LEAN SIX SIGMA: A METHODICAL APPROACH TO IMPROVING SURGICAL PATIENT HEALTHCARE

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Abstract—*Lean Six Sigma(LSS) is the combination of Lean and Six Sigma methodologies, both of which are meant to increase productivity without sacrificing a good's quality. Whereas Lean focuses on improving product flow and eliminating waste, Six Sigma emphasizes decreasing variability in production. Combining both Lean and Six Sigma is more beneficial than using one technique over the other, as each method's strength compensates for what the other method is lacking. Lean Six Sigma results in an ideal process that combines the streamlining of Lean with the standardization of Six Sigma.*

The LSS approach was initially used in manufacturing, but has more recently had applications in the health care industry. Lean Six Sigma's particular application in modifying the patient care procedures throughout the pre-operative, operative, and post-operative process has minimized patient's duration of stay in hospital, infection rate, and overall costs. Lean Six Sigma is a versatile process that adjusts hospital protocol based on specific issues identified by hospital staff. Recently, the healthcare industry has adopted LSS as the cost of the country's healthcare system is being scrutinized. LSS was specifically selected because it minimizes costs while still prioritizing the quality of patient care. When implemented in hospitals, Lean Six Sigma has had large impacts. If executed correctly, this technique will ultimately improve both the patient's well-being and the economy. Utilizing LSS can reduce a country's healthcare spending and promote economic sustainability, as the millions of dollars saved can be allocated elsewhere.

Key Words—Hospital performance, Lean Six Sigma, Minimizing hospital expenses, Optimization, Patient care

AN OVERVIEW OF LEAN SIX SIGMA AND ITS USE IN HOSPITALS

Lean Six Sigma is a quality management technique employed by engineers to maximize resources and reduce costs while still valuing the quality of the good, product, or service. Lean Six Sigma(LSS) developed as a result of combining the separate quality management techniques of Lean and Six Sigma. In using Lean and Six Sigma individually, engineers recognized that the two separate processes had major faults. However, if the two techniques were combined, they compensated for each other's weaknesses. Resulting from the combination of these two methodologies was a process that focuses on streamlining, standardizing quality, and considering the consumer's perspective. Lean Six Sigma can be implemented in any industry, but has recently been introduced to the healthcare industry. Lean Six Sigma's particular application in modifying the patient care procedures throughout the pre-operative, operative, and post-operative process has minimized patient's duration of stay in hospital, infection rate, and overall costs.

Today, implementing Lean Six Sigma in hospitals can be beneficial to hospitals, patients, and the general public. James Harrington, an engineer and author of multiple books on quality improvement, reported that annually two million patients in the United States get an infection while hospitalized. Of those two million people, 87,600 of them die as a result of the infection [1]. Additionally, according to the Public Broadcasting Station, healthcare costs account for 17.6 percent of the United States GDP, which is much higher than any other country [2]. These are alarming statistics that need to be immediately addressed. Implementing Lean Six Sigma has the potential to decrease the cost of healthcare, along with increasing the overall quality of patient care, which includes decreasing surgical patient infection rate.

THE INTEGRATION OF LEAN AND SIX SIGMA

Lean and Six Sigma are two independent methodologies that share the common goal of reducing waste with respect to time, money, and resources. However, the two processes aim to eliminate these wastes through different approaches.

When implementing Lean, a large focus is placed on increasing the speed of production. As with any process, there are multiple steps to be conducted to get a product to completion. As mentioned in *Lean Six Sigma in Healthcare*, engineers focus on improving product flow between each step of the process instead of looking at the actual steps of each part of the process [3]. The core concept of Lean is that the majority of waste stems from downtime between the different

stages of a production line, not the time spent producing the product.

The Lean method also provides a different perspective when assessing the value of a product. In Lean, the value of a part of a product is directly related to the consumer's opinion of that part. For example, the worth of a handle on a hospital bed is only considered in terms of value to the patient, the consumer, and its use to hospital staff has no impact. In the words of Jay Arthur, Lean thinking is to, "Let the patient pull the product or service; don't push" [1]. By allowing the consumers to influence the design of a product instead of assuming what consumers would want, the resources and time spent adding unnecessary parts are saved.

The strength of Lean is in its fundamental principles: satisfy the customer and reduce waste by producing only what is desired by consumers, then streamline the production process to improve flow. *Lean Six Sigma in Healthcare* discusses that while the concepts of Lean are excellent, the tools to analyze processes and implement Lean are lacking [3].

Six Sigma has the ability to compensate for the weaknesses of Lean. As detailed in *Lean Six Sigma in Healthcare*, Six Sigma is an extremely structured process [3]. Six Sigma has a hierarchal chain through which goals are given by project owners, and then assignments are passed down the chain based on the level of a person's Six Sigma training. As will be discussed in the following section, multiple techniques are used throughout the standard Six Sigma process, DMAIC. DMAIC is an abbreviation for define, measure, analyze, improve, and control, the five mandatory steps of Six Sigma. According to *What is Lean Six Sigma?*, these five steps can be considered, "the common thread that links strategies, tools and methods improving economic, environmental, and social performance," since the entire DMAIC process is based upon creating a more efficient, and thus more sustainable, system [4]. Six Sigma places a large emphasis on in-depth analysis of data [3]. In focusing on quantitative data, engineers are only considering non-human factors. They are searching for areas of variability, identifying the causes of variability, and then creating a procedure to minimize the variability. In standardizing procedures, large cost minimization occurs.

In looking at the strengths and weaknesses of Lean and Six Sigma, it is apparent how the combination of the two can provide a better technique for improving surgical patient care in hospitals. Six Sigma's emphasis on quantitative analysis means that the analyzed process is reduced to data points. When trying to improve the surgical process in hospitals with Six Sigma, reducing humans to data points means that quality of care can be unaccounted for, since patient well-being is difficult to quantify and factor into statistical analysis. Adding the Lean concept of evaluating the degree of healthcare based upon the patients' satisfaction creates a process that promotes the standardization and minimization of resources. In doing this, the standardized changes that Six Sigma analysis suggests are accepted only if they maintain or increase the well-being of the patient.

HOW TO APPLY LEAN SIX SIGMA

Lean Six Sigma follows the design, measure, analyze, improve, and control (DMAIC) process that Six Sigma does. However, within each of the five steps there are numerous processes carried out that include aspects of Lean.

As in both Lean and Six Sigma, the process begins by identifying one or multiple issues that need to be reformed. After establishing the issue, a chart or document must be created to outline the timeline for the LSS process, including a date to evaluate the success of LSS implementation. Within this document, the Critical-To-Quality (CTQs) indicators must be established. CTQs are measured factors to determine the success of LSS implementation [1]. A common CTQ measure is the number of customer complaints within a given time period. CTQs are used with Lean Six Sigma since a large concern of Lean Six Sigma is the customers' satisfaction.

After parameters have been established for LSS integration, data is then collected, with engineers verifying they have an ample sample size for accurate results.

The most time-consuming and crucial part of the process, the analysis, follows. Properly analyzing the data is an integral part of developing a lasting, effective solution to the problem identified in the first step of the Lean Six Sigma process, since modifying mis-identified production areas will do nothing to solve the problem. The analytical aspect of Lean Six Sigma has both a graphical and a statistical analysis component.

When graphing and creating charts for the data, there are multiple options. Three charts often used are the control chart, Ishikawa fishbone diagram, and a Pareto chart. A control chart graphs variation (which is determined by calculating standard deviation) over time. A mean point along the y axis is considered standard, and the data is plotted in regards to how many sigma, or standard deviations, the data is above or below the mean. Using a universally accepted set of rules for "unstable conditions", the graph can be analyzed to see the degree of variability in the process. If the plot reveals a highly unstable process, engineers must stabilize the process before continuing their analysis [1].

Looking at Figure 1, the control chart is divided into three sections, with the first section being from October 2008 to October 2009, the second section being from November 2009 to July 2010, and the third section being from July 2010 to March 2012. Each of these sections represents pre-implementation, implementation, and post-implementation of Lean Six Sigma respectively. Within each section, there is a straight blue line, the control limit (CL). The three dotted lines above and below the control limit represent one, two, and three sigma away from the control limit. Anything more than three sigma away is considered outside of the upper or lower control limit, and indicates extremely high instability. In the chart, the implementation period reveals the most stability in

the mean length of stay of the patients, as none of the data points are more than a sigma away from the control limit. Neither the pre-implementation or the post-implementation has any data points that indicate unstable conditions, but it should be noted that the control limit for mean length of stay decreased during the implementation and post-implementation of Lean Six Sigma in the Indianapolis hospital.

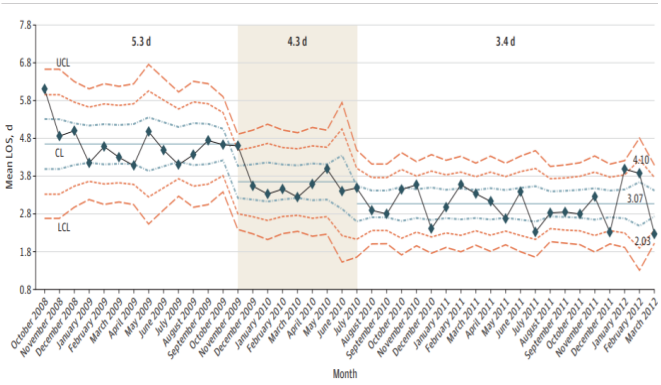

FIGURE 1 [5]
Control Chart for Length of Stay in an Indianapolis Veterans Affairs Hospital

The Pareto chart and Ishikawa fishbone diagram both help find the root causes of the problems, but they are constructed in slightly different ways. As seen in Figure 2, the Ishikawa fishbone diagram constructed for the case study of assisted related infections in surgical patients has one line that lists the main problem, and then has multiple lines pointing into the main line that list problem areas contributing to the larger problem [6]. Additional, smaller arrows point to the problem areas and list even more specific reasons contributing to the problem. The Ishikawa fishbone diagram is a multi-level cause-and-effect diagram, but groups the causes so that the main problem is more manageable to fix.

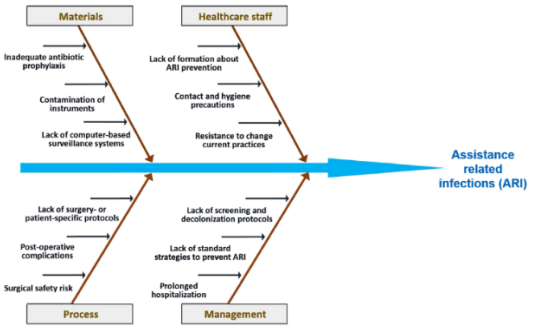

FIGURE 2 [6]
Ishikawa fishbone diagram for the causes contributing to ARI

The Pareto chart is a single-level cause-and-effect diagram. The basis of the Pareto chart is the Pareto principle: 80 percent of the problems stem from 20 percent of the causes [7]. The chart is structured as a bar graph, with the issues contributing to the larger problem placed along the x axis. Along the y axis are both the total frequency of occurrence, along with percentage. Starting from the left side of the graph, a line is plotted displaying how much each issue, summed with all of the issues to the left of it, contribute to the overarching problem. Thus, in constructing the chart, the key causes can be identified.

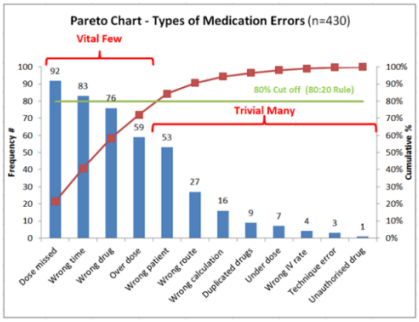

FIGURE 3 [7]
Example of the construction and analysis of a Pareto chart

Aside from analyzing charts and graphs, LSS also includes statistical testing. A chi-square test can be run to check whether or not a result occurred due to chance. This becomes useful when engineers analyze a graph or chart and think that they have found a relationship between a certain variable and the identified problem. Running a chi-squared test determines if the two factors do have a relationship, like when engineers working on a case study to reduce infections in the surgery department of a hospital used a chi-square test to confirm a relationship between the number of procedures performed on the patient and the number of bacteria the patients were inhabited with [6].

After determining the issues within the process, engineers put together a team of individuals with first-hand experience and knowledge of the process. Engineers then work with this team to develop solutions to the issues. This team provides additional insight to engineers, since engineers can propose solutions, but the experienced team will offer their opinion on whether the solution will work in practice, not just theory.

Once solutions have been developed to the identified problems, the process is remodeled to accommodate these solutions. Following an initial period of adjustment to these new procedures, the CTQ factors are analyzed. Statistical hypothesis tests are once again conducted to determine if the new procedure is more effective than the previous one. Based upon information gathered from the staff and data from the statistical analysis, any defective parts of the process are

reevaluated by the team and then altered. This reevaluation and modification process can be repeated as many times as necessary until the team is satisfied with the results.

FURTHERING ECONOMIC SUSTAINABILITY WITH LEAN SIX SIGMA

The definition of sustainability used by the United Nations is, "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [8]. In regards to this definition, Lean Six Sigma creates sustainable processes. When a problem is identified with Lean Six Sigma, data is analyzed and solutions are developed for the problem. Following the implementation of the solutions, further testing over a period of time ensures that the changes the engineers have made are having a positive effect. Positive effects could be a decrease in cost, time, or materials, while maintain or improving the quality of care. Engineers continue to remodel the process until the data shows positive results over a sustained amount of time. Lean Six Sigma is a methodology that benefits both the present and future generations by reducing time, wasted materials, and excessive costs. Lean Six Sigma is particularly useful in advancing economic sustainability in hospitals.

According to the Business Dictionary, economic sustainability is, "the use of various strategies for employing existing resources optimally so that a responsible and beneficial balance can be achieved over the long term" [9]. As stated by Jay Arthur, "Lean Six Sigma drives dramatic improvements in speed, quality, and profitability" [1]. Lean Six Sigma has the ability to create economically sustainable processes. Lean Six Sigma maximizes resources by reducing waste, maintains responsibility by upholding the quality of patient care, and improves profitability by minimizing costs. The Lean Six Sigma modifications are continuously evaluated over time to ensure that the processes are still benefiting the hospital and patients. Lean Six Sigma's focus on improving processes ensures that every patient benefits from the changes made to hospital procedures. This will become increasingly evident through specific case studies discussed in later sections.

LEAN SIX SIGMA IN HOSPITALS

When most people think about a hospital they do not envision it as a business. Because of this, it would seem that implementing the business strategy of Lean Six Sigma would have no place in a hospital. Even though we may not think of it as one, a hospital is a business in many ways. There is no room in a hospital for wasted materials or time. In hospitals, unlike in some businesses, this waste could be the difference between life and death. This is a big reason why removing waste, which includes both resources and time of the patient and workers, and streamlining processes are so important. Hospitals must take many things into account when making decisions to try and improve the care that they provide to patients, which is why treating the hospital as a business can be so beneficial.

Implementing Lean Six Sigma methodology allows hospitals to reduce the waste in their system as well as making sure they are consistently treating patents in the most effective way. In hospitals, providing high quality care on a consistent basis is just as important as removing waste from their systems. Unlike most models, Lean Six Sigma allows the hospitals to do both at once which leaves more time, man power, and funds to allow for the implementation of the improvements found from the process. This in turn leads to more satisfied patients and staff as well as saving money for all involved in the process.

MODIFICATIONS MADE TO THE PRE-OPERATIVE PROCESS

One of the most noted problems with the surgical process comes before the patient even reaches the operating room. According to the Institute of Medicine, one of the biggest problems with healthcare is the time it takes to receive care [10]. This includes the time between when a patient requests an appointment to the time they actually get their appointment, along with the time that the patient has to wait in the doctor's office. In most cases of setting up a patient's surgery, the patient is seen by the doctor and it is determined when a surgery needs to take place and what exactly the surgery entails. Since there are so many steps in the surgical process, delays in care can be caused by a number of factors, making it harder to find the root of the problem. Lean Six Sigma helps greatly in identifying the roots of the problem.

Decreasing Wait Time Through Improved Scheduling

In most cases the time between when a patient requests an appointment and when they are actually able to be seen is quite lengthy. To explore the causes behind this, a research team implemented Lean Six Sigma in a pediatric practice subspecialty ambulatory clinic in the Midwest [10]. One of the main causes that the team was able to pinpoint was the lack of standardization in the scheduling system [10].

In healthcare there can be a lot of unforeseen circumstances, such as a patient emergency. This patient is then prioritized, and other patients' appointment times are altered, therefore throwing off the whole scheduling system. Engineers realized that because of the lack of standardization in the clinic's scheduling process, staff struggled to determine how to deal with patients whose appointment had been moved. Would these patients have to start from the beginning, and make an appointment like they had never had one in the first place, or would they get special priority over other patients? These questions didn't have a defined answer within the practice. If a patient had to start anew they may once again be subjected to long wait times. This would cause many more

complications than just the staff's initial confusion. Researchers determined that causing patients to wait weeks and even months for appointments can lead to more cancelations, coming late to appointments or no-shows, which leads to even more backups [10]. Using Lean Six Sigma methodology allowed for this major problem to be identified which in turn allowed the practice to come up with a standard procedure to follow in these circumstances [10].

Eliminating Direct Wait Time

Once a patient makes it through the process of getting an appointment they still must deal with waiting in the doctor's office or waiting in the hospital for their surgery. Using the DMAIC method in pediatric practices, a group of researchers were able to determine several major causes that led to longer wait times in offices [10]. One source they were able to identify was the inconsistencies in the appointment lengths. Different conditions in patients caused variation in the length of time that each patient spent with the doctor. This timing affected all the appointments after it. If a patient spent less time with a doctor, the practice was in some cases able to move on to the next patient. More often, a patient took more time with the physician than was expected. This caused the next appointment to be delayed, which also often resulted in patients who were less satisfied with their care. With the engineers identifying the issue of wait time, this gave them another factor to take into consideration when they remodeled the clinic's scheduling procedures using LSS.

The researchers and staff at these clinics chose to focus on balancing the supply and demand of appointments [10]. During the initial analysis of this practice the researchers determined that not only were more patients requesting appointments at the beginning of the week, but there were also certain times of the day when there were more patients than the practice could handle [10]. To alleviate the drastic differences between patient flow, they decided to implement the Heijunka, or level-loading method [10]. This process is used to try and balance the supply and demand by spreading out the patients evenly throughout the day [10]. To use this technique the team first collected data from the practice, including physical limitations of the office size, preferred doctor schedules, and how long it takes to prepare a patient to be seen [10]. Using this data, they were able to create a schedule that evenly spaced out patient arrival time, along with considering each doctor's desired start and finish times. After the template was implemented the team began to collect data to ensure the new system was effective. The data collected after the implementation of level-loading showed that significantly more patients were seen with the new system in place [10]. Overall, the implementation of Lean Six Sigma in this case was shown to help improve these practices and their patients' satisfaction.

REFORMING THE OPERATING ROOM

While the pre-operative phase is the cause of most wasted time there is also still unnecessary delays in the operative phase. In a study taking place in a gastro surgical department, researchers used Lean Six Sigma to examine the hospital surgical procedures, beginning with the time in the surgical theater, or operating room, all the way to their discharge time [11]. Their analysis was focused on reducing the number of non-value adding steps in the surgical process. These engineer's initial analysis concluded that there was approximately 60 minutes of nonproductive time from the moment the patient is wheeled into the surgical area to the time the theater is ready for the next patient [11]. As their analysis continued, they found that this process included almost 100 steps [11]. The steps that seemed to be adding to the wasted time were split into categories and analyzed using an Ishikawa fishbone diagram that is seen in Figure 4 below [11]. These steps were then evaluated to see if they were controllable. The 6 steps that were found to be controllable became the basis for the implementation phase [11]. Engineers worked with licensed healthcare staff from the gastro surgical department and employed their new-found knowledge about the problems of improper scheduling, unprepared theaters, delays in moving patients, and wasted time when remodeling the operating room procedures [11]. Once these steps were eliminated in the implementation phase of the process, the nonproductive time was decreased to 28 minutes [11]. Along with the elimination of wasted time, this study showed a significant reduction in costs. The improvements made by implementing LSS in this specific case increased the hospital's profits by about $80,000 [11]. The more efficient surgical process increased the number of operations that could be performed, and thus generated profit. Additional revenue was accumulated by reducing unnecessary wastes. With LSS, this process permanently increases the gastro surgical department's profits, promoting economic sustainability within the department.

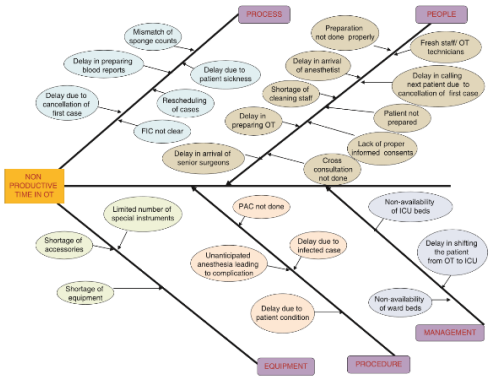

FIGURE 4 [11]
Analysis of Non-productive time in the operating theater through an Ishikawa fishbone diagram

This process once again proved to be very effective when used to analyze non-value adding steps in an outpatient surgery center [12]. In this specific study there were found to be 35 steps in each patient's process, with 14 of these steps found to be non-value adding [12]. The large number of non-value adding steps were because of increased patient involvement in the surgical process. With the facility being an outpatient center there were less serious surgeries taking place, and therefore more responsibility was given to the patient. Some of the extra non-value adding steps that were caused by more involvement of the patient were patients reporting to the wrong operating area and being unable to find where they needed to go [12]. During the implementation phase these specific problems were resolved by adding detailed sketches of the area in several locations to aid with navigation [12]. Problems like ones addressed by the previous study of gastro surgical operating procedures were also corrected which led to a decrease in non-value adding time from 57 minutes to just 24.5 [12].

Another major problem that occurs during operation can be the introduction of foreign bacteria [6]. The introduction of bacteria can lead to infections which leads to even more complications for a patient. Because of these factors, a study was specifically conducted that implemented Lean Six Sigma to reduce the risk of infections in surgical patients [6]. Once again, the engineers used a fishbone diagram to look at the four main areas that led to patients contracting infections: material contamination, healthcare staff, process, and management [6]. When it came time for the implementation phase, the researchers found ways to improve each of these areas including new training protocol for the staff that interacts with the patients, as well as updating the procedure for sterilizing equipment [6]. Because of these new procedures and others implemented by the team, the percentage of infected patients was reduced from 0.37% to 0.21% [6]. Overall the study was shown to decrease the average length of stay as well as increasing the satisfaction of patients. From the hospital management perspective, it led to a decrease in costs for the hospital and an improved quality of care given [6].

ADJUSTING THE POST-OPERATIVE PROCESS

The area that prolongs length of stay the most is the post-operative process, and thus many case studies of Lean Six Sigma in hospitals have made multiple adjustments in the post-operation procedures. Discharging a patient from the hospital is extremely time-consuming in regards to completing paper work, but there are other factors that also lengthen hospital stay duration.

Rehabilitating Patients Faster

In order to be discharged, especially following a surgery, patients must be deemed fit to leave the hospital. This includes clearances from multiple doctors and a physical therapist. Following surgery, the physical therapist plays a large role in rehabilitating the patient so that they are able to function once they leave the hospital. Hospitals will not allow a patient to leave if they do not think that the patient has the tools and resources to allow them a full recovery.

The dilemma with putting patients through physical therapy is that sessions are not brief. There are a plethora of patients requiring physical therapy, and time is wasted transporting the patients to and from physical therapy. When Lean Six Sigma was used in the Richard L. Roudebush Veterans Affairs Medical Center in Indianapolis, they established a certain room in the surgery recovery wing for the physical therapy room so that patients would be transported down the hall instead of to a different sector of the building [5]. They also established group physical therapy sessions, since each patient was undergoing similar joint replacement surgeries, therefore increasing the volume of patients being rehabilitated and hastening patients' recovery.

Lean Six Sigma cannot be used to shorten the length of physical therapy appointments, since an adequate session requires performing a multitude of time-consuming exercises, but LSS can be used to improve the effectiveness of the time spent in physical therapy. Along with the Veterans Affairs hospital in Indianapolis, the University Hospital Trust 'Federico II' in Italy standardized their physical therapy rehabilitation program [5][13]. Researchers recognized that a variety of exercises given to patients were non-value adding. In both hospitals, they defined value adding exercises as those that would enhance a patient's ability to be mobile without assistance. Certain exercises were then eliminated from the rehabilitation program, and the exercises improving, "functional independence" remained [13].

Streamlining and Standardizing the Discharge Process

Furthermore, completing paperwork to discharge a patient further extends a patient's length of stay. Since discharge requires so many approvals from various hospital staff, the paperwork is shifted between many different desks. Shifting the paperwork wastes time and additional time is wasted as the paperwork sits on various desks, needing approval or processing. An effective way to eliminate this wasted time is to remodel the discharge paperwork process using Lean's idea of single-piece flow integrated with Six Sigma standardization. Single-piece flow is the idea that the paperwork will move from one desk to another with as little time in between. In a case study of an Indian hospital where LSS was implemented, the layout of the medical records department floor was remodeled so that the staff sitting next to each other completed the following step of paperwork. In doing this, single-piece flow was achieved [14].

In further using LSS to improve the medical records department(MRD) of the Indian hospital, engineers analyzed

the current department procedures. Part of this assessment included identifying areas where non-value adding actions were carried out. They recognized that in the first step of a six-part process, a MRD staff looked up the code for the patient's medical issue, and then wrote the code on the paper. Once the paper was transferred to the following step, MRD staff found the code on the paper and input it into the computer records [14]. Dividing these two steps, which can easily be combined into one step, appeared to add no value to the process. Conducting a statistical analysis to compare the time spent doing the two processes separately versus combining the two steps confirmed that merging the two would reduce the discharge process time [14]. In making these adjustments, the time to process discharge papers decreased by half [14]. Lean Six Sigma was useful in this application because Lean aspects allowed for an analysis of wasted time, which was found to be in conducting unnecessary steps and moving the papers through the medical records staff assembly line. Once these areas were identified, statistical analysis with Six Sigma verified whether or not making adjustments in these areas would be beneficial to the process, and then further testing allowed the engineers to determine the best way to remodel the discharge process to maximize efficiency. By halving the length of discharge time, hospitals are simultaneously decreasing patient length of stay and decreasing resources used in the MRD.

In improving the efficiency of the MRD, the number of required staff was reduced from six employees to four. This decrease in the number of employees did not compromise consumer satisfaction; consumer satisfaction was increased due to the swiftness of the discharge process [14]. If patients are consistently satisfied with their care at the hospital, the hospital is likely to receive increased patient influx, and will generate more money. Combined with the money gained from increased patient flow and the money saved from reducing resources and unnecessary staff, LSS is creating an economically sustainable system where hospital revenue is accrued and the quality of patient care is permanently improved.

IMPLICATIONS FOR ENGINEERS AND THE WORLD

Healthcare plays a big role in the world. Whether it is a simple well visit or major surgery, every person finds themselves at the doctor's office at some point. When it's yourself or a loved one, every person wants to know they are receiving the best care that they possibly can. Just as much as health care officials, engineers play an important role in making sure that this care is the best that it can be. An engineer's job is to make people's lives better and this area is no exception. The use of Lean Six Sigma is becoming much more prevalent as its benefits in the healthcare world are being proven. It cuts wait times and increases the total quality of care. For people running the hospital, using Lean Six Sigma allows for the best allocation of recourses, including materials and man power.

Hospitals are in many ways like a business. The hospitals spend a lot of money to keep everything up to the high standards needed to operate, which means that it also costs quite a bit for the patient. When finding ways to cut costs without sacrificing quality of care everyone wins. One way to ensure these mutual benefits is by using Lean Six Sigma to identify sources of waste within the healthcare system that can be modified.

These benefits are not exclusive to the United States. So far, the use of Lean Six Sigma has mainly been in the United States and other more developed countries. However, LSS provides benefits that can help equalize healthcare on a global scale. The processes that cut costs in United States hospitals can be applied to hospitals in underdeveloped countries, allowing them to provide a higher standard of healthcare to their citizens. Currently, low- and middle- income countries (LMICs) account for, "90% of the global burden of disease but for only 12% of global spending on health" [15]. This disparity between the percentage of people needing treatment and the resources spent treating them highlights the lack of economic sustainability in the healthcare system. Basic healthcare cannot be provided because both individual citizens and the government cannot afford it. The implementation of LSS in underdeveloped countries can make healthcare more affordable and therefore more accessible to their citizens.

The implementation of LSS in hospitals demonstrates its effectiveness in creating sustainable processes. The promising results found in hospital case studies in developed countries show that LSS can potentially be effective in improving healthcare in underdeveloped countries, thus increasing sustainability worldwide.

RE-ESTABLISHING LEAN SIX SIGMA'S USEFULNESS

As demonstrated in this paper, Lean Six Sigma has been useful in hospitals across the world. Whether Lean Six Sigma was used to alter the pre-operative, operative, post-operative process, or a combination of the three, it greatly improved the efficiency of the surgical process, thereby reducing hospital spending. Additionally, the quality of patient care greatly improved. Patients spent less time in hospitals and were less susceptible to infection. In looking at these positive results, we can see that the general public benefits from hospital's use of LSS. LSS is a process that is advantageous to both the provider and consumer, thus engineers should continue to use this process when attempting to reconfigure hospitals to maximize efficiency and reduce costs.

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ACKNOWLEDGMENTS

We would like to thank Caroline Denniston for helping us revise our outline and answering any questions that we had about our assignment. Additionally, we would like to thank Michael Reinhart for dedicating his time to helping us write our papers.