map, which also takes into account the value for the customers. As discussed in Section 2.4 VSM is usually utilized by a Lean Implementation team to position process improvement strategically (ASSEMBLY Magazine, 2013). A current state map would provide for an effective visual representation of the existing system. Within the map, the opportunities for improvement are specifically marked; their solutions represent the major design parameters for the next step, the future state map. The future state map depicts the ideal system. With both value-added and non-value-added steps, a project owner is able to streamline and simplify the process to increase its efficiency (University of California - Irvine, 2013).

Since the project goal was to reduce the operational cost and environmental impact, I modified the traditional VSM to be energy-consumption-focused instead of lead-time-oriented. Once enough information was collected, I compiled the current state VSM and discussed this with the Facility Manager.

10.3 Developing and Comparing Alternatives

After completing the VSM, the student conducted a comprehensive analysis which included both economic and environmental factors. First, different equipment alternatives were researched and selected. The total initial investment, operational cost reduction and environmental benefit of each selected alternative were then considered. The total operational cost includes: machine depreciation, transportation cost, maintenance, labor cost and utilities. Environmental benefits cannot be directly acquired. The value of these factors do not directly transfer to physical products or services, thus they do not have market price. Therefore, the Analytic Hierarchy Process (AHP) was used because it could account for all the factors. These alternatives were compared in all dimensions to find out the most favorable option. All the data and information collected through the interview and site assessment were put into this analysis.

The Analytic Hierarchy Process is a useful tool for decision makers (Zhu, 2012). First, the selection criteria were listed. In this case, these criteria included initial investment, energy consumption, efficiency, and operational cost, ease of implementation, water usage, staff training and safety. Then, the significance of each factor was compared to the other seven factors and compiled to reach a final weighting factor. The data for each alternative was filled in the columns as input according to the information acquired from equipment suppliers. A qualitative score for each alternative for each criterion was assigned a unit-less value range from 1-3. Then weights were assigned to each criterion according to the requirements and preferences of Brockton Facility Management. I was able to calculate the final score for each alternative, summing up their products of weight and value. Finally, in order to guarantee the validity of the answer, I conducted a check for consistency. This would allow me to detect any possible error in the calculation.

The eight criteria for comparison were selected for multiple reasons. Initial Investment and Operational Cost were crucial for such a project since the return of investments would be the major metric. The Energy Consumption and Water Usage were a good reflection of sustainability for this project. Efficiency, Implementation and Staff Training embodied practical feasibility. Finally, Safety should always be included for consideration of the employees.

11.0 Results and Analysis

In this section, I presented the findings of the current process in Brockton Laundry Facility, the Alternatives compiled for the retrofit plan and the comparison of these alternatives.

11.1 Current State

To effectively process soiled linen from all over New England, the VA Brockton facility has its equipment running continuously from 5:30 am to 3:15 pm on weekdays. There are different shifts for employees but the utilization of the machines is the priority. The entire laundry process includes various steps; a process map and Value Stream Map can be found in Figures 27 and 28

The process starts once the linen is used and collected in the soiled linen bags. These soiled linen items come from the various VA hospitals in tubs transported by trucks on a daily basis. The facility manager first decides which facilities' linen should be washed next, and then all the soiled linen carts from that specific location are weighed to keep track of the input quantity. After that, the soiled linen is hand-sorted by the employees into different linen types. Each type of linen is stuffed into a hanging bag. Each bag has the same weight and this helps the workers at the washing station to better balance the capacity of the machines. These bags are divided into two batches: one batch, mostly including large flat items that need standardized folding (e.g. flat sheets, blankets, etc.), is processed by the ironer-folder units after the washing process; the other batch, including the rest of the items, is washed and proceeds directly into the dryers. The linen items only need to be dried or ironed, not necessarily both due to their repetitive functions. The former batch is automatically stacked and transported into the clean linen tub while the latter goes through the hand folding process once the drying is finished. Then these items, dried and folded, are transported into the clean linen tubs. Finally, all the tubs from one specific location are delivered to its destination on a daily basis.

Figure 27--Laundry Process Map

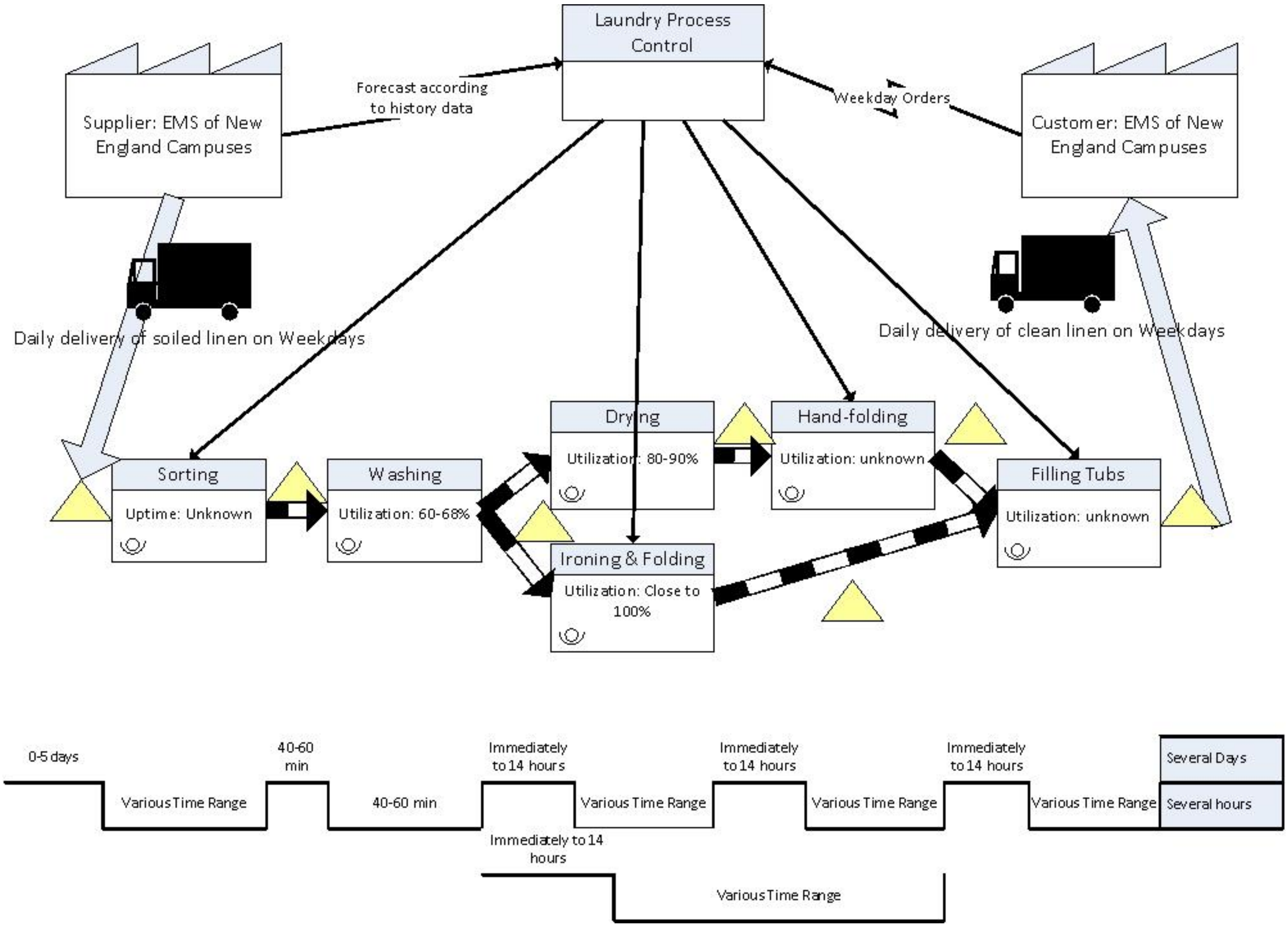


Figure 28--Laundry Facility VSM

To run any of the machines, energy is needed. The VA Brockton Laundry Plant utilizes both steam and natural gas to heat water and machines while electricity is used to operate the laundry equipment. The steam comes from the boiler plant next to laundry facility. This plant has enough capacity to support the steam demands of both the VA Brockton Medical Center and the Laundry Facility, with a maximum load of 40,000 pounds per hour. Specifically, 16,000 pounds of steam per hour is the maximum capacity for the laundry operation. The functions of steam in the laundry plant include: heating of the building, production of hot water, sterilization and humidification. Steam is supplied at 110 psi pressure while the heating radiation and hot water production require low pressure. The distribution system for the steam is a branched underground piping system. Three boilers used at the plant consume primarily natural gas as fuel at an efficiency of 88%. According to the engineer at the plant, while problems do exist, they do not affect the laundry plant as much: "Our main problems with the campus steam system are the underground distribution, age of air handling units/coils, traps and extent of DDC control systems. Projects are underway to replace the underground systems, replace aged AHUs as well as traps, and to expand the DDC system. The problems with the underground system do not affect the laundry as the proximity of the laundry to the boiler plant means the underground system is about 40 feet long – no leaks are evident." (Krockta, 2013).

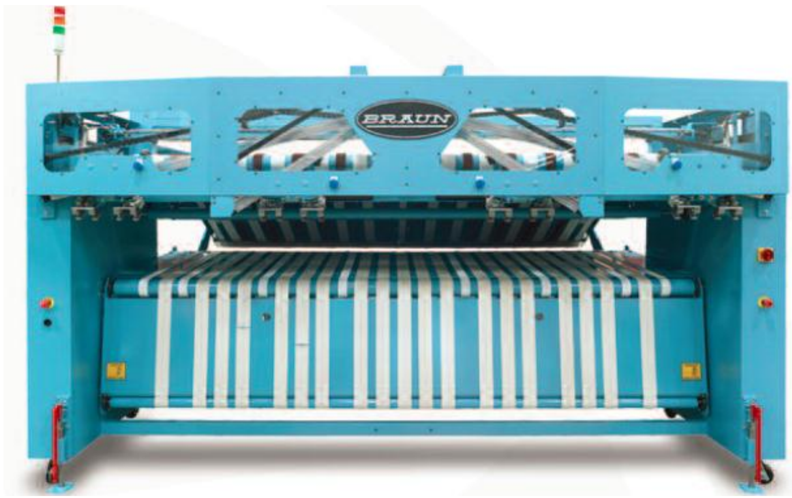
The first cleaning process starts with the washing of linen items. VA Brockton has 12 industrial washers in total: 6 with larger capacity than the rest. The total maximum washing capacity is 4910 lbs. Small washers are all Open Pocket models operating at 165 degree Fahrenheit (Delaporte, 2013). These machines are used for special items such as patient clothing and surgical linen. These items come in small batches. While utilizing the larger washers would be economical, waiting for a larger amount may lead to delay of linen delivery as well. So it is efficient to operate in such a manner. The large washers are all Split Pocket model with 3 pockets and operating at 165 degree Fahrenheit water temperature. 3 machines have maximum capacity at 900lb, 2 at 300lb while the other 1 at 230lb. The normal operating load is 80% of maximum capacity for safety consideration (Delaporte, 2013). However, the utilization of these washers is not ideal, at only 60-68%. There is room for improvement due to the lack of consistency in capacities between units. Open Pocket and Split Pocket washers are shown in Figure 29.

(a) (b)

Figure 29--Open Pocket (a) vs. Split Pocket (b) (Inc, G.A.Braun, 2012)

The soiled linen becomes clean and wet after the washing process, so it is time for dryers to play their role. Five large industrial dryers at the Brockton Laundry Facility have a capacity of 400lb per load while the 5 smaller ones take the smaller batches. All small dryers operate on natural gas; so do 3 large dryers. The remaining 2 dryers use steam for heating. Operation time varies from item to item depending on their materials, weights and ability to maintain moisture. A cool down period is also included in each run. Since the total process time of dryers and ironers does not match exactly with that of the washers, the dryers and ironers operate at much higher utilization: 80-90%.

As can be seen in Figure 30, the linen finishing system consists of three major components: a feeder conveys the wet linen to the ironer in a flat manner; the ironer uses high temperature pressing to dry the linen and eliminate wrinkles; the folder/stacker folds the ironed linen and stacks them automatically. These three components are independent from each other. The major challenge in the operation is to adjust the processing speed so that the entire unit can function at a consistent rate. Besides the constraints of the integration, the finishing system is also limited by operators. The feeder can have maximum of two operators working at the same time. The maximum feeding rate for each operator is 325 sheets per hour, but the average rate is only 250 sheets per hour considering the entire working day (Delaporte, 2013). The current problem is the lack of continuous high pressure steam supply, which hurts the efficiency of the ironers. This is one of the major motivations for changing the equipment, to switch from steam heating to a direct-fired natural gas system.



(a)

(b)

(c)

Figure 30--Ironer unit: feeder (a), ironer (b), folder/stacker (c) (Inc, G.A.Braun, 2012)

11.2 Alternatives

In order to address current issues and better support the healthcare facilities in New England, three alternatives for retrofitting the plant were compiled for the VA Brockton Laundry Facility: the Tunnel System consists of a continuous tunnel of washers, gas dryers, steam ironers with standard feeders, folders and stackers; the Steamless System includes all gas-fired tunnel washers, dryers and ironers with standard other equipment; and the Efficient Steam System utilized the steam heated machines but with a higher efficiency than current equipment in the facility. Detailed information for each alternative can be found in Table 11, including cost, configuration, capacity and energy consumption information.

Table 11--Alternatives Information

VA Brockton Laundry Facility Retrofit Alternatives			
	Alternative 1	Alternative 2	Alternative 3
Parameters	Continuous Tunnel	No Steam Tunnel	More efficient steam
Washers #	Braun, 8/11/14 components available each system, total 2 systems	Jensen, Universal, 5-20 compartments	Braun TSL, 4 Large 2 medium 2 small
Washers Energy	Steam 300-400 BTU per pound	Lower compared to steam models	Lower than current models
Washers Temp (F)	Customized Up to 180 F	Customized Up to 180 F	Customized Up to 180F
Washers Load (lb.)	220 each batch	264 each batch	900 large 450 medium 230 Small
Washers Lead Time	19 per batch	Longer than 19 mins	Same as current
Washer Water Usage	0.5-0.8 per pound	Low	Same as current
Washer Energy Efficiency	85%	Potentially 100%	80%
Total Washer Capacity (lb)	# of components X 220lb per batch X # of systems	# of components X 264lb per batch X # of systems	Large: 3600, 1360
Dryer #	5 Large	5 Large	5 Large

Table 12-Continued

Parameters	Alternative 1 Continuous Tunnel	Alternative 2 No Steam Tunnel	Alternative 3 More efficient steam
Dryer Energy	Steam 1,334,115 BTU/hr. Steam Supply Connection: 3" NPT	Gas Fired, Burner Firing range: 600,000-2,800,000 BTU/hr. Nominal Firing range: 1,500,000 BTU/hr. Gas Supply Connection:2" NPT	Steam 1,334,115 BTU/hr. Steam Supply Connection: 3" NPT
Dryer Temp (F)	175-190 F	175-190 F	175-190 F
Dryer Load (lb.)	500	500	500
Dryer Lead Time	Variable	Variable	Variable
Dryer Utilization	Potentially 100%	Potentially 100%	Potentially 100%
Dryer Capacity	2500	2500	2500
Feeder Operator	max 2, normally 2	max 2, normally 2	max 2, normally 2
Feeder Capacity	Max 325/hour	Max 325/hour	Max 325/hour
Ironer #	2	2	2
Ironer Energy Type	Steam 229 psi max	Thermal Fluid (no boiler)	Steam
Ironer Energy Consumption	30BHP=1,004,250BTU/Hr.	1,372,000 BTU/Hr.	30BHP=1,004,250BTU/Hr.
Ironer total roll	3 X 2	2 X 2	3 X 2
Ironer Length/Roll Diameter	185"4699mm/32"813mm	194"/48"	185"4699mm/32"813mm
Folder #	2	2	2
Stacker #	2	2	2
Folder and Stacker capacity	Same as Ironer	Same as Ironer	Same as Ironer

11.2.1 Tunnel System

This alternative is differentiated from the current system by incorporating the Continuous Tunnel System for washing and upgraded machines for other stages of the laundry process.

Specifically, I used GA. Braun as the major sample manufacturer for its complete spectrum of products as well as their cooperation history with VA Brockton Laundry Facility.

The Continuous Tunnel system offered by the company consists of multiple individual components to form a complete system. It comes with 8, 11 or 14 batches, with each batch having the capacity of 220 lb. The most appropriate and economic design would be 11 batches for the Brockton facility. With two of such tunnel washers, the washing capacity of the facility would be 4840lb, approximately the same level as the current capacity of 4910 lb. Although the absolute value of capacity decreases, the real capacity would improve by a significant amount, due to higher efficiency and utilization of the tunnel system. The company literature also indicates a lead time of 19 minutes per batch, which is significantly better than the current lead time range of40 to 60 minutes (Delaporte, 2013). The process exemplifies lean thinking by utilizing smaller batches rather than waiting for a larger batch.

Five new dryers would have higher efficiency in this alternative as well; with a maximum load of 500lbs each machine. By replacing all current dryers with larger ones, the lead time would decrease and energy efficiency increase thanks to the better utilization of energy and machines with a larger batch of linen. The economies of scale could help from this perspective. The two steam ironers would also be able to increase the energy efficiency with the new technology utilizing steam better. Two feeders, tow folders and two stackers are all the same with current machines but with slightly better energy efficiency and durability.

11.2.2 Steamless System

This alternative features on the entire system without usage of steam. As discussed in the previous sections, steam is not the optimal option for laundry facilities due to safety, cost and sustainability reasons. With this steamless system, the entire system would be able to achieve an amazing possible energy efficiency of 99% (O'Neill, 2009).

The Jensen Universal Steamless Tunnel System could be the best option purely from an environmental perspective. The direct heat source for the machine is burning natural gas. Such a system is much more efficient than steam heating due to fewer steps and smaller energy loss during the heat exchange process. The steamless dryers are larger, with higher energy efficiency as well which would have same impact on the system mentioned in the previous section. The direct-fired ironers would also solve the major obstacle in the plant now for lack of steam pressure to operate at its full capacity. The rest of equipment is currently powered by electricity and would not create demand for steam. The facility could even eliminate all the steam pipes to reduce any risk.

11.2.3 Efficient Steam System

This alternative has the least change from the current system other than the slight increase in capacity and efficiency. New washers would have the similar combination of large models (900lb maximum capacity), medium models (450 lb. maximum capacity) and small models (230 lb. maximum capacity). With a total capacity of 4960 lbs., this alternative includes four large washers, two medium and two small ones. Five steam dryers are selected with a 500lb load on each. With the hope that high pressure steam would be accessible, the 2 ironers remain to utilize steam as the heat source. The entire system has limited changes from the current system, making the impact of improvements minimal.

11.3 Comparison of Alternatives

Incorporating the opinions from the management of Brockton Laundry Facility, I completed the pairwise comparison matrix of the eight evaluation criteria. The raw rating and the normalized rating (value 0-1) for pairwise comparison are found in Tables 12 and 13. A higher number in a cell symbolizes the criterion in that row is more significant than the criterion in that column. The higher the value is, the more important it is compared to the other factor. First, all the values over 1.0 are filled in. Then empty cells are filled by reversing the values from the filled cells. For example, the bolded 3.00 (3rd row, 2nd column) signifies the factor of Energy Consumption of an alternative is three times more important in our consideration than the factor of Initial Investment. It was filled first. Then the bolded 0.333 was calculated and filled by putting 1 over the filled value 3.0. All other cells are filled in a similar manner.

Table 13--Pairwise Comparison of Criteria-Raw Ratings

Criteria	Initial Investment	Energy Consumption	Efficiency	Operation Cost	Implementation	Water Usage	Staff Training	Safety
Initial Investment	1.000	**0.333**	2.000	0.500	0.500	2.000	3.000	4.000
Energy Consumption	**3.000**	1.000	3.000	2.000	2.000	3.000	4.000	4.000
Efficiency	0.333	0.333	1.000	0.333	0.333	0.500	2.000	2.000
Operation cost	2.000	0.500	3.000	1.000	0.500	3.000	3.000	4.000
Implementation	2.000	0.500	3.000	2.000	1.000	3.000	4.000	4.000
Water Usage	0.500	0.333	2.000	0.333	0.333	1.000	2.000	3.000
Staff Training	0.333	0.250	0.500	0.333	0.250	0.500	1.000	2.000
Safety	0.250	0.250	0.500	0.250	0.250	0.333	0.500	1.000
Sum	9.417	3.500	15.000	6.750	5.167	13.333	19.500	24.00

The normalized value was calculated by using the raw rating divided by the sum of that column. Priority is the final average of all values in that row, symbolizing the weight of the criterion in that row. Additionally, the Weighted Sum and Consistency Measure were calculated to ensure the rating was consistent throughout the matrix and weighting factors reflected the real importance of each criterion.

Table 14--Pairwise Comparison of Criteria--Normalized Matrices

Normalized Matrices	Initial Investment	Energy Consumption	Efficiency	Operation Cost	Implementation	Water Usage	Staff Training	Safety	Priority	**Weighted Sum**	**Consistency Measure**
Initial Investment	0.106	0.095	0.133	0.074	0.097	0.150	0.154	0.167	0.122	**4.896**	**40.127**
Energy Consumption	0.319	0.286	0.200	0.296	0.387	0.225	0.205	0.167	0.261	**6.079**	**23.332**
Efficiency	0.035	0.095	0.067	0.049	0.065	0.038	0.103	0.083	0.067	**2.504**	**37.465**
Operation cost	0.212	0.143	0.200	0.148	0.097	0.225	0.154	0.167	0.168	**5.300**	**31.507**
Implementation	0.212	0.143	0.200	0.296	0.194	0.225	0.205	0.167	0.205	**5.622**	**27.392**
Water Usage	0.053	0.095	0.133	0.049	0.065	0.075	0.103	0.125	0.087	**3.634**	**41.647**
Staff Training	0.035	0.071	0.033	0.049	0.048	0.038	0.051	0.083	0.051	**2.380**	**46.436**
Safety	0.027	0.071	0.033	0.037	0.048	0.025	0.026	0.042	0.039	**1.316**	**34.060**
										λ	**35.246**
										CI	**3.892**
										CR	**2.760**

The same process was conducted for the three alternatives with each of the criterion. An example of the calculations can be found in Tables 14 and 15. The rest of the calculations are found in the Appendix. Each alternative was given a value to symbolize how favorable it is in this criterion. In this case, Tunnel System has the lowest initial investment, therefore, is more favorable than both the other two alternatives. The bolded value of 3.0 was given according to its favorability while the bolded 0.333 was calculated by taking the reciprocal.

Table 15--Example Alternative Evaluation--Initial Investment

Initial Investment			
Raw Rating	Tunnel System	Steamless System	Efficient Steam System
Tunnel System	1.000	**3.000**	2.000
Steamless System	**0.333**	1.000	0.500
Efficient Steam System	0.500	2.000	1.000
Sum	1.833	6.000	3.500

Then the values were normalized by dividing them over the sum of each column. The Priority was calculated as the average of each row. Finally, the Consistency Index was calculated again for each criterion comparison to ensure the consistency of the ratings as discussed.

Table 16--Normalized Alternative Evaluation--Initial Investment

Normalized Rating	Tunnel System	Steamless System	Efficient Steam System	Priority
Tunnel System	0.545	0.500	0.571	0.539
Steamless System	0.182	0.167	0.143	0.164
Efficient Steam System	0.273	0.333	0.286	0.297

After the entire calculation was completed and analyzed, the results were compiled. Looking at the criteria weighting matrix, the weighting factors reflected the nature of the project well: a feasible project with an environmental focus, targeted at cost reduction and efficiency. With a weight of 0.261, Energy Consumption is the most significant criterion and followed by

Implementation of the project at 0.205. These values are 5 times of weights for Safety, the least significant factor. Thus, the results demonstrated a good range of values, making the difference in importance quite obvious. Details of the weighting factor of each criterion, and the final rating for each alternative, are displayed in Table 16.

Table 17-Alternative and Criteria Weights Summary

	Initial Investment	Energy Consumption	Efficiency	Operational Cost	Implementation	Water Usage	Staff Training	Safety
Weight	0.122	0.261	0.067	0.168	0.205	0.087	0.051	0.039
Tunnel System	0.539	0.297	0.297	0.378	0.297	0.297	0.297	0.297
Steamless System	0.164	0.539	0.539	0.414	0.164	0.539	0.164	0.289
Efficient Steam System	0.297	0.164	0.164	0.208	0.539	0.164	0.539	0.414

As can be seen in Table 16, the Tunnel System scored the highest in Initial Investment, based on its low equipment price while the Steamless System was the most expensive option as expected. The real difference is between Steamless Tunnel System which is 1.5 times more expensive than normal tunnel washers. Since the supplier refused to provide pricing information, this data was estimated after analyzing the differences of pricing between steam and gas ironers and dryers. It is surprising that the cost of the Efficient Steam System was higher than the Tunnel System. This, from another perspective, demonstrated the tunnel washer’s advantage over conventional washers: faster process time, similar capacity and lower price. The washers and ironers were the main cost while other equipment was only priced at a fraction of the prices of dryers and washers. Another observation is that the cost includes only initial purchase prices, without taxes, fees, and shipping cost. The overall pricing of three alternatives is found in Table 17, with detailed pricing information for equipment included in the Appendix.

Table 18-Total Price of each Alternative.

	Initial Investment
Tunnel System	$ 1,928,000.00
Steamless System	$ 2,422,000.00
Efficient Steam System	$ 2,068,000.00

The System dominated the environmental-related factors: Energy Consumption, Efficiency, Operational Cost and Water Usage. This was expected and the benefits of this alternative with respect to sustainability were obvious. However, it is not as feasible as the other two alternatives due to the extra layout and process change and staff training required. On the other hand, the Efficient Steam System had absolute advantages in feasibility thanks to its similarity to current equipment. The need for staff training and change of layout was also limited. Finally, the Tunnel System was a balanced alternative with decent priorities in most of the factors, displaying a generally good standing without obvious weakness.

The final results of the AHP analysis can be found in Table 18. The AHP successfully incorporated all factors and generated a clear priority between the three alternatives. The final scores demonstrate that the Steamless System stood out as the best alternative, based on its strong focus on sustainability. The Tunnel System was second choice with its balanced characteristics. The Efficient Steam ranked last despite its ease of implementation.

Table 19-Final Results of Cost Benefit Analysis

Final Results	**Priority**
Tunnel System	0.340
Steamless System	0.366
Efficient Steam System	0.293

The analysis was logical and functional given the available amount of time and information. It provides the best recommendation with the support of quantitative and qualitative analysis. However, the limited project time span and the lack of information did constrain the depth of this analysis. The information about the current plant was valid but incomplete, due to ineffective communication with some of the employees. The capacity, specifications, energy consumption and water usage information of many current machines were not available due to the lack of willingness of employees to offer help in their tight schedule. The information about the equipment for each alternative was limited due to information provided by suppliers. Some of suppliers were not willing to give the information since the project would not lead to a contract for them. Others offered limited information due to company policies. With these limitations, savings and monetary benefits could not be calculated, so a traditional Cost Benefit Analysis could not be conducted. Therefore, further communication with equipment manufacturers and detailed analysis in engineering aspects would be crucial to finalize the retrofit plan for the VA Brockton Laundry Facility. For the AHP analysis, a sensitivity analysis would be necessary to study the influence on each factor and the influence of the change in each factors' weights as well. This would allow better understanding of the real important factors and to achieve the accurate optimization of the decision.

12.0 Recommendation and Conclusion

The goal of this part of the project was to provide valid recommendations for improving the renovation plan for the Brockton Laundry Facility, with the primary purpose of reducing the environmental footprint, decreasing the total operation cost and enhancing the capacity as well as the efficiency of the facility. To accomplish this goal, three alternatives for retrofitting the plant were compiled for the VA Brockton Laundry Facility: the Tunnel System, the Steamless System, and the Efficient Steam System. The results of an analytic heirarchy process (AHP) analysis suggested that the Steamless System should be selected and implemented in the VA Brockton Facility. This proposed system demonstrated great potential to reduce the environmental impact of the plant and provide an efficient and effective solution for the entire VISN 1 laundry. The elimination of steam in the facility would also be great improvement in energy efficiency and safety for employees. However, there exist constraints to this alternative as well. Because the detailed layout and structure of the facility was not analyzed specifically, this could determine the ultimate success of the implementation. Failure in floor loading or inadequate space could be obstacles for such a plan to be realized. The current workforce in the plant has limited education, which might hinder the implementation as well since the operational training might be hard for employees. The operators and staff may also show strong resistance towards new system simply due to the fear of change. Incorporating the employees in the implementation process would be the major challenge for the management.

In order to make this significant decision, more detailed studies should be carried out with respect to the structure and layout of the building. The possible natural gas input system needs to be considered as well. Multiple meetings with employees should be held to discuss the alternatives and to listen to the voice of the staff. In addition, sensitivity analysis could be conducted to evaluate the actual influence of factors in each alternative. The management of the plant would then be able to acquire a quantitative and more objective opinion about the factors and alternatives. Furthermore, with the aging of "Baby Boomers", the demand for healthcare may continue to increase for the next several years. This requires the Laundry Facility to consider the likelihood of greater throughput, adding another challenge to the plant. This would allow better understanding of the most important factors and support a more robust decision.

Therefore, room for expansion needs to be considered as part of a long term development plan for the plant.

In conclusion, the project was a great learning opportunity for me to understand the relationship between Industrial Engineering and Environmental Engineering. My academic and professional growth during the project was phenomenal, thanks to the application of theories to real life problems. I used to believe sustainability could be easily achieved as long as people made the right choice. The only problem the current society was the lack of willingness to protect the environment. However, I realized after this project that it is impossible to look at only one side of the story. Any enterprise would not be able to sacrifice too much of its economic interests for environmental-friendliness. And in other situations, trying to be green would physically not be an option due to various constraints.

Fortunately, I am not discouraged by the challenges ahead. I still believe that sustainability can be achieved in many levels and with the help of Industrial Engineering tools; it is more likely that both environmental and economic success can be achieved. I sincerely hope VA Brockton Laundry Facility will be able to implement a retrofit plan and become the flagship of an efficient and green laundry plant in VA Healthcare nationwide.

Bibliography

American Laundry Systems. (2010, 10 07). *100% Steamless Laundry Plant Rededication.* Retrieved 01 28, 2013, from The Laundry Forum: http://www.thelaundryforum.com/100-steamless-laundry-plant-re-dedication/

ASSEMBLY Magazine. (2013, 02 28). *Lean Manufacturing: The ABCs of A3 Reports*. Retrieved from ASSEMBLY Magazine: http://www.assemblymag.com/articles/87753-lean-manufacturing-the-abcs-of-a3-reports

Baldwin, W. (1890). New York: Wiley & amp sons.

Beggs, B. (2010, 11 12). *Michigan Co-op Plant Becomes 1st 'Steamless' Healthcare Laundry in U.S.* Retrieved 01 28, 2013, from American Laundry News: http://www.americanlaundrynews.com/article/michigan-co-op-plant-becomes-1st-%E2%80%98steamless%E2%80%99-healthcare-laundry-us-part-2-2

Dara Singh, G. Q. (2009, January 03). *International Journal of Health Science.* Retrieved 08 27, 2012, from Quality Control in Linen and Laundry Service at a Tetiary Care Teaching Hospital : http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3068780/

Delaporte, L. (2013, 01 30). Chief of Laundry Services VISN1. (X. Zhang, Interviewer)

Department of Veterans Affair. (2010). *Textile Care Management.* Washington, DC.

Department of Veterans Affairs. (2010). *Textile Care Management.* Washington, DC.

Department of Veterans Affairs. (2011). *Mission, Vision, Core Values and Goals*. Retrieved 09 01, 2012, from http://www.va.gov/about_va/mission.asp

Department of Veterans Affairs VA Boston Healthcare System. (2012, August). Environmental Management Service (EMS).

DMAIC Tools - Six Sigma Training Resources. (2013, 02 28). *DMAIC*. Retrieved from DMAIC Tools: http://www.dmaictools.com/

Furturer, S. (2011). Applying lean Six Sigma to reduce linen loss in an acutecare hospital. *International Journal of Engineering, Science and Technology*, 39-55.

Grudzinski, W. (2013, Feb 15). Lead Engineer, WPI Power Plant. (X. Zhang, Interviewer)

Gupta, P. (2001, 10). *Six Sigma: Implementation.* Retrieved 10 10, 2012, from Accelper: http://www.accelper.com/pdfs/SS_Implementation.pdf

Hammer, M. (2011, 05 04). *Role of the Process Owner*. Retrieved from Hammer and Company: http://blog.hammerandco.com/role-of-the-process-owner/

Inc, G.A.Braun. (2012). *Laundry Equipment and "Smart" System solutions.* Syracuse: G.A.Braun Inc.

Institute for Healthcare Improvement. (2005). *Going Lean in Health Care*. Retrieved from Institute for Healthcare Improvement: http://www.entnet.org/Practice/upload/GoingLeaninHealthCareWhitePaper.pdf

Jensen USA. (2010, October 11). *Steamless Plant*. Retrieved from The Laundry Forum: http://www.thelaundryforum.com/forums/general-discussion/steamless-plant-article-t409.html

Julian, K. (2011). *CleanCare*. Retrieved 08 25, 2012, from Outsourcing Linen Services Reducing Operating Costs: http://www.cleancarelinen.com/news_outsource0411.php

Krockta, J. P. (2013, Feb 11). Acting Engineering Manager. (X. Zhang, Interviewer)

Occupational Safety & Health Administration . (2012, 08 27). *United States Department of Labor*. Retrieved 08 27, 2012, from Occupational Safety & Health Administration: http://www.osha.gov/

O'Neill, G. (2009). Steamless or Less Steam. *Textile Rental*, 118.

Process Excellence Network. (2013, 02 28). *Champion*. Retrieved from Process Excellence Network: http://www.processexcellencenetwork.com/glossary/champion/

Resources Systems Consulting. (2011). *Safety Stock Calculation*. Retrieved from Lean Sigma Supply Chain: http://www.resourcesystemsconsulting.com/blog/safety-stock-calculations/

Sharma, P. (2010, 02 26). *Calculating COPQ using weighed risk of potential failures*. Retrieved 10 14, 2012, from Six Sigma: http://www.isixsigma.com/implementation/financial-analysis/calculating-copq-using-weighted-risk-potential-failures/

Sharma, P. (2010, 02 26). *Calculating COPQ using weighed risk of potential failures*. Retrieved 10 14, 2012, from i Six Sigma: http://www.isixsigma.com/implementation/financial-analysis/calculating-copq-using-weighted-risk-potential-failures/

Singh, D., Qadri, G., Kotwal, M., & Syed, A. (2009, January 03). *International Journal of Health Science.* Retrieved 08 27, 2012, from Quality Control in Linen and Laundry Service at a Tetiary Care Teaching Hospital: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3068780/

Spratt, W. (2013, Feburary 23). WPI Facility Manager. (X. Zhang, Interviewer)

The Laundry Forum. (2012, 08). *Linen Par Level Management*. Retrieved 02 28, 2013, from http://www.thelaundryforum.com/linen-par-level-management/

The Ohio State University. (2010). *Bulletin.* Retrieved 10 10, 2012, from Purdue - Engineering: https://engineering.purdue.edu/watersheds/resources/Academy/Evalution_Handbook_Water_Projects.pdf

Tuckman, B. (1965). Developmental sequence in small groups. *Psychological Bulletin* , 384 - 399.

University of California - Irvine. (2013, 02 28). *Six Sigma Lean*. Retrieved from Extension: http://unex.uci.edu/areas/business_mgmt/lean_six_sigma/

VHA Office of System Redesign. (2011, May). System Improvement Framework. *VA TAMMCS*.

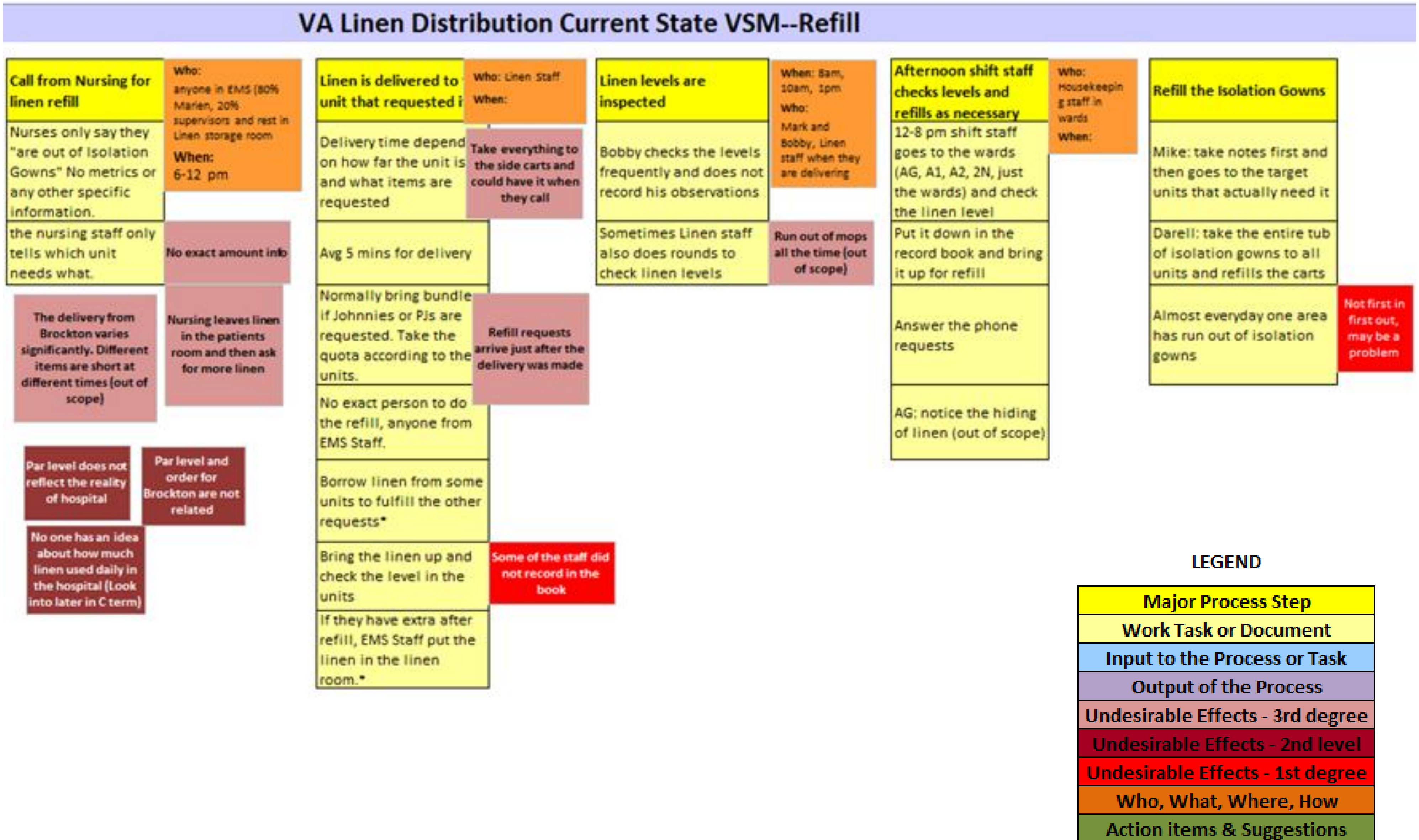
Wilson, L. (2010). *How to implement lean manufacturing.* New York: McGraw Hill Education.

Zhu, J. (2012, March). Senior Industrial Engineering Seminar. *OIE4410*. Worcester, MA, USA: WPI School of Business.

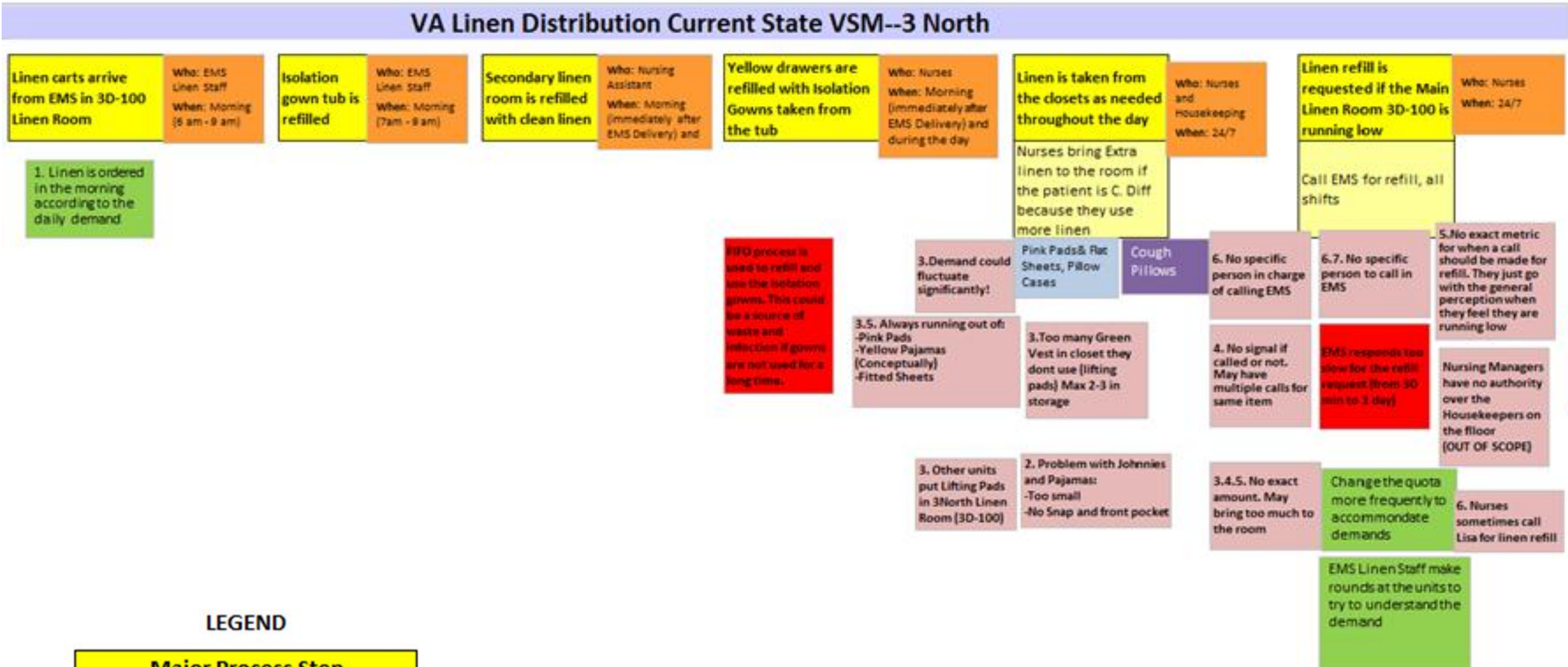
Appendix

Project Timeline

Current State VSM – Refill Process



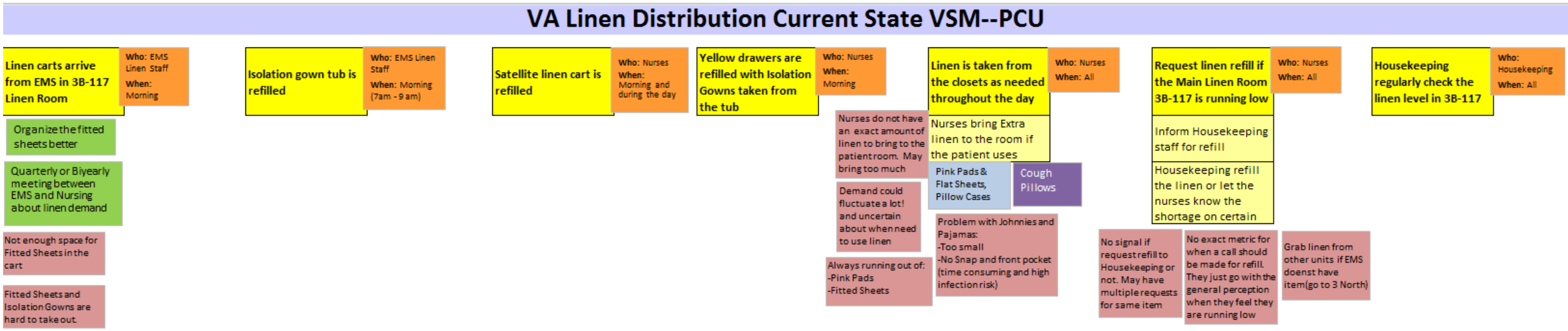
Current State VSM – 3 North

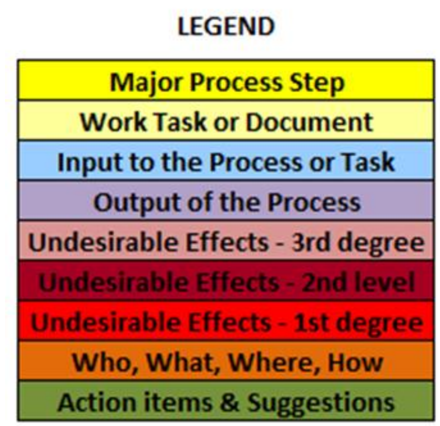


LEGEND

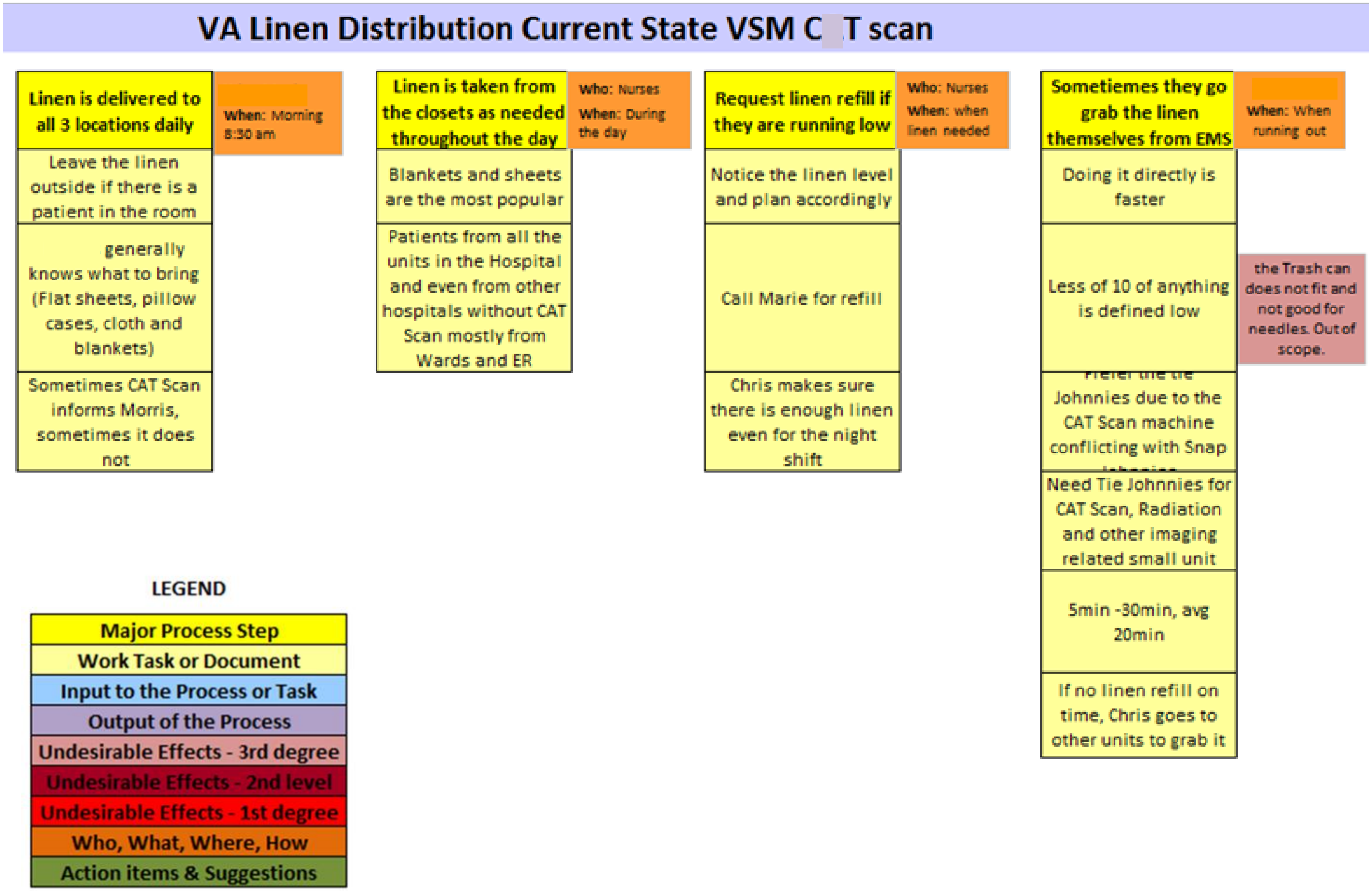
Major Process Step
Work Task or Document
Input to the Process or Task
Output of the Process
Undesirable Effects - 3rd degree
Undesirable Effects - 2nd level
Undesirable Effects - 1st degree
Who, What, Where, How
Action items & Suggestions

Current State VSM – PCU





Current State VSM – CT Scan



Future State VSM – Refill

VA Linen Distribution Future State VSM--Refill

Call for linen refill

Who: From Nursing staff to EMS Help Desk or Pager of Supervisor
When: 6-12 pm

Nurses say exactly wha at Red Level in which unit/ward

The nurse request linen write on the Laminated Signal (red side) their own name, time called, and item requested

EMS Help Desk gets the call and record following info:
-Time of Call
-Item requested
-Location
-Number of that day

Then Help Desk Staff try to contact Linen Staff within 10 Min

After contacted the Linen Staff, Help Desk staff records the time contacted and name of linen staff contacted

Linen is delivered to th requested it

Who: Linen staff all shifts
When: Anytime requested

The Linen Staff take th write down the record book and deliver linen to the closet.

The Linen Staff flip the laminated poster on top fo the cart to red side after taking exact amount of linen items (equal to green level of that item)

Linen Staff Refill the linen (FIFO) and then copy the info to the record sheet on the wall. Then erase the record on the signal, and flip it to the green side.

Linen carts in EMS Storage Room restocke

Who: Linen Staff all shifts
When: 12-8 pm

12-8 pm shift staff goe: the wards and check the linen level

Afternoon shift staff checks levels and refills as necessary

Who: Housekeeping staff in wards
When: 12-8 pm

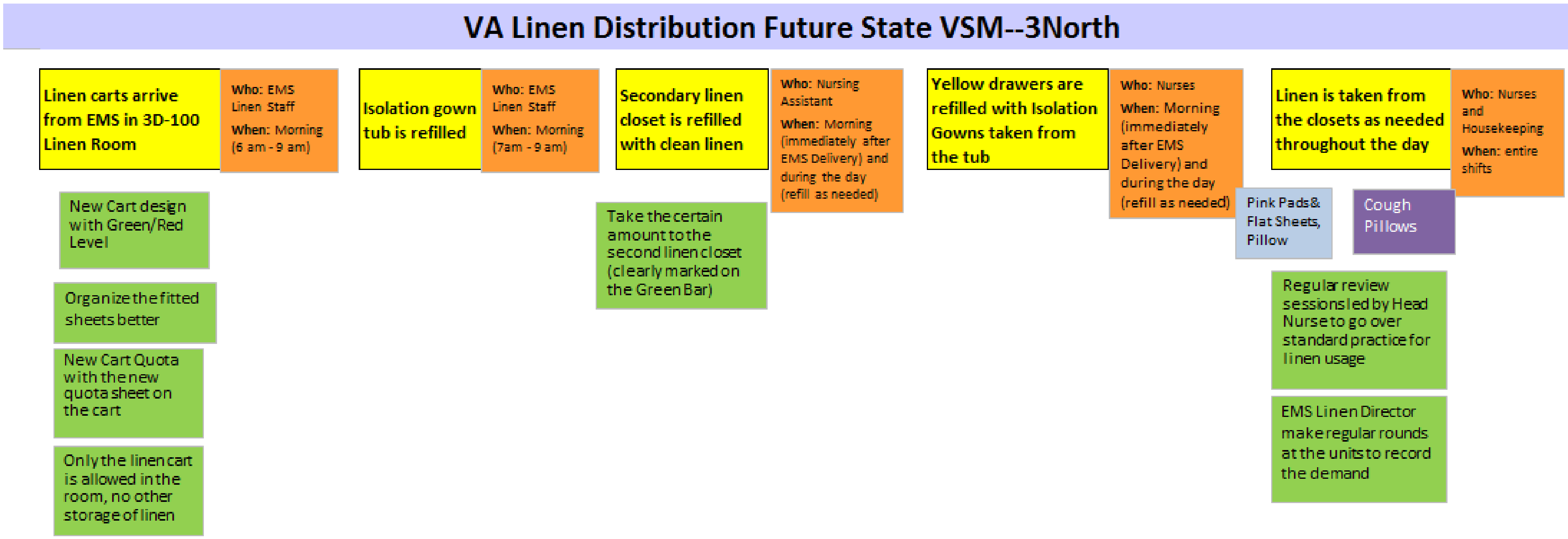
12-8 pm shift staff goe: to the wards and check the linen level

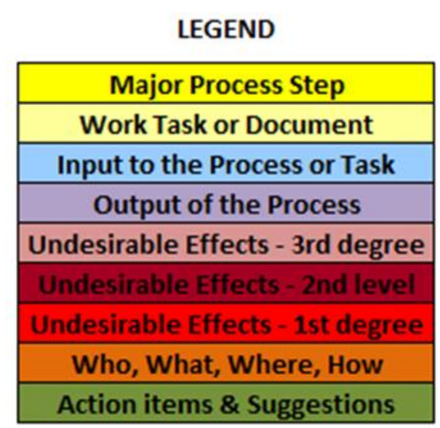
Refill each item to full and then make record about the refill in the log book for record

LEGEND

- Major Process Step
- Work Task or Document
- Input to the Process or Task
- Output of the Process
- Undesirable Effects - 3rd degree
- Undesirable Effects - 2nd level
- Undesirable Effects - 1st degree
- Who, What, Where, How
- Action items & Suggestions

Future State VSM – 3 North





Future State VSM – PCU

VA Linen Distribution Future State VSM--PCU

Linen carts arrive from EMS in 3B-117 Linen Room

Who: EMS Linen Staff
When: Morning (6 am - 9 am)

- New Cart design with Green/Red Level
- Better organize of fitted sheets and other linen for user-friendliness
- New Cart Quota with the new quota sheet on the cart
- Only the linen cart is allowed in the room, no other storage of linen allowed in the unit

Isolation gown tub is refilled

Who: EMS Linen Staff
When: Morning (7am - 9 am)

Yellow drawers are refilled with Isolation Gowns taken from the tub

Who: Nurses
When: Morning

Linen is taken from the closets as needed throughout the day

Who: Nurses
When: entire shift

- Pink Pads & Flat Sheets, Pillow Cases
- Cough Pillows
- Regular review sessions led by Head Nurse to go over standard practice for linen usage
- EMS Linen Director make regular rounds at the units to record the demand

LEGEND

Major Process Step
Work Task or Document
Input to the Process or Task
Output of the Process
Undesirable Effects - 3rd degree
Undesirable Effects - 2nd level
Undesirable Effects - 1st degree
Who, What, Where, How
Action items & Suggestions

EnvironmentalProject Timeline

Task	Duration (in weeks)	C term							D term				
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 1	Week 2	Week 3	Week 4	Week
Background Research	5												
Interviews	5												
Plant tours	4												
Market research	5												
Compile Alternatives	2												
Cost Benefit Analysis	3												
Project Proposal	3												
Final Project Report	7												

Input for the Project

Project Outcome

Detail Equipment Pricing Information

Batch Tunnel Washer 150BTW11	$	426,000.00
Conventional Washer: 800NMTDPV	$	155,000.00
400NMTVP	$	99,000.00
200NMTVP	$	72,000.00
Dryers: 500PT-NGF or PGF	$	93,000.00
Dryer: Steam	$	99,000.00

Feeder: MP4SSF-G2	$	66,000.00
Ironer steam 3S32-120	$	170,000.00
3S32-130	$	180,000.00
Ironer gas - 3T32-120	$	261,000.00
Ironer Gas large: 2SCT48-130	$	214,000.00
Folder: 2PF3CFA-130W	$	46,000.00
Stacker: LPS1	$	13,500.00
	Initial Investment	
Tunnel System	$	1,928,000.00
Steamless System	$	2,422,000.00
Efficient Steam System	$	2,068,000.00

Alternative Evaluation Matrices

Initial Investment

	Tunnel System	Steamless System	Efficient Steam System
Tunnel System	1.000	3.000	2.000
Steamless System	0.333	1.000	0.500
Efficient Steam Systen	0.500	2.000	1.000
Sum	1.833	6.000	3.500

	Tunnel System	Steamless System	Efficient Steam System	Priority
Tunnel System	0.545	0.500	0.571	0.539
Steamless System	0.182	0.167	0.143	0.164
Efficient Steam Systen	0.273	0.333	0.286	0.297

Energy Consumption

	Tunnel System	Steamless System	Efficient Steam System
Tunnel System	1.000	0.500	2.000
Steamless System	2.000	1.000	3.000
Efficient Steam Systen	0.500	0.333	1.000
Sum	3.500	1.833	6.000

	Tunnel System	Steamless System	Efficient Steam System	Priority
Tunnel System	0.286	0.273	0.333	0.297
Steamless System	0.571	0.545	0.500	0.539
Efficient Steam Systen	0.143	0.182	0.167	0.164

Efficiency

	Tunnel System	Steamless System	Efficient Steam System
Tunnel System	1.000	0.500	2.000
Steamless System	2.000	1.000	3.000
Efficient Steam Systen	0.500	0.333	1.000
Sum	3.500	1.833	6.000

	Tunnel System	Steamless System	Efficient Steam System	Priority
Tunnel System	0.286	0.273	0.333	0.297
Steamless System	0.571	0.545	0.500	0.539
Efficient Steam Systen	0.143	0.182	0.167	0.164

Operation Cost

	Tunnel System	Steamless System	Efficient Steam System
Tunnel System	1.000	0.500	2.000
Steamless System	2.000	1.000	3.000
Efficient Steam Systen	0.500	0.333	1.000
Sum	3.500	1.833	6.000

	Tunnel System	Steamless System	Efficient Steam System	Priority
Tunnel System	0.286	0.273	0.333	0.297
Steamless System	0.571	0.545	0.500	0.539
Efficient Steam Systen	0.143	0.182	0.167	0.164

Implementation

	Tunnel System	Steamless System	Efficient Steam System
Tunnel System	1.000	2.000	0.500
Steamless System	0.500	1.000	0.333
Efficient Steam Systen	2.000	3.000	1.000
Sum	3.500	6.000	1.833

	Tunnel System	Steamless System	Efficient Steam System	Priority
Tunnel System	0.286	0.333	0.273	0.297
Steamless System	0.143	0.167	0.182	0.164
Efficient Steam Systen	0.571	0.500	0.545	0.539

Water Usage

	Tunnel System	Steamless System	Efficient Steam System
Tunnel System	1.000	0.500	2.000
Steamless System	2.000	1.000	3.000
Efficient Steam Systen	0.500	0.333	1.000
Sum	3.500	1.833	6.000

	Tunnel System	Steamless System	Efficient Steam System	Priority
Tunnel System	0.286	0.273	0.333	0.297
Steamless System	0.571	0.545	0.500	0.539
Efficient Steam Systen	0.143	0.182	0.167	0.164

Staff Training

	Tunnel System	Steamless System	Efficient Steam System
Tunnel System	1.000	2.000	0.500
Steamless System	0.500	1.000	0.333
Efficient Steam Systen	2.000	3.000	1.000
Sum	3.500	6.000	1.833

	Tunnel System	Steamless System	Efficient Steam System	Priority
Tunnel System	0.286	0.333	0.273	0.297
Steamless System	0.143	0.167	0.182	0.164
Efficient Steam Systen	0.571	0.500	0.545	0.539

Safety

	Tunnel System	Steamless System	Efficient Steam System
Tunnel System	1.000	0.500	2.000
Steamless System	2.000	1.000	3.000
Efficient Steam Systen	0.500	0.333	1.000
Sum	3.500	1.833	6.000

	Tunnel System	Steamless System	Efficient Steam System	Priority
Tunnel System	0.286	0.273	0.333	0.297
Steamless System	0.571	0.545	0.500	0.539
Efficient Steam Systen	0.143	0.182	0.167	0.164