Application of Six Sigma and Lean Tools to Facilitate use of an Electronic Health Record System in a Medical Office in a Sub-Urban Area of Puerto Rico

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Abstract *— The study was conducted within a primary medical care office with the goal of determining how the implementation of an Electronic Health Record (EHR) system affected the attendance and patient wait time in said workplace. Using some Six Sigma and Lean manufacturing tools and techniques, it was determined that both the attendance and patient wait time were affected. The attendance was determined to have decreased by approximately 33% on average during the sampled time period, while the patient wait time increased by approximately 15 minutes, which accounts for a 33% increase. Thus, it was determined that the implementation strategy utilized during the integration of the EHR system was suboptimal, and in need of revision in order to increase both parameters.*

Key Terms *— EHR, DMAIC, Six Sigma, Wait Time.*

INTRODUCTION

In the wake of the current economic recession, many opportunities have risen to improve and optimize existing processes in many industries. While the Healthcare Industry is not commonly associated with the use of Manufacturing Industry tools, such as Six Sigma and Lean, it can greatly benefit from using these tools on a daily basis in order to streamline processes used in broad settings, such as hospitals, or in smaller, but specific settings, such as private medical practice offices.

This design project was performed as a way to investigate the claim of a perceived disturbance in the overall quality of services of a medical practice office due to the implementation of an electronic medical record system, which was intended to quicken the office workflow, and increase the services provided in the office. This disturbance includes the daily attendance of the office and patient wait time. Patient wait time is an important component toward the overall Quality of the services provided within the medical practice office.

RESEARCH DESCRIPTION

Research was performed on relevant Six Sigma and Lean Manufacturing tools in order to help define the problem and employ techniques that would result in strategies to correct it. It was assessed that the implementation of the EHR was performed in an incorrect manner, which included a lack of an implementation strategy of the system, as well as other problems directly associated to the implementation, such as a lack of applied technical knowledge and inconsistency in following a prescribed set of process guidelines. These deviations in the overall process resulted in patients having to wait longer periods of time for services performed in the medical practice office. After the implementation of the EHR, data was collected for a specific time period in order to measure office parameters. From the data, simple statistical analysis was performed. These results were compared to archived data, in order to compare office parameters.

RESEARCH OBJECTIVES

The objectives of the research include the use of information related to studies performed in a Healthcare environment, which can be hospitals or

medical offices, where Six Sigma and Lean Manufacturing concepts were used to produce results related to improvements in efficiency or waste reduction. The principal objective of this project is to generate a reduction in the suspected increase in wait times due to the implementation of an electronic health record system, as well as maintain an acceptable level of quality of service and wait time. By reducing wait time, it is expected that the overall quality of service will increase, as well as the number of serviced patients per day. The implementation of the EHR provided improvements to many logistical issues within the medical practice office, however, its incorrect use proved to worsen other existing process issues, mainly the increase to the overall wait time of patients. It is expected that strategies can be implemented in order to reduce this time, which would coincidentally reduce patients' wait time, as well as increase the number of patients that can be services per 8 hour workday.

RESEARCH CONTRIBUTIONS

The main research contributions of this project are to the overall improvement of office procedures in this medical practice office, as well as providing a blueprint or guideline for other medical practices to follow in order to properly implement EHR systems without adversely affecting their daily functions. To this end, the use of Six Sigma and lean Manufacturing tools and concepts can be utilized to help improve a medical practice offices' workflow process and help provide a more evident sense of quality to their serviced patients. By providing a simple guideline towards the implementation of such systems to the Healthcare field in Puerto Rico, it can be expected that individuals can have a better understanding of what to expect during this process.

LITERATURE REVIEW

For this project, the general research area will mainly be focused on Health Care services, more specifically on studies relating to office and hospital settings, as well as Quality studies closely associated with these settings. This is relevant to the topic since the location where the project will take place uses both order of arrival and appointments to assign an attending order for the patients. However, some exceptions may affect the order of attendance, such as a patient suffering from an open injury, severe symptoms akin to dengue, complaints of chest pains, etc. Also, research into electronic health records (EHR) and its' associated advantages, disadvantages, legal and technical issues will be done in order to provide a wider scope. While it's not illegal to have an EHR system, Medicare has an incentive program for practices that do wish to commence upgrading their recordkeeping systems. This incentives program began on 2011 and is slated to end in 2016. Although it may seem like some years away, the earlier one adopts such systems, the more prepared one can be when other areas in Healthcare undergo a similar level of automation. In order to receive Medicare incentives however, medical providers must demonstrate that a certified EHR technology was meaningfully used each year. An electronic health record (EHR) is a systematic collection of health information about individual patients or groups of patients. It is a digitally formatted record that comprises health information about an individual, such as demographics, medical and medication history, allergy and immunization status, and his or hers progress notes, among other information. Since the information is in a digital format, it becomes much easier to transport and inform other medical professionals' about that patients complete medical information. According to [2]*National Institutes of Health National Center for Research Resources,* an EHR is "generated and maintained *within an institution*, such as a hospital, integrated delivery network, clinic, or physician office", therefore, unless stored in a nationwide database, a patients' corresponding EHR will usually reside with his or her primary care physicians' custody.

Other selected bibliography focuses on the reduction of errors. For this purpose, as stated, the

use of Six Sigma and Lean Manufacturing tools will be applied in whatever capacity in order to streamline the process. Six Sigma is a methodology that uses statistical information in order to improve the quality of a process output by minimizing or removing detected errors. In order to achieve "six sigma", a process' output must not have more than 3.4 defects per million opportunities. This discipline is not limited to industrial applications, since its methodologies can be applied to anything that produces something as its output. In order to apply this set of methodologies to a Healthcare environment, we must analyze the intended process and services provided in it in order quantify where an error can occur. This may sometimes prove to be difficult, since in this case not all patients require the same service, which can make producing a map of the process a bit difficult. In consonance with [4]*Caldwell, et al*. "Healthcare is one of the most complicated industries in which to build quality systems and that is why most Six Sigma Black Belts (BBs) from outside Healthcare fail, after initially saying all industries are alike in that they all manage processes". In that sense, for this process, the fact that specific defects are not to be quantified means that we should instead focus on when deviations from the process guidelines occurs. In that sense, the 'philosophy' behind the design of the process guidelines may need to be modified. Lean Manufacturing is centered on the basis of preserving value with less work. It is a manufacturing philosophy derived from the Toyota Motor Corporation's production system, whose purpose is to increase efficiency by optimizing a process' workflow. It does this by utilizing empirical methods to decide what aspects of a process matter and decreasing or eliminating anything that may be considered wasteful. As such, variation or variance can sometimes create waste, and it is expected that Lean will remove any unnecessary procedures from the process. Before Six Sigma can be implemented, however, Lean is used to locate and identify where steps or parts of the process exist that do not add value to the overall process. A Lean technique that can be used in order to more clearly illustrate the medical office process is Business Process Illustration. By creating flowcharts, the flow of materials and information used to provide a service to the consumer can be visualized. Using this visualization, Wastes can be identified. These Wastes are activities that are performed that do not add value to the process, for example, any deviation of the office procedures guideline, a nurse handling issues that are better suited for a secretary, etc. their elimination is vital in order to streamline a process in order to deliver a higher quality product. While there are seven types of Waste, the ones that should be focused on in this project are Inventory, Motion, and Waiting Waste. Just as [3]*Wennecke, G*. engages on in his article, which was the use of Kaizen to help reduce different types of Waste. In this case, Inventory Waste can be associated to the patient database in the EHR, in the sense that its mishandling is a non-value added activity; Motion Waste can be linked deviations in office procedures by worker type, for example, a secretary taking patient vitals, a nurse doing paperwork suited for the physician, etc; Waiting Waste being the time lag generated by the other two Wastes.

Another methodology that was referenced was DMAIC. This refers to an improvement cycle that uses data in order to improve, optimize, and establish a process or design, and is a core process used to drive Six Sigma projects, although DMAIC is not exclusive to Six Sigma and can be used as the framework for other applications. DMAIC is an abbreviation for five steps: Define, Measure, Analyze, Improve, and Control. In regards to the project, the steps breakdown as such:

- Define: Concepts of Wait Time and Quality
- Measure: Office Attendance
- Analyze: Attendance versus Time
- Improve: Six Sigma and Lean tools towards Attendance and Wait Time
- Control: Monitoring of Attendance and office process

The data extracted from this procedure for the year 2011 will be compared to the statistics from

the previous year in order to determine if any historical changes have occurred. These records exist in the medical office in the form of spreadsheets, as well as in the EHR attendance calendar. It is important to note that although the office operates on Saturdays, the attendance data from those days were not taken into account in the statistical analysis.

METHODOLOGY

The general purpose of this project is to further improve the concepts of wait time and quality of services through measured quantities such as patient attendance in a medical practice office environment. A direct correlation between these variables is expected and will be further discussed in the results section. During the past year, certain Lean and Six Sigma methodologies were employed on the process of the medical office in question. This produced some positive results, such as a reduction in the use of toner, paper, folders, and other miscellaneous items; however it also produced some negative experiences, such as a slow transition from a non-digital to a digital file format database. Starting in early January of 2011, an electronic health record was implemented, and the staff of the medical practice underwent a tutorial stage in order to familiarize itself with the system. Meanwhile, a "soft opening" was performed while using this new system, which was intended to apply what was learned in the tutorial stage with low patient traffic. However, this system suffered from some serious technical issues, such as the manual upload of patient information from the regular patients' physical medical record, a learning curve of use of the EHR system past the tutorial stage, as well as an increase in the patient waiting time as a direct result of slow data entry. This project intends to investigate statistically if there was a negative impact in the Quality of the medical practice's process, as well as to use Lean Manufacturing and Six Sigma tools to implement changes in the process in order to further reduce the patients' wait time and increase the overall Quality of the services provided.

The first phase of the project will detail the implementation of the EHR: statistical analysis of the number of patients serviced on a timeframe prior to the launch date of the system and during the initial launch of the system, as well as a timeframe some time after the initial phase of the system. This step would account for the Define and Measure phases of a DMAIC methodology used in Six Sigma. The methodology used for the implementation of the EHR system will be noted, and will be used for designing a blueprint for such endeavors. Firstly, using the medical clinics patient register, an attendance list was formulated for the calendar year of 2011, with the exception of January. Statistical analysis was performed using the attendance data, which in turn will help calculate or *infer* a metric for patient wait time. This variable is difficult to quantify, since many factors directly affect it, so sometimes an 'educated guess' is warranted. As was mentioned, the initial phase data will correspond to attendance data from the month of February of 2011, as well as the months of August, September, and October of 2011, for a comparative analysis with the same timeframe from the previous year. The tabulation of such data will include attendance data from worked days; however, data from Saturdays will be tabulated, but not taken into account when performing calculations. This is because it is not common for medical clinics to work on Saturdays, much less midday's, like the medical clinic used for this research project. The treatment of the data will be further discussed in the Analyze phase of the methodology.

The second phase would be to analyze the acquired data. A patients' wait time must be determined for a time interval prior to the implementation of the EHR in order to determine if there was an increase or decrease in the wait time. Once this is established, steps to improve this wait time may be proposed which will be implemented in the next phase. This phase corresponds to the Analyze phase of the DMAIC methodology of Six

Sigma. Using the data acquired from the Define and Measure phases, simple descriptive statistics such as average patient attendance, variance, and standard deviation, among others, will be calculated. Also, a time series plot will be done to visualize the data. A wait time was calculated from the attendance data for the months of August, September, and October of 2011. This particular wait time is very useful, since it will be taken from data months after the implementation of the EHR. As such, it is expected that certain issues that were present at the initial stages have been 'ironed out' and a more 'true' value is determined. The wait time was initially determined by calculating the quantity of serviced patients and dividing it by the typical amount of hours in a work day, usually eight hours. After calculating the quantity of patients seen in an hour for a given day, a ratio is determined until it is close to 1 and the lowest time using the greatest common divisor, an example would be like 1.20 patients every 20 minutes, which in this case the wait time would be 20 minutes per patient. In order to facilitate the calculations, an average of patients per day per week was calculated for the specified timeframe. This number represents the average number of patients serviced per day for that week in the specified month. This calculation was performed for every month of the previous year (2010) in order to calculate an average minimum wait time. A similar approach will be taken in order to calculate wait times related to the acquired data for the year 2011.

The third phase will see the proposed steps being implemented in order to determine if an improvement in the wait time is achieved. This is the Improve phase of the DMAIC methodology of Six Sigma. In this phase, an inference will be taken to the treatment from the data of the months of August, September, and October of 2011, since it is somewhat implied that certain light changes were made to the process already in order for the workflow process to stabilize. This is one of the reasons why the wait time from these months is being compared to the same timeframe from the previous year, in order to verify if the process corrected itself, or further adjustments related to the treatment of data entry are needed to positively impact the process.

The final phase will see if the proposed changes to the process will remain within an acceptable margin of deviation. This phase corresponds to the Control phase of the DMAIC methodology of Six Sigma. Apart from the other phases, this one should be considered to be ongoing, since if other improvements are suggested they will be implemented and it will be determined how they affect the efficiency of the medical clinic's process. To this end, accurate recordkeeping is very important in order to recalculate data, and adjust any particular thing from the office process. If the proposed changes to the process do not yield the expected result of a reduction in the patients' wait time, additional time will be needed for the implementation of different proposals and their analysis.

RESULTS AND DISCUSSIONS

All of the attendance data, as well as the calculated information have been tabulated. They contain patient attendance data for the months of February through December of the year 2011, as well as the patient attendance data for the months of August, September, and October of the year 2010; specifically, the weekly attendance and the average daily attendance for those weeks and months. From the daily averages of each week in that month, an average for the month is calculated. This average represents the average number of patients that were serviced daily for that month. However, the averages that will be used and compared are the ones for the timeframe of August through October for the years 2010 and 2011.

Table 1

Summary of Patient Attendance Averages for 2009-2011

Month	2009	2010	2011	Change	% Change
August	16.438	18.75	14.64	-4.11	-28.074
September	15.89	19.275	13.3	-5.975	-44.9245
October	17.583	17.275	14.575	-2.7	-18.5249
Average	16.637	18.433	14.172	-4.262	-30.5078

From the data presented in Table 1, it was determined that the daily attendance average for the specified timeframe decreased by approximately 31%, however, it must be noted that the attendances in the month of September 2011 were dramatically lower compared to the 2010 total. This attendance total was significantly less than the previous year total, approximately 44%, and it served to skew the attendance total calculations for the specified timeframe. In Table 2, the calculated wait times for the years 2009-2011 are provided. It was determined that a significant change in patient wait time did occur, providing a similar patient attendance number, but with an increased time ratio. The maximum wait times for the years 2009-2011 are shown in Table 3, accounting for an increase of around 33% in this statistical category. From this result, the suspected increase in wait time mentioned in the research projects' problem statement is considered to be a verified fact.

Table 2

Summary of the Minimum and Maximum Wait Times for the Months of August, September, and October of 2009-2011

Minimum Attendance	Maximum Attendance	Hourly Attend-ance (Patie-nts per Hour)	Maximum Wait Time Ratio (Patients per Minutes)	Minimum Wait Time Ratio (Patients per Minutes)
8	26	3.25	1:60	1.0833:20
8	34	4.25	1:60	1.0625:15
5	21	2.625	~1:90	1.3125:30

Table 3

Summary of Average Wait Times for the months of August, September, and October, of 2009-2011, Calculated with Average Attendances

Year	Average Daily Attendance for Timeframe	Hourly Attendance Average for Timeframe (Patients per Hour)	Maximum Wait Ratio (Patients per Minutes)
2009	16.637	2.079625	1.0398125:30
2010	18.4333	2.304125	1.1520625:30
2011	14.17167	1.77145875	1.1809725:45

As has been noted, the office patient attendance decreased historically for the specified time period of the months of August, September, and October for the years of 2009 through 2011. Using the collected data, histograms were created which show the frequency of attendance for the specified time period. Figure 1 corresponds to the histogram for the year 2010, while Figure 2 corresponds for the year 2011. Lastly, a Time Series Plot was created to present the behavior of attendance for the years of 2010 and 2011, which corresponds to Figure 3. It can be noted that the data for the year 2010 performs better than the data corresponding for the year 2011.

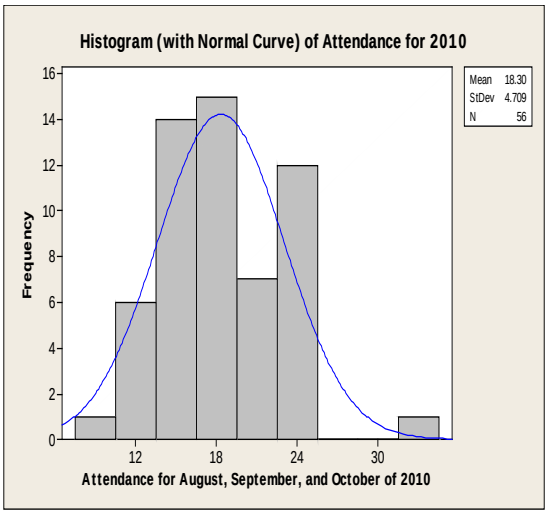

Figure 1

Histogram of Attendance for the Specified Timeframe of 2010, Obtained Using Minitab 15 Statistical Software

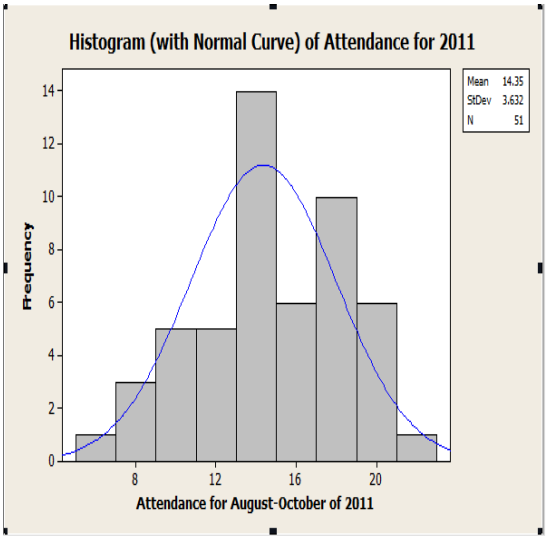

Figure 2

Histogram of Attendance for the Specified Timeframe of 2011, Obtained Using Minitab 15 Statistical Software

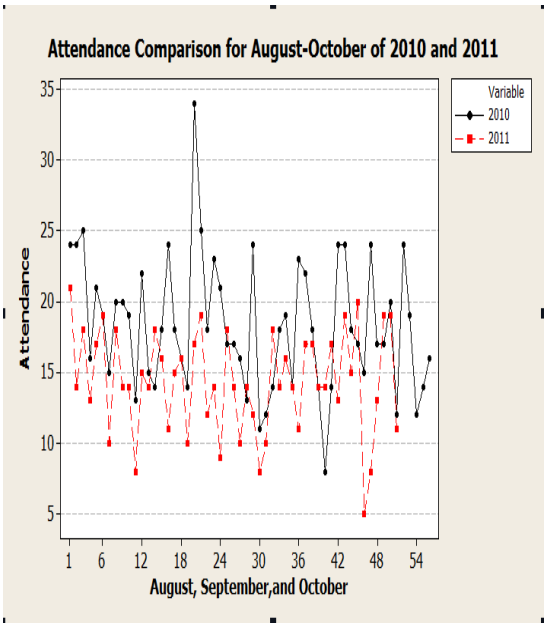

Figure 3

Time Series Plot of Attendance for the Months of August-October of 2010 and 2011, Obtained Using Minitab 15 Statistical Software

CONCLUSION

After analyzing the attendance data, it can be concluded that as was suspected, the patient wait time did indeed suffer from an undesirable increase. Although the results were presented for a limited timeframe, it can be safely assumed that this occurrence happened throughout the year, and was not just limited to the specified months. In order to rectify this increase, an immediate intervention regarding patient data entry must be performed. This will involve the verification of data for patients with future appointments, with the expectation that this will cut some time prior to their time spent with the physician. It is possible that many factors contributed to a lower patient attendance turnout. During 2010, the H1N1 Influenza virus scare occurred. This situation created a temporary increase in personal health conscience and may have attributed to a small increase in attendance.

Another important aspect that this project was investigating was the status of Quality of service associated with the medical office. As has been

previously mentioned, this is a difficult metric to gauge, since patient satisfaction is directly associated with it. It can be concluded that the quality perceived by the patient is different compared to the staff that operate the medical clinic, since their expectations are different. Regarding the patient, it is concluded that the quality did not decrease, since they receive adequate healthcare service with additional marginal benefits without an added cost; however, the possibility that the staff perceive quality as having decreased is a possibility, given a lower attendance average, given the results of the specified timeframe.

Lastly, it was proposed that a guideline towards the implementation of an EHR was to be presented. The following can be used in order to have a more fluid start when implementing such a system:

- Determine a date for the implementation of the system.
- If possible, have firsthand knowledge of its use, or set up tutoring sessions towards its use on non-office hours.
- If possible, commence its use on known low work periods or set up low intensity appointments in order for the staff to gain practical knowledge of the system.
- If data entry is needed for certain aspects in the use of an EHR system, perform this task on non-work hours whenever possible.
- Customize the program as needed in order to develop shortcuts when on routine appointments, for example when the physician is attending a patient bringing in laboratory results.

Although these points may seem trivial, having an idea of how an average workday can increase becomes beneficial. In this sense, planning activities related to the use of an EHR in its initial implementation stage can result in positive repercussions later on.

REFERENCES

[1] Barry, Robert, Amy Murcko, and Cliff Brubaker. *The Six Sigma Book for Healthcare: Improving Outcomes by Reducing Errors*. Ann Arbor: Chicago Health Administration press, 2002. Print.

[2] National Institutes of Health National Center for Research Resources. *Electronic Health Records Overview*. April, 2006. http://www.ncrr.nih.gov/publications/informatics/ehr.pdf

[3] Wennecke, Gitte. *Kaizen - LEAN in a week: How to implement improvement in healthcare setting within a week*. MLO: Medical Laboratory Observer 40.8 (2008): 28-31. Academic Search Premier. EBSCO. Web. 29 Mar. 2010.

[4] Caldwell, Chip, Jim Brexler, and Tom Gillem. *Engaging Physicians In Lean Six Sigma*. Quality Progress 38.11 (2005): 42-46. Academic Search Premier. EBSCO. Web. 29 Mar. 2010.

[5] Panchak, Patricia. *LEAN HEALTH CARE? IT WORKS!*. Industry Week/IW 252.11 (2003): 34-40. Business Source Premier. EBSCO. Web. 29 Mar. 2010.