A Thesis

entitled

A Lean Six Sigma Approach to Red Bag Waste Management in Hospitals

by

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Submitted to the Graduate Faculty as partial fulfillment of the requirements for the

Master of Science Degree in Industrial Engineering

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An Abstract of

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Lean Six-Sigma methodology is an approach to improve value streams in term of meeting customer desire by elimination waste and defect. This method is a combination of lean thinking and Six-Sigma. Lean thinking provides an integrated overlook tool to business operations to perform more coherent technologies and assets flow instead of focusing to improve separate departments. Six-Sigma improves quality by decreasing the number of defects. The objective of this thesis is to eliminate errors in Regulated Medical Waste specifically red bag wastes. In order to achieve the goal of the research, lean six-sigma application in healthcare, a full process analysis of red bag waste in hospitals (including human factors), and an economic-environmental impact study of red bag waste and minimization methodology has been studied.

Red bag waste is one type of regulated medical waste (RMW), also known as ‘biohazardous’ waste or ‘infectious medical’ waste. This portion of the waste stream by definition is contaminated by blood, body fluids or other potentially infectious materials. In case of improper management, significant risk of transmitting infection would threaten the public heat and environment. In order to prevent confusion and mistakes in discarding
these wastes, specified regulations and guidelines are developed. Each category of regulated medical waste has special handling requirements that may be state-specific.

This thesis reveals the current red bag waste problems in an existing healthcare facility, a hospital in Toledo, Ohio. The study develops a universal model for improving red bag waste management value stream and focuses on human factors as key elements to improvement.
First and foremost I dedicate this work to the people around the world, each and every one of them who share this life, earth and environment with me, and to my parents who have been my unconditional lover, teacher and supporter. To John, Ehsan and Maryam who are a constant source of inspiration and friendship, and to my loved ones.
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Chapter 1

Introduction

1.1 Introduction

The purpose of this research is to develop a universal model to utilize in medical facilities in order to manage regulated medical waste while meeting the medical safety standards. Using Lean Six Sigma leads to the defect elimination which in this research would be non-regulated medical waste disposed improperly into the regulated medical waste containers. Applying Lean culture would lead to educating employees and satisfying customers, in this case medical employees by improving efficiency, productivity and quality of service and ultimately reducing costs. Lean thinking focuses on elimination the seven sources of waste (by lean definition) and adding value in all steps of processes.

1.1.1 Why medical waste management

Waste generated by healthcare activities in any related facilities including doctor offices, medical clinics and hospitals, laboratories even nursing houses, wastes which were used as a patient treatment is called medical waste (HCWM). According to Medical Waste Tracking Act of 1988, the exact definition of medical waste is: “any solid waste that is
generated in the diagnosis, treatment, or immunization of human beings or animals, in research pertaining thereto, or in the production or testing of biologicals.” Over the past decade, there has been a tremendous increase in the public concern about managing medical waste around the world (Enkohtesetseg et al., 2008). The possible impact of healthcare waste on public health and the environment has received a lot of attention such that Waste Management dedicated a special issue to the management of healthcare waste (Healthcare Wastes Management, 2005. Waste Management 25(6) 567–665). Disregarding this matter would cause irreversible damaged to environment and lives. It shall be mentioned that characterization and segregation of medical waste makes an important chapter in solid waste management and follows regulation and rules. Medical waste includes general non-hazardous waste, and hazardous waste (World Health Organization (WHO) 1990). Different categories that seek different types of treatments. As it could be implied medical waste includes larger than just infectious or biological waste (Cross, 1990). Improperly management of hazardous healthcare wastes would increase the risk of exposure to them and could lead to infections, infertility, genital deformities, hormonally triggered cancers, mutagenicity, dermatitis, asthma and neurological disorders in children; typhoid, cholera, hepatitis, AIDS and other viral infections through sharps contaminated with blood (Ngwuluk, Nididi, et al., 2009).

1.1.2 What is Regulated Medical Waste (RMW)

According to WHO, 85% of the generated waste by medical activities are categorized as general waste and are considered non-hazardous, the remaining 15% is what could be infectious, harmful and toxic in case of exposure. Latter portion of waste is composed of:
1. “Infectious Waste: contaminated with blood or other bodily fluids collected from diagnostic samples, lab work or treatment steps (operation rooms or patient rooms)

2. Pathological waste: human tissues, organs or fluids, body parts and contaminated animal carcasses;

3. Sharps: syringes, needles, disposable scalpels, and blades, etc.;

4. Chemicals: for example solvents used for laboratory preparations, disinfectants, and heavy metals contained in medical devices (e.g. mercury in broken thermometers) and batteries;

5. Pharmaceuticals: expired, unused and contaminated drugs and vaccines;

6. Genotoxic waste: highly hazardous, mutagenic, teratogenic1 or carcinogenic, such as cytotoxic drugs used in cancer treatment and their metabolites;

7. Radioactive waste: such as products contaminated by radionuclides including radioactive diagnostic material or radiotherapeutics materials” (WHO, Fact Sheet no 253)

All hazardous wastes are subjected to regulations that emphasize on proper and safe waste management mostly known as Regulated Medical Waste. Out of all these hazardous rated wastes only some are categorized as Red Bag wastes and all collected in red colored bags in medical facilities:
1. “Liquid or semi-liquid blood or OPIM, this includes: Blood in blood tubes, blood or OPIM in suction canisters

2. Contaminated items that would release blood or OPIM in a liquid or semi-liquid state if compressed, this includes: Blood-soaked gauze

3. Items that are caked with dried blood or OPIM and are capable of releasing these materials during handling, this includes: Blood-soaked gauze that has dried and the blood could flake off, Bloody gloves or other items that have not absorbed the blood

4. Contaminated sharps, including Needles, syringes with needles attached, scalpels, dental capsules with blood in them

5. Pathological and microbiological wastes containing blood or OPIM*

Please note that urine and feces are not listed above, therefore items contaminated with them are not considered regulated medical wastes”

(Sharps compliance, Inc.).

OPIM *Other Potentially Infectious Materials (OPIM) means (1) The following human body fluids: semen, vaginal secretions, cerebrospinal fluid, synovial fluid, pleural fluid, pericardial fluid, peritoneal fluid, amniotic fluid, saliva in dental procedures, anybody fluid that is visibly contaminated with blood, and all body fluids in situations where it is difficult or impossible to differentiate between body fluids; (2) Any unfixed human tissue or organ from a human
Medical waste definition and classification has been subject of many studies and medical research projects. Following it’s sorted in the table 1, a list of finding:

Table 1: Definition and general classification of waste arising from healthcare facilities.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Definition</th>
<th>Classification</th>
</tr>
</thead>
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<td>Healthcare waste</td>
<td>General waste and medical waste</td>
</tr>
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<td>Nemathaga et al. (2008)</td>
<td>Hospital waste</td>
<td>General waste, medical waste and sharp</td>
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<td>Hospital waste</td>
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<td>Healthcare waste</td>
<td>Hazardous and non-hazardous waste</td>
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<td>Abd El-Salam (2010)</td>
<td>Medical waste</td>
<td>Domestic waste and hazardous waste</td>
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<td>Kaisar Alam Sarkar et al. (2006)</td>
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<td>Ruoyan et al. (2010)</td>
<td>Healthcare waste</td>
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<tr>
<td>Tsakona et al. (2007)</td>
<td>Medical/Hospital waste</td>
<td>Infectious and municipal waste</td>
</tr>
<tr>
<td>Jang et al. (2006)</td>
<td>Medical waste</td>
<td>Tissues and other</td>
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<tr>
<td>Patwary et al. 2009a and Patwary et al. 2009b</td>
<td>Medical waste</td>
<td>Hazardous and non-hazardous waste</td>
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</table>

(Hossein et al, 2010)

According to the table 1, in some studies medical waste is divided into tissues and other, whereas in another studies infectious and non- infectious make the classification criteria.
1.1.3 Historical Background of medical waste management

In 1976 the congress of United States enacted the Resource Conservation and Recovery Act (RCRA) to pass principal federal law address the growing concerns of municipal and industrial wastes (Wikipedia). Due to RCRA hazardous wastes was consisted of infectious wastes generated from before 1988, State laws dictated the proper way of medical waste disposal entirely. In the summers of 1987 and 1988 however, medical waste wash up onto beaches attracted tremendous attention from the public and demonstrated fear and panic over the subject of adequate medical waste disposal issue. In respond to the public concern in 1988 Congress formed the Medical Waste Tracking Act and MWTA later that year on 1 November signed into Federal law that was coded as 42 USC. 6992 et seq. The enactment of MWTA was the beginning of other federal and state activities in regard to medical waste management (Lee, 1996).

After forming the MWTA, the term infectious waste was replaced with the term regulated medical Waste (RMW) by Environmental Protection Agency (EPA) aiming at disposal of medical waste generated from various sources. In 1990 EPA Report to Congress the annual amount of regulated medical waste was estimated as 456,000 generated from 375,000 medical facilities. Hospitals were responsible for the highest share of the RMW (about 77%) whereas other facilities comprise more than 98% of the total number of generators. Hospitals produced the vast and the remainder was generated by a diverse group of facilities such as laboratories, dentists and physicians’ offices,
veterinarians, etc. Most of these generators did not produce relatively large quantities of RMW (about 50 pounds per month) (Lee, 1996).

In 1993 a study conducted results from surveys sent to 225 hospitals in Washington, Idaho and Oregon states (Klangsin and Harding, 1998). That study examined practices of medical waste management along with offering the uniform definition for medical waste. However, hospitals were queried to provide the definition of infectious waste, clarifying segregation methods and disposal treatments. The results offered there was not a consensus on infectious waste but huge progress in regards to medical waste management compare to prior years. Considering respond rate of 72.5% of surveys the average of 72.66% of hospitals in all three states was practicing one or some medical waste treatments. The highest rate belonged to Oregon with 75.7%, whereas in comparison the average rate of 46% in U.S in 1987 and the rate of 51% 1989 indicated a huge success (Turnberg, 1989, Rutala, et al., 1989).

Studies show improper medical waste management in all countries had led to nation’s issues and concerns as well. The study conducted by World Health Organization (WHO) indicated that in 22 developing countries very insignificant proportion of healthcare facilities were using proper waste management, ranging from 18% to 64% (WHO, Fact Sheet no 281). Another example of poor medical waste management was the spread of blood-borne pathogens in health care waste that enforced the WHO to issue an urgent international policy calling for the development of national regulations, guidance, and plans for medical waste management in 2004 (Institute of Waste Management of Southern Africa-Botswana Chapter 25TH).
Studies suggest that a proper medical waste project enforces certain components: Formation of the national legislation and policy making for regulated medical waste management; execution of medical waste management policies; raising awareness and responsiveness to medical waste management; and evaluation and assessing the entire process (Takiguchi, 2016).

1.1.4 Medical West Management processes

Medical waste management poor management is the result of a combination of malfunction in either or all processes including generation, collection, storage, transportation and treatment (Manyele, 2004). Despite few differences in managing medical waste processes, a typical MRW project has general steps to follow:

1. Segregation: Recognizing the waste that segregates from general waste and should be treated as regulated medical waste in each medical facility based on its activity.

2. Collection: Collecting MRW from operating areas.

3. Transportation: transporting generated waste from operating areas to temporary storages to rest before collecting by haulers.

4. Temporary Storage: The closets that RMW is temporarily stored before transferring to a treatment center.

5. Treatment and disposal: This process could happen inside the medical facility. However, most of the treatment sites are outside of medical centers.

There are several methods of treatment and disposal for hazardous waste that closely depends on RMW type. Landfill, storage, thermal, biological, physico-chemical and recovery are some of those methods (Freeman, 1989).
However, historically incineration had been known as an important method of RMW treatments because of it’s advantages such as volume reduction, waste heat recovery (Hyland, 1993) but considering the flue gas emissions and lack of proper heat control requiring expensive flue gas treatment system (Williams, 2013).

1.2 Lean Six Sigma birthplace

The Toyota Production System (TPS) is the most famous system which valued integrity and appreciated the interaction between people and technology as a socio-technical system. This kind of system constantly evaluates and relearns its management philosophy and practices. The TPS originally was designed to organize manufacturing and logistics for the Toyota automotive manufacturing system which included all processes among manufacturers, suppliers, and customers. Toyota production system was the trigger for later methods "lean manufacturing." That was developed by Japanese industrial engineers Taiichi Ohno and Eiji Toyoda between 1950s and 1980s. However, in the beginning, the lean thinking was called "just-in-time production," amid at minimizing flow times in production and reducing the response time to customers. Natural reducing the response time involved the suppliers as well as manufacturers (Wikipedia). THE Toyota production System has long been known and referred as the source of Toyota's spectacular performance as a manufacturer. The system's distinctive practices -its kanban cards and quality circles, for instance - have been widely introduced elsewhere (Spear, et al., 1999).

Toyota industrial engineers were well aware of Japan’s distinguished features as a small island with growing population and turned it into starting point of TPS. The most
idiosyncratic feature of Japan is the natural resources limitations which make importing goods only option to provide necessary commodities including food. This counts as the most important disadvantage of Japan in competing with Europe and the USA in term of meeting customers demand. In this situation it was almost inevitable for industries in Japan to produce high-quality goods, having higher added value and possibly less expensive to maintain the world share of the market (Sugimori, et al., 1977). On top of this natural poverty, in post-World War II era, Japan economy experienced huge difficulty that caused many companies to collapse and thousands, suffered tremendously. Since the period of time that Toyota Motor Corporation was continuing to grow Kiichiro Toyoda had to come up with creative solutions in order to avoid bankruptcy and overcome the cash flow problems. Asking for Voluntary retirements, some pay cuts and resigning from company presidency were some examples of conflict management in the post-war era. Surviving the hardship motivated Toyota Company to plan, design and develop a production system that it could flourish not only in the thriving economy but also in incredibly difficult time to) survive such as recessions and war times (Badurdeen, 2012). What helped Ohne and his colleagues outperform Americans was their observation of car makers in the US especially Ford. “High production volume with zero product variety, infinite model life, and completely stable demand” (Roose, et all., 1991). Instead, they invested in designing and developing a system which cut costs of production aiming at producing less number of large varieties of car types (Ohno, 1988). However, this style didn’t attract much attention before THE OIL CRISIS in 1973, but during that period Toyota remained sustain although making fewer profits whereas many other companies collapsed (Ohno, 1988). As Taiichi Ohne who has been most credited of
TPS writes “Prior to the oil crisis, when I talked to people about Toyota’s manufacturing I found little interest. When rapid growth stopped, however, it became so obvious that a business could not be profitable using the conventional American mass production system that had worked so well for so long” (Ohne, 1988). There was a secret to this method of thinking and that set the primary purpose of TPS as making a profit through cutting unnecessary cost, using the most effective tools and achieving the ultimate goal by improving productivity (Monden, 2011). In the time that other companies noticed TPS, Ohno had led to transform Toyota to a sustainable and profitable manufacturing operation by hiring Kanban or just-in-time principles and waste elimination (Saito et al, 2012). Obviously, TPS was being driven by need (Ohno, 1988). However the company was open to sharing its successful practice and numbers of industries had toured inside the Toyota plants, yet other companies were unable to replicate the methods therefore continued to believe that the secret was related to the cultural roots (spear, 1999). In 1979, a researcher from MIT developing the International Motor Vehicle Program to study the challenges facing the automobile industry came up with the term lean (Krafcik, 1988) to explain the much less resource-hungry essence of TPS compared to other companies in the west (Williams, 2014). In 1980s Toyota was officially invited to bring TPS to the United States in collaboration with GM entitled New United Motor Manufacturing Inc. (NUMMI) and started the first example of lean manufacturing in greenfield plants (Womack, et al, 2010). Some resistance and denial against the Japanese took place among American manufacturing in the 1980s, and finally, Womack and Jones unfolded lean thinking in their book: The Machine That Changed the World: The Story of Lean Production (Womack, et al, 1996).
1.2.1 What is Lean?

Womack and Jones believed that five elements display Lean thinking principles: specifying value by specific product, identifying the value stream for each product, providing value flow without interruption, letting the customer pull value from the producer and striving for excellent (Womack, Jones, 2010). In another word to become a lean manufacturer, the main focus should be on elimination interruptions in the production flow, the customers’ demand should pull the operation, and a culture should be created that every single one feels responsible for continual improvement (Liker, 1997) when the concept is adding desired value.

In order to form a lean firm, identifying Value, adding value steps, and non-adding value steps are important to recognize. Since waste is determined by these parameters.
Lean principles have been described in different ways, sometimes one or two of the principles were embedded in others.

Table 2: The Basic Principles of Lean Development

<table>
<thead>
<tr>
<th>Add Nothing But Value (Eliminate Waste)</th>
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<tbody>
<tr>
<td>Center On The People Who Add Value</td>
</tr>
<tr>
<td>Flow Value From Demand (Delay Commitment)</td>
</tr>
<tr>
<td>Optimize Across Organizations</td>
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</table>

(Poppendieck, 2011)

Some of the studies explained the core ideas of lean as 3Ps; Purpose, Processes, people. Designing new product, process improvement, relocating processes and increasing manufacturing capacity are examples that 3P has been used according to Coletta in his book *The Lean 3P Advantage* (Coletta, 2012). Some researchers defined lean basics in or 8Ps: Purpose, Process, People, Pull, Prevention, Partnering, Planet, Perfection (Wickeramasinghe, et al., 2014). Regardless of the presentation form of lean core
elements, it emphasizes on the following list to demonstrate the path to magnificent improvement in operating systems.

- Specifying the value: The vital component in lean thinking is value. Value is desired by the end customer, and it is shaped in a form of product or service or combination of both. Value is provided to the customer at a specific price and time and amount (Womack, Jones, 2010).

- Identifying the value stream: Monitoring all sets of action in the chain of creating value for the ultimate customer. In the process of monitoring, any action that is not adding value should be recognized, categorized and removed if possible. The only action that is benefiting primary or secondary customers should be kept. In this regard, some action would be found as neither quietly valuable nor removable based on technologic limitations. These kinds of processes are called one Muda. Some actions which are totally wasteful with no adding value capability are called two Muda and be removed from the chain. Muda in Japanese means waste.

- Flow: After identifying the value and mapping the stream value, it is time to make the flow smoothly. Any waiting time should be minimized or possibly eliminated. Lean suggests each unit redefines its work from in order to influence value flow. The employees need must be seen in this step to provoke interests and respects.

- Pull: When the customer demand is driving the firm, dramatically inventory level drops, end product reaches to customer, therefore, return on investment speeds up.
• Striving for perfection: Since the more companies get involved with first four principles the more is discover to perfect, it seems that this circle repeats itself every time in a higher level. Continually seeking excellent is the fifth core component of lean thinking that pushes other four to improve. Redefining values, mapping the value based on the new finding, optimizing the flow and hiring newer technologies and pulling from new demands are all inspired by perfection tendency (Womack, et al, 2010).

1.2.2 What is a waste?

As discussed the ultimate goal of lean is to provide the most value for end customer and it chooses to achieve the goal through driving out waste from processes and empowering employees. Ohno in his book identifies seven sources of wastes in operation systems:

1. Waiting
2. Overproduction
3. Defects/Rework/Errors
4. Motion
5. Over-Processing
6. Inventory
7. Transportation

As it can be seen in each category some type of value is being wasted, from time to stock and even process. All kinds of wastes lead to increase in cost and ultimately decreasing the value that customer requests. All waste types directly or indirectly have an influence
on product price or service quality. People skills and expertise also could be considered as waste when it is not being utilized in the best location of chain or being neglected???

1.2.3 Lean tools

Lean Thinking as any other quality improvement methods has developed tools to implement principles and evaluate the progress. Lean thinking has gone a long way to building a lean culture to be one main pillar to the lean house in organizations. It is well obvious in lean history that over the course of twenty years the attention shifted from Only Lean Tools to Mix of Tools and Teams (emphasizing more on people) to Culture + Techniques (a good combination of people and tools). People often are called soft side of lean (Yang et al., 2010). It is TPS characteristic inherited in lean thinking that respect for people holds a fundamental position. Based on TPS culture employees are highly respected and well recognized. They are multi-skilled, empowered and involved in decision making and problem solving (Melton, 2005). Striving for perfection culture makes a reliable base for waste elimination tools, shortening lead time tools. Pull/Kanban, Cellular/Flow, Standardized Work, Visual control, Plant Layout, Quality at Source and Value Stream Mapping are some of 25 top essential lean tools (Lean Production). Kaizen Blitz, rapid improvement, standardized work are some used tools in healthcare (Radnor et al., 2012).

1.2.4 Need for Lean in health care

Lean thinking concept and tools are originally designed and developed to improve car production. However, lean principles could be hired to improve almost any manufacturing system (Womack and Jones, 1996). Healthcare services around the globe
have adopted improvement tools and thinking methods originated in the manufactures industries like lean production in other to achieve operational sufficiency (Zoe et al., 2012). The quality problems and Incidents in healthcare are often considered primary cause that makes leaders look for taking advantage of the concepts used is lean thinking (Joosten et al., 2009). NHS Institute for Improvement and Innovation suggests that implementation of lean in healthcare would eliminate wastes such as duplicate processes and unnecessary procedures, excessive waiting time for doctors , extra cost for unnecessary longer stay and more (NHSI, 2007). Healthcare like any other service provider needs to sustain competitive, cost efficient and innovative. Six Sigma lean can offer tools to access the effective innovative dynamic system (Koning et al., 2006) Interestingly enough lean has met up to expectations and reports on lean-related improvements in health care claim that; “the Lean message is 100 percent positive. Lean can improve safety and quality, improve staff morale and reduce costs—all at the same time “ (Joes et al., 2006). It is fair to declare that staff empowerment and striving of gradual and continuous improvement intrinsic to lean theory are two main characteristics that make lean more acceptable to healthcare arrangements than other improvement strategies are. Lean healthcare is earning acceptance because it leads to sustainable results not through to its “new movement' or “management fashion” (Brandao de Souza, 2009). But it can be said that first lean concept application in healthcare was suggested in the mid-1990s to adopted manufacturing successful practice in term of reducing inventory (Heinnbuch, 1995). However, the date of the first study on lean implementation in healthcare is not certain, first lean labeled studies took place in UK 2001 and in USA 2002 (Brandao de Souza, 2009).
Although lean healthcare is a young field compare to lean manufacturing, many reports of studies and practices in the different field of healthcare have been published. Quick-start Lean methods to cut clutter, applying lean thinking to outpatient registration, to establishing a standardized and efficient client laboratory application and improving accommodation and organizational arrangements are examples of lean application in hospitals (Ahmed et al., 2013). In published report from a pilot project at intermountain healthcare, all kind of improvement from a small positive change in accessing to the resource to reducing a significant amount of wasted time was reported. Requiring very little to no investment in most of these improvements was the remarkable fact about this project (Jimmerson et al., 2005). One of the well-known healthcare facilities that adopted TPS concepts and lean thinking is Virginia Mason center in Seattle. This center developed its own lean healthcare system: Virginia Mason Production System (VMPS) seeking for perfection and aiming at achieving zero defects (Forman, 2005). This healthcare center is an example of collaboration among care providers, payers, and employers to improve the quality of care and decreases in unnecessary care/cost. They have accomplished high patient satisfaction and built rapid responsive system (Blackmore et al., 2011).

According to Brandao De Souza in “History of using lean in healthcare”, the evidence indicates that 57% of articles are based on works occurred in the USA, implying that lean is being a successful trend for improvement in the private sector. It also claims that in the UK the approach to lean healthcare is increasing in fast pace (Brandao de Souza, 2009).
1.3 Case Study Facility introduction

The hospital that is being studied in the research is among the largest acute care facility in Toledo, Ohio. More than 4800 healthcare professional employees are serving patient from 27-county area in northwest Ohio and southeast Michigan. This hospital is one of the healthcare facilities under private ownership with 794 hospital bed. The facility has been rated among America’s 100 best hospitals in 2016, offers a wide range of medical services such as Breast Care, Diabetes care, Heart and Vascular care, Stroke clinical care, Surgical services, Vascular Neurology, Weight loss surgery and Women’s Services.
Chapter 2

Introducing lean to RMW

Healthcare waste hasn’t been managed well in many facilities around the world. Recognizing the roots and causes and planning actions toward improvement in the systems are the key solutions.

The case study Hospital has outsourced its Medical Regulated Waste disposal service to an outside company that removes the waste every Monday. However, the waste is being removed from patients units momentarily and stored in the temporary storages called closets. Closets are getting emptied twice, per day.

This study intends to introduce lean tools to Red Bag waste management process in the hospital in order to reduced non-value adding processes.
2.1 Methodology:

The methodology adopted for this study includes a two-stage strategy; the first stage is a combination of methodology that Oweis and colleges (2005) developed to evaluate medical waste management practice in Jordan. The second step is applying Lean Six Sigma tools to identify wastes and suggesting improvement plan.

1. Examining the regulations and procedures, set forth by the hospital’s directory addressing the management of red bag waste generated at the hospital. Making several visits to different departments of the hospital and recording observation of the level rules and regulations are respected and practiced by employees who come in touch with Red Bag wastes (Oweis et al., 2005).

2. Lean Six Sigma tools

a. Lean 5 core principals were applied to develop a lean model to the process, Identifying possibilities, and capacities to lean medical waste management. To indicate sources of waste, a modified version of Value Stream Mapping (VSM) has been used. Value Stream Mapping (VSM) represents the key people, information flows, and material required to deliver a product or service, distinguishing between value-adding and non-value-adding steps.

b. After recognizing waste resources among the stream, some analysis such as trend analysis and cost opportunities, completed to estimate cost reduction of going lean in red bag waste management chain.
c. Lean 3P principals were adopted to suggest improvement opportunities, fulfilling perfection phase.

In order to gather information of how medical waste, and specifically red bag waste were generated regular visits were made to the hospital. Neonatal Intensive Care Unit (UICU), surgery floor, PACU, emergency floor, is departments that generate red bag wastes and were audited in visits. Wastes generated in floors are reported as wastes in floor A, B, C, D, E, F, emergency A, and emergency B.

Regulated medical waste handout was provided by hospital directory. The same information has been posted in the temporary storages and data gathering form was designed to record department information including the name of department, amount of generated waste on that morning (lbs.), contents, the usage percentage of each red bag and accuracy of segregation by generators.

The site visits were extremely useful in obtaining data. Hospital directory helped closely in transferring data and attended in the interviews either in person or via email about the methods of spreading knowledge of medical waste management and raising awareness. The results obtained from visits also are presented and discussed to the hospital under a project report.

Observations indicate that hospital was successful in managing to protect environment and lives by not landfiling regulated medical (red bag) waste. Applying right tools and applications would present opportunities to:

1. Reducing red bag waste
2. Improving efficiency and reducing cost.

3. Significant reduction of errors.

4. Educating the staff.

The outcomes consist of observations of visits to one building in the hospital. During the visits auditions including eight sample collections took place. The generation and segregation have not been observed at the time happening, however, the collected samples from each temporary storage, were precisely traceable to the source department. An unoccupied patient room visit was part of one of the trips to the hospital.

During the visits over 130 observations of waste and accordingly suggestions for improvement were identified.

2.2 Developing the model-Lean 5 principals in red bag wastes

2.2.1 Identifying red bag waste management value

As it is mentioned in the introduction, value stands for extremely critical point for lean thinking. Value is completely defined by the end client. Value is desired by customers and what they are willing to pay for it. Firms in manufacturing industries or service industries exist to fulfill this request in form of goods or service or combination (Womack and jones, 2010). However, due to complexity in healthcare and the number of players from care providers to insurance companies, value remains misunderstood and difficult to measure. In such situation measuring value will not be achievable properly.
without encompassing all activities or services that determine success in satisfying a set of patient needs jointly. Patient’s medical condition determine these needs, defined as an “interrelated set of medical circumstances that are best addressed in an integrated way” according to Porter (Porter, 2010). The integrated way of addressing patient’s need might not look directly relevant in some cases, for example, registration, although registration updates the information and the care history.

Managing regulated medical waste, as discussed, provokes enormous attention outside the medical facility among public, but for hospitalized patient might be the last issue to focus on. In this case, a deeper covered value should be recognized that indirectly influences patients and that is safety. Regulated medical waste management addresses general safety against biomedical potential threats inside the medical facilities.

In addition, to achieve safe processes, elimination wastes and non-adding value steps from the value stream leads to decreasing total cost and benefits patient.

### 2.2.2 Identifying red bag wastes management customer

Since regulated medical waste management ties with public safety and environment, there would be the wider concept of the customer to consider.

Care providers, insurance companies, medical equipment industries, healthcare administration are all considered customer at one point in healthcare but ultimately the entire chain links function jointly to satisfy patient as the primary client.

Although in medical facilities patient exposure to red bag wastes is limited or zero after the medical procedure is finished, but other groups of caregivers like nurses, physician
and janitors still remain vulnerable. Thus in this study secondary customers are considered as target client, remembering that of secondary customers’ safety and health directly affects primary customer state of safety and health.

2.2.3 Flow in red bag waste management

Based on observations in the hospital, red bag waste management flow starts from the patient room or any operational room that patient is being treated. Therefore value stream mapping should begin from the point that medical treatment with generating red bag waste is being delivered. Due to biohazardous nature of materials, the first step of red bag waste management will be performed immediately after waste generated, and following steps will follow:

1. **Segregation at source**: Each patient room is equipped with closed disposable sharp containers and stacks of brand new unopened red bags ready to use. Nurses and medical assistants are trained to collect numbers of wastes as red bag wastes including visibly bloody gloves, visibly bloody plastic tubing, visibly contaminated PPE, saturated gauze, saturated bandages, blood saturated items. There is also a list of what doesn’t belong to the red bag consisting of medication, garbage, loose sharps, radioactive waste, hazardous and chemical waste, compressed gas cylinders and fixatives or preservatives.

2. **Collection**: Medical caregivers are expected to segregate the waste at the source, tie the red bag in a special fashion called gooseneck tie and immediately transport the bag to the temporary storages called closets.
3. **Transportation**: Since each floor has its own closet, transportation the bad bags doesn’t consume noticeable time and at the longest distance would be less than 4 minutes.

4. **Temporary Storage**: First group of Temporary storages or closets are the places that big lidded red bins collect red bags. The closets’ door must be closed at all time as well as red bins lids. Caregivers are supposed to dispose of their gloves after tossing the red bags and covering the bins. Washing and sanitizing hands in the sink located in the closet before leaving are emphasized. There is a poster explaining regulated medical waste segregation criteria in each closet. Red bag wastes are to rest in closets before collecting by haulers twice a day. Collected red bags will be transported by specially trained haulers to the second temporary storages and will be stored in bigger bins to ship out to the treatment site.

5. **Treatment and disposal**: This process happens outside the hospital. Waste management company carries away the red bag wastes among other regulated medical waste. However, each category of regulated medical waste is collected on a separate day. The hospital will be a charge based on the volume of collected red bags.

   Interruption of the flow of the red bag waste is less than interruption of Information flow between the treatment company, hospital and the employees.

2.2.4 **Pull from customer in red bag waste management**

Regarding the nature of red bag waste management, it naturally drives a customer pulled service. Remembering that red bags are transported from patient rooms immediately, red
bag waste customers are nurses and other caregivers. Removing red bag wastes safely and quickly is demanded by customers who are exposed to risk due to their professional nature. However, there are numbers of support processes in the value stream that currently are pushed towards the customer. Customers showed little interest to receive those kinds of service. Those processes should be revised or removed aiming a waste free value stream.

2.2.5 Perfection

Seeking to improve the entire chain of actions is the last principal of 5 lean core basics. With considering the last principal, the process of ongoing continuous improvement would increase customer satisfaction and efficiency. Cost reduction is also another accomplishment in this project. Indicating sources of wastes helps to design a system to eliminate them and continually improving value stream.
2.3 Value Stream Mapping

Referring to red bag waste management characteristics such as lack of cycle time and unknown and unpredictable demand, this study has adopted the modified version of value stream mapping developed by Cookson and colleagues (2011) in a similar healthcare setting.

![Figure 3: Hospital Red Bag waste management Process map (Case study)](image)

Based on the observations, besides five general red bag waste management steps, four additional processes exit. One process is related to preparing and sending the invoice to hospital directory. This step is completely managed by treatment Company and the
hospital has no control on it. The treatment company also provides reports of the amount of total regulated medical waste monthly that includes red bag waste as well. These series of reports are not categorized base of the composition of red bag wastes and don’t present the percentage of non-red bag waste still they present a perspective to monitor fluctuation on waste generation rate.

From receiving invoice step by the hospital directory, three more processes occur. The directory is responsible for

1. Providing reports based on data received from treatment company.

2. Performing audits to evaluate the process.

3. Designing training material and signs to post in the temporary storages.

4. Offering training meetings for department managers.

Training meeting is the only process in the stream that transfers the data and knowledge to operational department managers. The hospital directory also posts educational signs and wallpapers related to regulated medical waste via hospital intranet, aiming at refreshing employees knowledge.
Next process is training sections delivered by department managers to employees. In this step departments’ managers train the employees (customers in this value stream). The number of the meeting requested from hospital directory. Audit results also may urge training sections to the customers.

As it can be implied from the process map there is no direct meeting between hospital directory and the customers. This lack of connection raises a red flag and causes risk of misunderstanding about the value.

Since treatment step and preparing monthly reports completed outside of the hospital by treatment company, this study did not evaluate them. However, suggestion to make reports more educational are made.

2.3.1 Findings

Source of wastes in the processes:

As it was mentioned earlier all steps of red bag waste consisted of non-adding value actions or Muda that can be improved by lean thinking.

1. **Red bag waste generation**: Since customers are extremely sensitive to the bio-hazardous waste, it could be implied that in the moment of waste generation a set of actions will be taken immediately. Therefore in this step customer needs to
have access to inventory (unused red bags). Red bags should be enough in numbers and stored in a quickly accessible shelf. The storage should be appropriately labeled to prevent any kind of confusion and risk of wrong usage or inventory waste. The generation step has a potential of waste of motion in a case that red bag is not in place and the customer has to make a trip to supply satiation and access to the red bags. To prevent this waste, there should be a system to control red bag inventory in any room before hosting patients. Another major source of waste in the whole process is inventory waste. The red bags are available in two different sizes, small and big. It was observed that even the small size was relatively large in many cases.

Figure 4: Big size of red bag used for small amount of waste
Another source of inventory waste was sharp containers. Sharp containers by classification belong to red bag wastes. Sharp containers are supposed to be full before disposal. In many cases, containers were found not nearly full. Due to the bulky volume consuming shape of containers, they should be transported to the temporary storages without being wrapped in a red bag. Although in the second storage they will be stacked up carefully and packed in red bins. However but placing them in the red bag among other wastes from the patient room would take too much unmanageable volume and increase inventory waste.
Figure 6: Unused space of a disposed of sharp container

Figure 7: A sharp container disposed in red bag improperly
2. **Segregation at source**: The segregation step is considered one of the key steps through the whole value stream. It performs an important adding-value role. Thus improving its quality would affect the entire system. Based on observations segregation step is responsible for over 100 of waste identified thought out the value stream. It will be meaningful to deliver deliberate effort to eliminate wastes in this step. Elimination all sources of waste in segregation step would reduce the waste in value stream to less than 24% of the current amount. Studying the samples indicate that errors are the significant source of waste in segregation process. The amount of non-red bag waste disposed into the red bag is noticeably high. This amount in some operational department reached to 100% of total amount of the collected red bag waste. The majority of non-red bag waste present in the red bags was medical items that obviously did not match the definition of
red bag wastes. Plastic Suction Tubing, Plastic Suction canisters, empty urine catchers, emesis basins were the most disposed item which neither had no visible nor dripping blood. One sample contained a full pouch filled with 7 lbs. of liquid. An old testing device, Test strips, swabs, non-saturated gauzes, gloves and shredded paper were found in other samples. In a rare case, pharmaceutical waste including pills and unfinished ampules were disposed of improperly in red bags. Table 3 presents the weights and compositions of samples in a different department of the hospital.

<table>
<thead>
<tr>
<th>Location</th>
<th>Total Waste in Red Bags (lb.)</th>
<th>% Red Bag Waste</th>
<th>% Non-Red Bag Waste</th>
<th>Red Bag Waste (lb.)</th>
<th>Non-Red Bag Waste (lb.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor A</td>
<td>4.8</td>
<td>20%</td>
<td>80%</td>
<td>0.96</td>
<td>3.84</td>
</tr>
<tr>
<td>Floor B</td>
<td>3.75</td>
<td>100%</td>
<td>0%</td>
<td>3.75</td>
<td>0</td>
</tr>
<tr>
<td>Floor C</td>
<td>1.25</td>
<td>20%</td>
<td>80%</td>
<td>0.25</td>
<td>1</td>
</tr>
<tr>
<td>Floor D</td>
<td>5</td>
<td>50%</td>
<td>50%</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Floor E</td>
<td>1.6</td>
<td>40%</td>
<td>60%</td>
<td>0.64</td>
<td>0.96</td>
</tr>
<tr>
<td>Floor F</td>
<td>7</td>
<td>90%</td>
<td>10%</td>
<td>6.3</td>
<td>0.7</td>
</tr>
<tr>
<td>Emergency A</td>
<td>10.25</td>
<td>0%</td>
<td>100%</td>
<td>0</td>
<td>10.25</td>
</tr>
<tr>
<td>Emergency B</td>
<td>1.5</td>
<td>100%</td>
<td>0%</td>
<td>1.5</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>35.15</td>
<td>45.23%</td>
<td>55.47%</td>
<td>15.9</td>
<td>19.5</td>
</tr>
</tbody>
</table>

As table 3 demonstrates, the total weight of red bag samples was 35.15 lbs. and only 45.23% of this amount was filled with red bag wastes. The table also shows that different operational areas carry segmentation in uneven skill level. This issue should be investigated to discover the empowering key factors that lead to better performances. Errors are not the only sources of waste in the segregation step. Over-processing is
another source of waste in this stage of red bag waste management. Red bags that have been tied twice and double-bagged wastes are examples of over-processing in segregation. Over-processing doesn’t account for noticeable waste in this stage. Other sources of waste could have been found in the segregation step if the author had been observed the real-time process in the patient room. In this study, only one visit to an unoccupied patient room was made and no related waste was observed. Figure 9 shows one of the samples that contains no red bag wastes. The sample is filled with all not red bag wastes and empty space adds up to the inventory waste. Some of the canisters are not even used, and if they disposed properly there is an option to recycle them and save some resources in term of raw material.

![Image of red bag waste](image.png)

**Figure 9:** Non-red bag waste, plastic suction tubing, canisters with no blood trace
Figure 10: Non-red bag waste, a 7 lbs. pouch filled with liquid

Figure 11: Non-red bag waste, municipal waste
3. **Transportation to the temporary storage**: The hospital temporary storages are located at a convenient distance from all patients’ rooms. There are two
temporary storages in the departments that are bigger in size or have higher demands such as an emergency room. Storages are called closets and have signs that emphasize “keeping the door closed at all time”. In all closets educational signs should be posted against the walls reminding red bag segregation guides and proper methods to dispose of them. There are sinks built inside all closets and recommendation to wash hand before exiting for employees. Also sanitizer all available for extra care. It could be concluded that in the case of proper waste bagging transportation does not impose a risk of Muda. However, in one of the visits, a drop of bloody liquid was observed beside the closet door while an un-bagged canister was found in the closets’ red bin. This incident raised the red flag of ignoring value by employees. This could the results of underestimating the value or lack of responsibility to self and others health. That should be noticed by everyone and addressed in an effective manner.

4. **Collection stored red bag wastes by expert haulers**: this step consists of sources of waste since results of errors by segregation step carry over collection process. Rework is a source of most wastes in this step. Some of the correctable mistakes would be fixed by haulers. For instance, if the bag is not tied properly, the expert tries to correct it. Red bags are expected to be tied in gooseneck style. In another example, if some municipal waste bag is found in the red bins, the experts would remove it from red bins and dispose into the other waste bins.

As it was mentioned earlier, red bags are available in two different size categories. Almost all of the red bags have empty unused space left at the time of disposal. In the
collection, step accumulation of extra material occupies a room and adds to the inventory waste. In another hand, because the hauler transports red bins on a platform hand truck, on each trip there is limited space available. Therefore the volume consuming empty red bags might cause waste of transportation.

Figure 14: Rework waste, improperly tied bag

Figure 15: Rework waste, municipal waste being removed from red bin
Threatening other employees’ health is a direct result of underestimating the value. As it could be seen in figure 14, an un-bagged bloody canister was disposed into the red bin.

5. **Transportation:** The fifth stage of red bag waste management includes transporting collected red bins from first temporary storages to the second temporary storages, where the treatment company loads them onto a truck and transport them to the treatment site. Every closet would be emptied twice a day by one of two expert haulers. Observations indicate that collecting red bins from all closets twice a day is wasteful. Although some operational areas generate a greater amount of waste, but instead two closets are located at those areas. This step of value stream imposes waste of transportation according to the number of trips each hauler has to make in order to collect the red bins on each floor. It also causes waste of people, considering non-utilized people or wasted intellect.
The expert hauler time that goes to waste of checking an empty closet could be utilized in other productive processes.

6. **Treatment**: From transporting red bag bins to the treatment site, few more steps exist. Following is the list of those steps that are handled by treatment company:

   - Weighing the red bag waste collected from hospital
   - Performing the treatment of red bag wastes
   - Providing the monthly reports
   - Sending invoice and the report to the hospital directory

There is no information or reports available about how the treatment company manages their steps. Therefore, this study has not confident to announce any waste detective statement or suggestions to improve. Establishing a collaborative relationship with treatment company in regards to upgrade the whole value stream can be useful. The treatment company has the potential to become an educational source for hospital in the waste management field and help the hospital directory to design more effective training material.

Based on interviews with hospital red bag waste management representative Next steps are followed by hospital directory after receiving the invoice,

   - Making payment to treatment company
   - Providing annual reports, using treatment company’s data
Designing training material for training department managers

Hospital directory offers training sections for managers of the operational department. These classes are designed for raising awareness among leaders about the necessity of managing regulated medical wastes properly. The latest methods and procedures are shared with managers in these sections as well. After completing a training program, managers are expected to train employees under their supervision and transfer the refresh knowledge to those who are implementing the regulated medical waste management procedures. Equipping caregivers that are exposed to regulated medical waste to effective skills are results expected results of the chain of training. Managers also should monitor the accuracy of implementation.

This study has not found the training program efficient or productive. The entire process does not appear to be working in full potential. This malfunctioning outcome could be the result of a failure in transferring knowledge, structural problems, irresponsibility from managers or employees to perform, a combination of all above or simply because of training program disability in provoking the value in employees.

Based on described reasoning author identifies the training sections for managers of departments wasteful or in another word Muda two type of process. The solution is to replace this non-adding value action with the more interacting educational program. Hospital directory can hold one series of training meeting, interfacing with all employees directly and receiving their feedbacks immediately. Managers and caregivers can share more broad aspects of the job in this kind of training. Health related issues, financial
aspects, common mistakes and many more subjects can be discussed. Therefore, the training mission would convert into empowering and strengthening the employees.

Figure 15 illustrates original stream value map including sources of waste in each step. As it can be seen, there is no data assigned to waste treating steps.

The driving force between red bag waste management steps is customer pulled relationship, since there is a request for safety from employees. The actions related to training are not value adding and should be removed from the stream.
2.3.2 Customer pulled processes comparison

According to health threatening aspect of red bag wastes, there is an obvious request from customers to take parenting actions in operational levels. Employees that are in constant touch with regulated medical wastes show high interest to remove wastes out of the workplace. This interests that often causes errors of disposing of non-red bag wastes among red bag wastes demonstrate the courage towards waste management. Therefore the operational level processes are always customer pulled actions whereas in adminstarional level opposite results are observed. The relationship between the hospital and the treatment company is the businesslike type and limits to financial exchange. The monthly reports from treatment company don’t go above routines and stay at the data level.

If both sides, hospital, and treatment company put a deliberate effort to correct this trading into a cooperative relationship, the process will promote to customer pulled action.

On the other direction, hospital directory pushes the training program toward managers as well. The training program at current value stream is not welcomed by all managers. There is always a chance of undermining the purpose of training compared to patient related medical educational programs. In order to attain more appreciative attitude towards training meetings, there is a need to involve customers in the process and help them own it.
Figure 18 exhibits red bag waste management modified value stream map. In the new value stream map, all sources of waste including inventory waste, motion waste, errors, waste related to over-processing, rework waste, transportation waste and a waste of utilizing peoples’ skills are eliminated. In the same picture, the non-adding value step of managers training is consolidated into interacting empowering training for all level of employees. The risk of undermining the value is reduced to zero as well.

In figure 18 unlike figure 17, all processes are being requested from customers. This property makes customer pulled actions and satisfies the second principle of lean thinking. It should be reminded that treatment company processes are not evaluated in this study due to the scope of research.
Figure 18: Lean Value Stream Map.

- Once a week, deliver the material to the hospital.
- Once a day, collect the materials.
- Share the inventory.
- Transport to the repository.
- Store the inventory.
- Source separation.

Operation area:

- Monthly inventory check.
- Send invoice to the hospital.

Next steps:

- Pay the invoice.
- Company makes return with materials.
- Designate team members.
- Identify emergency contacts.
- Enhance employee relationships with employees.
Chapter 3

Red bag waste trend analysis

As mentioned earlier the treatment company reports the amount of collected red bag waste every month. However, the reports neither specify the composition of waste nor reveal the percentage of non-red bag waste, still studying the reports can lead researchers to understand the pattern of generating red bag waste in the hospital for future considerations.

The trend analysis has been done based on reports received from the treatment company. It should be cleared that to respect the confidentiality of the hospital, real numbers are not presented. Instead, the data are manipulated to new ones keeping the ratios constant and as consequence trend in both sets of numbers stays the same.

Table 3 contains monthly reports of red bag waste disposal from 2013 to 2015. According to WHO the average amount of regulated medical waste per bed in high-income countries exceeds to 0.5 kg or 1.1 lbs. whereas these numbers drop to 0.3 kg or 0.66 lbs. in lower income countries, the difference could be the result of lack of medical waste management programs in the second group of countries. It should be reminded that
regulated medical waste that WHO refers to, consists of red bag waste, pathological waste, pharmaceutical waste, genotoxic waste and radioactive waste. The quick glance over the table and comparing the numbers to WHO scale indicates that average amounts of monthly waste are noticeably high since they only present red bag wastes, and not all categories of regulated medical waste as WHO considers. The numbers look even higher considering the fact that all 954 beds in the hospital could not be staffed over the course of three years.

As table reports, the range of red bag waste fluctuates between maximum 46278.05 lbs. generated in December 2013 to 22439.95 lbs. when it touches the minimum throughout the entire three years in the very next month January 2014.

<table>
<thead>
<tr>
<th>Month</th>
<th>Red bag 2013</th>
<th>Red bag 2014</th>
<th>Red bag 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>29074.058</td>
<td>22439.95</td>
<td>33012.59</td>
</tr>
<tr>
<td>Feb</td>
<td>30573.27</td>
<td>39530.79</td>
<td>32224.27</td>
</tr>
<tr>
<td>Mar</td>
<td>29731</td>
<td>33152.21</td>
<td>23027.03</td>
</tr>
<tr>
<td>Apr</td>
<td>35252.88</td>
<td>30356.04</td>
<td>42651.18</td>
</tr>
<tr>
<td>May</td>
<td>29005.21</td>
<td>40168.96</td>
<td>31667.74</td>
</tr>
<tr>
<td>Jun</td>
<td>29054.35</td>
<td>33877.87</td>
<td>29705.65</td>
</tr>
<tr>
<td>Jul</td>
<td>30145.83</td>
<td>32905.6</td>
<td>36278.32</td>
</tr>
<tr>
<td>Aug</td>
<td>36965.5</td>
<td>40485.77</td>
<td>30646.07</td>
</tr>
<tr>
<td>Sept</td>
<td>30572.62</td>
<td>33174.57</td>
<td>29286.79</td>
</tr>
<tr>
<td>Oct</td>
<td>39280.8</td>
<td>44195.58</td>
<td>38915.76</td>
</tr>
<tr>
<td>Nov</td>
<td>23232.3</td>
<td>33340.19</td>
<td>30274.79</td>
</tr>
<tr>
<td>Dec</td>
<td>46278.05</td>
<td>39004.03</td>
<td>31800.47</td>
</tr>
<tr>
<td>Total</td>
<td>389165.868</td>
<td>422631.56</td>
<td>389490.66</td>
</tr>
<tr>
<td>Average</td>
<td>32430.489</td>
<td>35219.29667</td>
<td>32457.555</td>
</tr>
</tbody>
</table>
The year 2014, scores highest collected amount of waste with 4 months of over 40000 lbs. and the average of 35219.29667 lbs. in another hand 2013 and 2015 have very similar averages around 32400 lbs. which is very close to the overall average of all 36 months equal to 3339.11 lbs.

![Chart 1: Red bag waste Normal Frequency Distribution](image)

Normal frequency distribution chart summarizes the frequency of data fitting in each group of range, starting with the lowest point in table 4, 22439.95 and increase of 2000 in each step. The chart declares that out of 36 months only 3 months generated less red bag waste than WHO standard. The greatest frequency belongs to the range of 2943.95 to 31439.95 with a value of 9. In 18 months collected red bag waste exceeded the average of 3339.11 lbs. This surplus in some months reaches to 14 percent.
Graph 1 plots ups and downs of red bag waste in the hospital. In the period of 4 months from September to December, all three years follow the same pattern. Red bag waste generation drops in September followed by a dramatic increase in October that makes the peaks either the highest point of each year or the second highest. Then in Novembers, another steep decline occurs wherein 2013 the graph falls to the second lowest amount of red bag waste in three years. All Decembers the numbers ascend erratically. As it was pointed out earlier December 2013 claims the highest generation of red bag wastes. As a rough conclusion, the common raise in Decembers could be related to holiday-related activities that leave injuries behind such as road accidents. Increasing emergency care demand would cause a jump in generating red bag waste as well.

Beside very close correlation in the last 4 months of each year, years 2013 and 2015 show the same trends from February to September. Although approaching to month June
is slightly different in comparison. The year 2015 owns a rather turbulent graph, unlike years 2013 and 2015; the year 2014 does not obey same rules and runs a quite different model. The fact that first 8 months of 2014 don’t match with the rest of our data and the relatively high average of collected waste in 2014 challenges the accuracy of collected data in that year.
Chapter 4

Cost Reduction Opportunity

Indicating the sources of waste provides the opportunity to remove them and cost reduction is the very first results of removing wastes.

The hospital pays two types of fees to the treatment company for waste removal:

- Minimum pick up fee.
- Charges per lbs. of wastes

Therefore the hospital is able to reduce the cost by reviewing the volume of the red bag waste as well as minimizing the weight of the wastes.

Table 3 contains data from the collected samples in the red bag waste management value stream in operational floor of the hospital. The percentage of non-red bag waste that was disposed in the red bags varies from 0 to 100.
As it’s clear in table 3, 54.47% of total weigh of sample belongs to non-red bag wastes. However, the composition in the real population might be slightly different, since the scope of this project was identifying the sources of waste, not statistical study.

Considering the same composition for the hospital red bag wastes as samples would result in producing 220,236.16 lbs. non-red bag wastes in average. Assuming that the hospital pays $0.14 per lbs. the cost of non-red bag wastes adds up to $30,833.07. Based of treatment company this amount of non-red bag waste requires 51 extra pick up service, that would add up $828.75 fee to the previous expenses. Obviously any reduction in non-

<table>
<thead>
<tr>
<th>Location</th>
<th>Total Waste in Red Bags (lb.)</th>
<th>% Red Bag Waste</th>
<th>% Non-Red Bag Waste</th>
<th>Red Bag Waste (lb.)</th>
<th>Non-Red Bag Waste (lb.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor A</td>
<td>4.8</td>
<td>20%</td>
<td>80%</td>
<td>0.96</td>
<td>3.84</td>
</tr>
<tr>
<td>Floor B</td>
<td>3.75</td>
<td>100%</td>
<td>0%</td>
<td>3.75</td>
<td>0</td>
</tr>
<tr>
<td>Floor C</td>
<td>1.25</td>
<td>20%</td>
<td>80%</td>
<td>0.25</td>
<td>1</td>
</tr>
<tr>
<td>Floor D</td>
<td>5</td>
<td>50%</td>
<td>50%</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Floor E</td>
<td>1.6</td>
<td>40%</td>
<td>60%</td>
<td>0.64</td>
<td>0.96</td>
</tr>
<tr>
<td>Floor F</td>
<td>7</td>
<td>90%</td>
<td>0%</td>
<td>6.3</td>
<td>0.7</td>
</tr>
<tr>
<td>Emergency A</td>
<td>10.25</td>
<td>0%</td>
<td>100%</td>
<td>0</td>
<td>10.25</td>
</tr>
<tr>
<td>Emergency B</td>
<td>1.5</td>
<td>100%</td>
<td>0%</td>
<td>1.5</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>35.15</td>
<td>45.23%</td>
<td>54.47%</td>
<td>15.9</td>
<td>19.25</td>
</tr>
</tbody>
</table>
red bag waste would save noticeable amount of money for hospital. Mixing non-red bag waste into red bag waste imposes other general costs to hospital as well. Since municipal waste doesn’t require regulated transportation methods, special licensing and handling, it would cost much less than regulated transportation for medical waste. Indeed mixing general waste with medical waste scales up the unnecessarily fees hospitals pay for waste disposal.
Chapter 5

Environmental impact improvement of red bag waste management

Life cycle assessment (LCA) is a tool for the systematic evaluation of the environmental aspects of a product or service system through all stages of its life cycle. LCA provides an adequate instrument for environmental decision support. Reliable LCA performance is crucial to achieve a life-cycle economy” (UNEP). Using LCA helps to quantify the energy and material consumed in entire life cycle of product. LCA estimates damages made to environment including human health, ecosystem, mineral resources and air/water/soil pollutants, in life time of a product or service. All products will be considered as wastes after ending the use stage and entering end of life step. All steps impose kinds of damages to environment. For example mining raw material deducts from natural sources, transporting raw material to manufacturing plants emits air pollutions and noise, production units consume energy, and disposing the waste leads to soil pollution as well.
As it is shown in figure 17, from production to end of life stage, often energy is being consumed. For some items energy consumption is noticeably higher than others, for example electrical appliance.

This section of research overlooks at environmental impacts of managing red bag waste improperly and opportunities to reduce the negative effects.

5.1 Single-Unit Trucks for hauling waste

According to the report of trucks size and weight that US government published, Single-unite trucks with three or more excel; dump trucks, transit mixers, trash trucks, are most common commercial vehicles to use in local and intrastate, short haul operations. These trucks are commonly called specialized hauling vehicles (SHVs). “The most common commodities that they haul are construction material, grain, milk, petroleum products and garbage or waste”. The capacity is 10,000 lbs. or more (USDOT (2000)).
As it was calculated in chapter 4, the hospital generated 220,236.16 lb. non-red bag waste mixed in red bag waste in average annually. Based of treatment company reports, the maximum capacity of every pick up exceeds to 4,345 lb. equal to 2.18 US ton. This amount of waste demands 51 truck/trip for hauling non-red bag waste (disposed in red bags) to the treatment site.

5.2 Greenhouse gas emission

“GLOBAL warming is one of, if not the greatest, environmental threat currently facing our society. Global warming is believed to be caused by emissions of gases that trap heat in the atmosphere” (Warming, C.O.G, 2004).

However some studies present theories that non-greenhouse gas emissions are responsible for climate change in the twenty-first century (Hansen et al., 2000), the common belief claims that global warming is one of the direct results of accelerating greenhouse gas emissions (Abrahamson, 1989). Despite uncertainty exists about the reasons of climatic changes the role of the transportation sector in the production of greenhouse gases is not deniable. Carbon Dioxide (CO2) is one of the byproducts of any engine that burns carbon-based fossil fuels. The energy consumption and the engine efficiency affects the amount of carbon dioxide (CO2) released per unit of transportation service (i.e. per ton-mile). 22.8 lbs. of CO2 is released by every gallon of diesel fuel (FHWA, 1997b). Burning fossil fuels in manufacturing units also is another source of producing greenhouse gases such as CO2 that has important role in global warming (Jacobson, 2002).
Segregating non-red bag waste from red bag waste would noticeably reduce the amount of fuel consumption due to reduction the number of truck trips to the treatment site.

5.3 Air pollution caused by extra transportation

Studies claim that internal combustion engines used to transport passengers and freight is a major cause of air pollution. Emissions composition in the United States in 1994 caused by highway vehicles accounted for 62.3% of all carbon monoxide (CO) and 31.9% of all nitrogen oxides (NOx) (Bureau of Transportation Statistics, 1996, Forkenbrock, 1999). For diesel engines, NOx (nitrogen oxides), is considered the primary emission followed by CO (carbon monoxide). After NOx and CO, PM10 (particulate matter under ten microns in aerodynamic diameter), SO2 (sulfur dioxide), and VOC (volatile organic compounds, mainly hydrocarbons) are the main air pollutants (TRB, 1995). Table 6 contains the emission rate for freight trucks. Carbon monoxide is not being calculated since it is too dispersed to affect the life and health of rural population (Forkenbroke & Schweitzer, 1997a).

Table 6: Emission rate for freight trucks

<table>
<thead>
<tr>
<th>Emission</th>
<th>Rate (lb. per ton-mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOC</td>
<td>0.000189</td>
</tr>
<tr>
<td>NOx</td>
<td>0.0030</td>
</tr>
<tr>
<td>SO2</td>
<td>0.000085</td>
</tr>
<tr>
<td>PM10</td>
<td>0.000227</td>
</tr>
</tbody>
</table>

Adopted from (Forkenbroke, 1990)
Considering the waste trucks capacity equal to 10,000 lbs. (4.5 metric ton), burning fossil fuel in every extra mile produces .00085 lb. of VOC, .0135 lb. of NOx, 0.000382 lb. of SO2 and 0.00102 lb. of PM10.

According to the hospital, distance between the healthcare facility and the disposal site is 7 miles, the reduction of emissions is calculated in table 7.

Table 7: Emission reduction by elimination of non-red bag waste

<table>
<thead>
<tr>
<th>Emission</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOC</td>
<td>0.15</td>
</tr>
<tr>
<td>NOx</td>
<td>2.33</td>
</tr>
<tr>
<td>SO2</td>
<td>0.066</td>
</tr>
<tr>
<td>PM10</td>
<td>0.18</td>
</tr>
<tr>
<td>CO2</td>
<td>17.194</td>
</tr>
</tbody>
</table>

5.4 Noise caused by extra transportation

Another form of air pollution that transportation imposes to the environment is noise pollution. This form of pollution is increasing more than ever and is a serious threat to health and well-being. Sustained growth in highway, rail, and air traffic, which remain major sources of environmental noise, increases the rate of noise pollution. Noise pollution has significant direct and cumulative adverse effects in environment. Impairing human health and well-being is the intangible result, and distracting the economy is the tangible outcome of noise pollution (Goines and Hagler, 2007).
The hospitals are one the sensitive arias to noise pollutions, therefore preventing any unnecessary transportation of red bag waste not only would contribute to the reduction of noise pollution, but also protects the hospital against economic damages due to noise.
Chapter 6

Practicing lean tools to improve the system

Seeking for perfection is the fifth principle of lean thinking that points out the importance of continually improving. Lean thinking does not consider an end for the ongoing improvement, since every day new innovations are available that can help processes become leaner. There are always new customers’ requests that should be recognized and accordingly new products should be invented. Value stream should be reviewed often for identifying new sources of waste; even value should be defined as many as it needed. Lean Six sigma offers tools to evaluate processes and detect the potential effects, sources of waste, problems, root causing issues, and solutions.

This research suggests applying Plan-Do-study-act (PDSA) cycle in corporate with lean 3P for continuous quality improvement. The concept and application of PDSA cycle also known as the Deming wheel, was first introduced to Dr. Deming by his mentor Walter Shewhart (The Deming Institute). PDSA consists of four steps:

Plan: Identifying goals for the systems, defining measurements, planning to success.
Do: executing the actions toward the goals.

Study: Measuring the success, evaluating the plan, identifying mistakes.

Act: Utilizing learnings from previous step, adjusting goal, theory, plan if needed and moving toward goal (The Deming Institute).

Figure 20: PDSA cycle

Red bag waste management process has been Planned and executed for many years. Therefore, it can be assumed that steps P and D are completed in the hospital. This study also has covered step S, by identifying errors and sources of waste. To improve red bag management value stream, solutions should be discussed. Step A wraps up findings to
improve the process. This research recommends using lean 3P tool for implementing the improving process in step A.

### 6.1 Improving the red bag waste management value stream using lean 3P

As a historical note, the term 3P was first introduced by 3M Corporation in 1975 long before lean was known. 3M designed 3P program to reduce the cost of operation while preventing environmental pollution. 3M preferred preventing pollution rather than controlling it and the program 3P emphasized on Pollution Prevention Pays (Sinton, 2010).

Hiring lean 3P is quite common whether there is a need for inventing a totally new product (Coletta, 2012) or improving an existing process (Ramakrishnan et al., 2011). Lean 3P has been presented in the different industries that have interpreted Ps in different combinations. An example of practicing this tool in healthcare is designing an endoscopy facility in northeast England where 3Ps stand for Production, Preparation, and Process. The lean 3P method creates structured approach to bringing corporate and clinical workers together with cognition of patients’ requests (Smith, 2016). Lean 3P has been used to create lean marketing with focusing on Purposes, Practices, and people (www.business901.com).

This study has adopted Womack version of 3P in “going lean in healthcare” (Womack, et al., 2005). In this work Womack summarizes the perfect process in three dimensions

- The right value (purpose).
- The best method and the least waste (process).
• The highest sense of accomplishment and satisfaction (people).”

The recommendations and suggestions for the red bag waste management value stream improvement are made by focusing on purpose, process, and people.

**Purpose:** The key to verifying whether the purpose is well understood or not is questioning the acceptance the value in the organization. The value in red bag waste management as it was discussed in value stream mapping section is to protect any person from getting injured or infected by hazardous waste and preventing the environment from getting contaminated by medical waste. In this specific process since the primary customer, patient, is not in direct touch with medical waste, the attention goes to support group or caregivers. There is no doubt that medical waste management would benefit patient by directs and indirect effects. In short term, peace of mind, and in long run, lowering the cost of healthcare are benefits for patients. So, to ensure that the purpose of medical waste and especially red bag waste is being clear to everyone involved in the value stream we shall review the stages carefully.

Observations indicate that out of 130 recorded errors, only 1 piece of evidence could be interpreted as a signs of undermining the value: When a bloody canister was found un-bagged in red bin. This sample showed the risk of violating safety. Although this case must be addressed, but there is enough data to support the idea that value is well understood and safety is an internal demand in the hospital. However, this statement could not be made as strongly about the purpose of training meetings. The training meetings are supposed to fulfill the same purpose as the other steps of the value stream,
but it does not receive the same attention and commitments as others. The following list could be useful practice to reinforce the importance of understanding the value:

- Designing new posters and signs enforcing the value of proper training toward segregation.

- Designing surveys and questionnaires to discover the desired form of training/empowering meetings.

**Process:** Sources of waste were detected in all five steps of red bag waste management.

Sources of wastes depending on

Some wastes are removable by hospital directory act:

- Ordering smaller size of red bags to prevent inventory waste from happening.

- Elimination the transportation waste by reducing the numbers of red bag collection trips to the temporary storages on the floors.

- Assigning responsibility to an associate to ensure red bags are available in all patients’ room at all time to prevent waste of motion.

- Contact the companies that provide re-usable sharps container programs and obtain cost information and quotes for implementing the program (Based on success story in California hospital).

- Designing educating posters to explain proper methods of stacking sharp container in the temporary storages.
• Establishing collaborative relationship with treatment company and involve them in designing educational material.

• Requesting the treatment company to provide composition reports on collected red bag wastes.

• Replacing training classes to problem solving section and empowering the employees.

• Hiring properly developed tools to asset the amount of generated waste in each period of improvement program and evaluating the decrease of waste generation by utilizing the tool. Hospital Assessment Tool (HAT) is a specific tool developed for hospitals to evaluate and reduce solid medical waste (Franchetti and Kumar, 2010). The tool has grading ability to score hospital skills in managing solid waste based of the answers to the questionnaire. In next page results of running the tool before and after improvements are shown. In figure 21, the score based on current amount of red bag waste is 83.3 out of 100. After reducing non-red bag waste the score goes up to 91.6 out of 100.
Figure 21: Hospital Assessment Tool, unimproved score

```
<table>
<thead>
<tr>
<th></th>
<th>How much percentage of your hospital’s waste is medical red bag waste? Is it &lt;15 %</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>156</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>157</td>
<td>How does your hospital dispose of your medical red bag waste?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>incineration (outside)</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>autoclave (outside)</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>autoclave (inside)</td>
<td>No</td>
</tr>
<tr>
<td>158</td>
<td>Is the Red bag packaging leak resistant?</td>
<td>Yes</td>
</tr>
<tr>
<td>159</td>
<td>Is the Red bag packaging imperious to moisture?</td>
<td>Yes</td>
</tr>
<tr>
<td>160</td>
<td>Is the Red bag packaging of sufficient strength to prevent tearing or bursting?</td>
<td>Yes</td>
</tr>
<tr>
<td>161</td>
<td>Are the Red bag packages sealed to prevent leakages during transport?</td>
<td>Yes</td>
</tr>
<tr>
<td>162</td>
<td>Are the Red bag packages puncture resistant for sharp?</td>
<td>Yes</td>
</tr>
<tr>
<td>163</td>
<td>Are the Red bag packages placed in secondary containers that are constructed</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>of materials that will prevent breakage of the bag in storage and handling?</td>
<td></td>
</tr>
<tr>
<td>164</td>
<td>Are all the red bag containers kept at the appropriate places (not near the</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>patient bed, near the wash basin, in the lounge etc)?</td>
<td></td>
</tr>
</tbody>
</table>

Total Score: 12

MAXIMUM SCORE

OVER ALL SCORE (GOOD)

<table>
<thead>
<tr>
<th>Sectional Score %</th>
<th>Category</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>Excellent</td>
<td>93.33333</td>
</tr>
<tr>
<td>70-89</td>
<td>Good</td>
<td>0</td>
</tr>
<tr>
<td>60-69</td>
<td>Poor</td>
<td>0</td>
</tr>
<tr>
<td>&lt;60</td>
<td>Very Poor</td>
<td>0</td>
</tr>
</tbody>
</table>
```

(Franchetti and Kumar, 2010)

Figure 22: Hospital Assessment Tool, improved score

```
<table>
<thead>
<tr>
<th></th>
<th>How much percentage of your hospital’s waste is medical red bag waste? Is it &lt;15 %</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>156</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>157</td>
<td>How does your hospital dispose of your medical red bag waste?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>incineration (outside)</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>autoclave (outside)</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>autoclave (inside)</td>
<td>No</td>
</tr>
<tr>
<td>158</td>
<td>Is the Red bag packaging leak resistant?</td>
<td>Yes</td>
</tr>
<tr>
<td>159</td>
<td>Is the Red bag packaging imperious to moisture?</td>
<td>Yes</td>
</tr>
<tr>
<td>160</td>
<td>Is the Red bag packaging of sufficient strength to prevent tearing or bursting?</td>
<td>Yes</td>
</tr>
<tr>
<td>161</td>
<td>Are the Red bag packages sealed to prevent leakages during transport?</td>
<td>Yes</td>
</tr>
<tr>
<td>162</td>
<td>Are the Red bag packages puncture resistant for sharp?</td>
<td>Yes</td>
</tr>
<tr>
<td>163</td>
<td>Are the Red bag packages placed in secondary containers that are constructed</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>of materials that will prevent breakage of the bag in storage and handling?</td>
<td></td>
</tr>
<tr>
<td>164</td>
<td>Are all the red bag containers kept at the appropriate places (not near the</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>patient bed, near the wash basin, in the lounge etc)?</td>
<td></td>
</tr>
</tbody>
</table>

Total Score: 11

MAXIMUM SCORE

OVER ALL SCORE (GOOD)

<table>
<thead>
<tr>
<th>Sectional Score %</th>
<th>Category</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>Excellent</td>
<td>91.666666</td>
</tr>
<tr>
<td>70-89</td>
<td>Good</td>
<td>0</td>
</tr>
<tr>
<td>60-69</td>
<td>Poor</td>
<td>0</td>
</tr>
<tr>
<td>&lt;60</td>
<td>Very Poor</td>
<td>0</td>
</tr>
</tbody>
</table>
```

(Franchetti and Kumar, 2010)
Some other sources of waste are not removable unless the employees as front liners are educated and stimulated. Records show that lack of proper education and commitments is the reason of over 85% of the waste observed. However lean 3P tool holds an important position for people as requirement for all improvements, it seems in this specific project people are even more important, and to achieve process quality improvement there is a special need to focus on the people.

![Diagram](image)

Figure 23: Lean 3P application in red bag waste management improving

People are fundamental component of improving the entire value stream. People are capable to improve the quality of the process and accomplish the purpose.

**People**: Unlike manufacturing systems, red bag waste management process offers two important roles to people. People are customers, since treating hazardous waste properly
ensures their health and safety; people are service provider and workers as well, since they execute the regulations and run the processes. Our findings magnify that vast range of errors and wastes are reasons of people. To address the quality improvement fist the approach should be defined.

The old mass production era that believed people were only parts of manufacturing system like machines, they should work isolated and individually, they don’t need to think but only to obey and execute (Taylor, 1911), does not fit in our current time any longer. In contrast, lean organizations; strongly support the idea of engaging empowered employees (people). Decentralizing Problem-solving and decision-making, transferring responsibilities from supervisors to individual workers and teams, are major strength of lean systems. A fundamental claim of lean production is that quality improvement, productivity increased, and flexibility boost can be obtained by transferring responsibility and decision making to employees. According to Capelli and Rogovsky (1994) the following characteristics of lean should be practiced in work place:

- employee empowerment and participation in decision making;
- group participation, or teamwork;
- supportive personnel practices including profit sharing, pay-for-skill programs, skills training and socialization programs

In the published research by Lawler and his colleagues (1995) who have surveyed the implementing employee empowerment, termed employee involvement (EI), in US
Fortune 1000 companies, EI was defined as pushing downward to employees throughout the firm four key factors:

- “Power to make decisions affecting how to perform their jobs and even what strategies the firm pursues;
- Information about business performance, plans, and goals;
- Rewards that are based on organizational performance; and
- Knowledge that gives employees the technical, interpersonal and group skills necessary to affect job and organizational”

The following suggestions are made to implement lean empowering principles to answer the needs red bag waste management in the hospital:

1. Holding empowering meeting engaging all people, repeat the meeting if needed.
2. Involving the people in the value defining process.
3. Forming problem solving groups.
4. Screening documentaries of out-side red bag waste treatment steps.
5. Presenting the images of improper red bag disposal.
6. Asking people to design solutions to the problem of undermining red bag waste management.
7. Asking people to decide of measurements metrics.
8. Providing fact sheets related to extra cost paid for non-red bag waste.

9. Inviting outstanding performers to facilitate the problem solving groups.

10. Asking people to propose internal auditing methods to stop depending on external inspection (Deming, 14 points).

11. Drawing bigger pictures, including environmental loss because of improper red bag waste management.

As it discussed employee involvement, is a vital element to improve red bag waste management in the hospital. After spending enough time practicing the lean guide lines quantitate assessment could be performed to measure the success metrics. The improvement made would be inspiring for people to enter another cycle of PDSA.
Chapter 7

Practicing lean tools to improve the system

Using lean six-sigma approach to red-bag waste management leads to significant improvement in many aspects. Cost reduction is direct tangible result, whereas reduction in air pollutants and noise is intangible result and will affect the public health. Table 8 includes improvement states in red bag waste (lb.), HAT score, and cost.

Table 8: Process Improvement by elimination of non-red bag waste

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Current State</th>
<th>Improvement state</th>
<th>Improvement %</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAT Benchmark</td>
<td>83.33</td>
<td>91.66</td>
<td>8.33</td>
</tr>
<tr>
<td>Red Bag Waste (lb.) (Average)</td>
<td>400,429.16</td>
<td>180,193.21</td>
<td>55.00</td>
</tr>
<tr>
<td>Cost ($) (Average)</td>
<td>57557.68</td>
<td>25900.96</td>
<td>55.00</td>
</tr>
</tbody>
</table>
References


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