ENHANCING LEAN SIX SIGMA METHODOLOGIES WITH OPERATIONS RESEARCH TOOLS AND MODELS:
A Case Study in Healthcare

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Abstract: Lean Six Sigma and Operations Research are each sets of methodologies that seek to achieve the same end: performance improvement and process optimization. Generally, the fields are applied independently and are often thought of as separate, depending upon the application's setting, the researcher's experience, etc. In a recent engagement with a healthcare industry client, we leveraged strengths of the two approaches in an effort to develop more robust solutions to the performance issues facing the organization. Due to the nature of the organization and the specific needs of the project, neither Lean Six Sigma nor Operations Research alone could provide the tools required to achieve the stated objectives. By focusing on process and flow management, and by applying the most appropriate technique to address a particular area of concern, we were able to achieve significant improvements across several areas of operations within the selected system. This paper highlights the project objectives; specific tools, techniques, and applications of our hybrid methodology; and key findings and sustainment planning for longevity of effect.

1 INTRODUCTION

Lean Six Sigma (LSS) tools have a well-established reputation for eliminating waste and improving processes in the manufacturing industry, with longevity as proof of their effectiveness; more recently, the healthcare industry has been taking note of the speed and value LSS has to offer. Healthcare providers have begun to adopt LSS tools and techniques to support the search for operational efficiencies that improve performance, advance patient care, and reduce non-value added work. Hospitals that have utilized LSS methodologies have generally reported great success in streamlining operations, reducing waste, and improving both patient and staff satisfaction (Plsek, 1999).

During the summer of 2011, we were invited to investigate operations in the Obstetrics (OB) unit at a community hospital with approximately 3,700 births per year. The hospital had limited exposure to LSS methods through previous training initiatives, and leadership was interested in conducting a case study to assess the effectiveness of implementing these techniques. After an initial assessment of several areas within the hospital, the OB unit was deemed to be the candidate that would benefit most from a process improvement venture. Known as the Birthing Center (BC), the unit consists of multiple semiautonomous sub-units within the larger entity: Triage; the Birthing Unit (BU), including Labor and Delivery (L&D) suites, Operating Rooms, and a Pre-/Post-Anesthesia Care Unit (PACU); the Mother-Infant Unit (MIU), including nurseries; Maternal-Fetal Medicine (MFM); a Maternal Special Care Unit (MSCU); and a Neonatal Intensive Care Unit (NICU). A majority of the project focus surrounded activities within the BU and MIU, but other areas were also analyzed and addressed due to the interactive nature of each area within the overall BC.

This effort began with two primary objectives. The first was to identify non-clinical methods that may help reduce the rate of Cesarean sections (C/S) at the hospital, which was among the highest in the state when compared against a group of peer hospitals. The second was to look at staff operations to identify opportunities for improved efficiency; the BC is operating near capacity, but anticipates demand growth of approximately 10% over the next two to three years. Secondary objectives were revealed throughout the course of the project, and efforts were made to address many of those as they became known. It is important to note that the project did not include an analysis of staff utilization, and all proposed changes were recommended and implemented within the framework of existing staffing levels.

In formulating a hybrid approach to process improvement, we hypothesized that success would best be obtained by reaching beyond traditional LSS tools and methods—not replacing those tools and methods, but rather complementing them with some rigorous, quantitative analytics and modeling efforts (Chaillet and Dumont, 2007). This hypothesis was motivated by the objective of reducing the C/S rate. The decision to deliver via C/S, unless elected by the mother, is driven by clinical factors and therefore is not particularly responsive to improvement via traditional LSS efforts. Each physician practices medicine differently, and each operates with the best interest of the patient in mind. However, research showed that other similar hospitals—in terms of socioeconomic factors, patient demographics, etc.—have been able to maintain a much lower C/S rate (Gregory et al., 1999) than is evident at this particular hospital, so the belief among hospital staff was that lowering the rate was an achievable goal. The importance of lower rates is twofold. First, there is evidence that vaginal deliveries result in better patient outcomes, for both mother and baby, and so a C/S should be performed only when there is a significant danger to either the mother or baby(ies) (Druzin and El-Sayed, 2006; Lagrew and Adashek, 1998). Second, vaginal deliveries are more cost effective, as they return greater revenue per patient-day to the hospital (Brown, 1996; Druzin and El-Sayed, 2006).

With this in mind, we felt that while we could investigate certain non-clinical processes to support this objective, we could also lend support to clinical processes by providing both leadership and the clinical staff with in-depth data analysis that might answer the question of why the hospital's C/S rate was so high. Furthermore, as one of the tenets of LSS is sustainment of process changes, we felt that the inclusion of decision support tools (DSTs) that would facilitate long-term, continued monitoring of performance improvement efforts would be vital. The intent of the sustainment plan, paired with DSTs and training, was to turn over continued management of process changes to the hospital staff at the conclusion of the project. While addressing immediate questions and concerns during our time on site, we wanted to leave the OB department management with enough information to continue application of the LSS techniques in other areas of concern after our departure. To ensure success in both completing this project and in preparing the staff for continued efforts, we brought together a team with expertise not only in LSS, but also in Operations Research modeling and DST development to work together in creating a more robust solution approach for the OB unit.

2 LEAN SIX SIGMA APPROACH

Lean Six Sigma combines two popular, yet initially independent, improvement methodologies:

- *Lean* is a manufacturing concept derived primarily from the Toyota Production System that essentially focuses on production or process efficiency. It seeks to reduce or eliminate waste, while preserving value (Hanna, 2007; Spector, 2006).
- *Six Sigma* was introduced by Motorola in 1986 as a management philosophy that seeks to improve quality by identifying and removing defects, typically by reducing variation in operations (Spector, 2006).

When combined into LSS, a more substantial impact may result as the process is analyzed from multiple perspectives, and additional concerns are addressed. Reducing non-value added waste and process variance that leads to additional waste can be a significant incentive when translated to dollars and cents. At the hospital, we defined waste to be activities that did not contribute to the patient's well-being and variance as the deviation from a set standard of care within the BC.

The first step in supporting the hospital's objectives was to implement a change methodology whereby LSS methods could be introduced and implemented. Among hospital staff and leadership only a handful had any familiarity with LSS, so a degree of education was necessary at the onset of the project. This education was designed to introduce the concepts of LSS, inform as to how it would be utilized over the course of the project, and encourage participation and buy-in from the staff.

The key components of LSS that were used in the hospital were personnel observations to identify value added and non-value added work, process flow and value stream mapping to determine any process constraints or resource bottlenecks, and method change templates to describe and support implementation of proposed changes.

The first few weeks of our on-site interaction with BC personnel was spent observing a variety of processes: triage workflow, vaginal deliveries, C/S operations, discharge procedures, scheduling efforts, etc. During this time we identified several areas that would benefit from minor changes that were relatively simple to implement, as well as other areas that demanded more in-depth attention and would require continuous monitoring long after we left the hospital, all of which are addressed later in this paper. We also used these observations to support the development of baseline performance metrics in conjunction with data obtained from the hospital's information systems.

Observing operations within the unit was essential to the success of the project. Before recommending and implementing any changes, it was vital that we fully understood the workflow and communication within and between units; recognized each area's roles, responsibilities, and tasks; and obtained information and suggestions from the staff. With this insight, we were better able to manage improvement ideas that addressed the most restrictive bottlenecks, understand past enhancement attempts, and most importantly get a feel for the group dynamic and working environment.

The first major opportunity for the unit's leadership and stakeholders to participate in the study came in the form of the value stream mapping (VSM) session, completed during the second week of the engagement. During this session, representatives from each area of the BC, including nurses, physicians, and directors aided in the develop of a process map that outlined the flow of a patient through the BC, from initial registration through delivery and discharge. Also identified during this session was an extensive list of process constraints and resource bottlenecks that staff members felt had the greatest impact on workflow. Due to staff responsibilities, we limited the session to a half-day, much shorter than similar Kanban events; however, out of this session came an extensive list of potential process change opportunities that we assessed for possible implementation.

Having conducted numerous process observations and the VSM session within the hospital, we began to refine our list of opportunities to identify those which would be feasible to implement within the 14-week period of the engagement and would potentially have the greatest impact on the stated objectives. As we zeroed in on a number of these opportunities to pursue, we utilized a method change proposal template to define the opportunity, provide supporting documentation for the proposed change, and vet the opportunity with department leadership and other stakeholders. These templates were vital to the success of the project: a change in the mindset and perception of staff working within the unit is needed to facilitate method changes, and this can only be accomplished if the staff has a complete understanding of the proposed changes and the rationale behind them. On a broader scale, the willingness of leadership to participate and take personal responsibility for change management ultimately determines how much success the BC will realize from adopting the LSS and DST ideologies.

3 OPERATIONS RESEARCH: DATA ANALYTICS AND DECISION SUPPORT TOOLS

Although there are several definitions of data analytics, most share the same essence: it is the science of examining information to draw conclusions (Robinson, 2000). In other words, what can we learn about a system (organization, process, etc.) from the information (quantitative and qualitative) available about that system? Similarly, DSTs can be described in many ways, but those definitions also share a common theme: they are information systems that aid leadership in understanding processes and performance in order to encourage more robust decision-making (Robinson, 2000). Oftentimes these DSTs are computer-based and typically rooted in data analytics.

It is not uncommon for hospitals to have a wealth of information available for analysis—the challenge generally lies in whether or not the data are relevant to the task at hand and how those data are stored. The subject hospital of this case study was no different.

Much information was collected within the BC, from patient flow information (e.g. admission, delivery, and discharge times), to encounter/ diagnosis data (e.g. type of delivery, complications), and staffing and scheduling records. However, many of these data were kept in disparate sources, making analysis difficult. The hospital operated using three separate information systems that were unable to communicate with one another in either direction; there was some overlap of data between the systems—although in some of these cases the data were in conflict with one another—but generally information was only available in one of the three. Furthermore, the systems were relatively incompatible, so information from each had to be loaded into yet another system in order to develop a complete picture. For example, one system maintained patient delivery records, such as when and how a mother gave birth, while another system collected admission and discharge times. In order to determine accurate length of stay (LOS) statistics by delivery type, it was necessary to cross-reference the records across the two systems. Fortunately these information systems were able to push reports such that data could be merged and analyzed.

Another challenge lay in the fact that not all relevant data were kept electronically or were not available in standard (or even customized) reports. Instead, many data elements vital to the analysis were found only in the manually-maintained delivery logbook or by reviewing computerized encounter screen shots. In these cases, we had to manually pull the relevant information in order to incorporate that data into our analyses.

Although these issues made data collection and analysis challenging at times, it is notable that not only did the hospital have a wealth of information available, but that information was of great value once it was identified and extracted. This, too, seems to be fairly common within the healthcare setting; it just requires a trained eye to find the right information and package it in such a way that it aids leadership in fully understanding the current processes and performance, then arms them with the supporting data to provoke and sustain change.

Once we had identified the challenges associated with the data and had begun to overcome them, we began to implement our plan for infusing the LSS methodologies with data analytics and DSTs. This started with extensive analysis of the available data, focusing on painting a comprehensive picture of what was driving the high C/S rate. Working closely with the departmental directors and Nurse Managers, we identified several common underlying (non-demographic) factors for C/S that allowed us to focus our performance improvement and change management efforts. We continued to follow this approach of investigating and mining the available data to provide empirical evidence for change throughout the project.

As performance improvement opportunities were identified, we focused our data collection and analysis on validating the need for a recommended change and determining what the expected impact of the change would be. Armed with this information, we provided more compelling evidence supporting the need for the change, and therefore were able to obtain more emphatic and widespread buy-in by the staff. Through this data analysis, we also formed the foundation for secondary performance metrics that would be used in assessing the results of the project.

4 CHANGE MANAGEMENT

4.1 Performance Metrics

An important aspect of change management is developing a thorough understanding of what improvements are required and then measuring progress in those areas of improvement. This is typically done through the establishment of performance metrics and corresponding baseline values against which to assess that progress.

During the early stages of the engagement, we identified several metrics, classified as either primary or secondary, to be the focus of performance measurement; appropriate baseline values were then identified for each. In most cases these baselines were based on performance data from the year immediately preceding the engagement—from May 2010 through April 2011.

The primary performance metrics that were developed to support the overall objectives of the effort included the hospital's overall C/S rate, the percentage of on-time starts for scheduled C/S (note: historical data for this metric were only available for March and April 2011, so those two months were used to establish the baseline), and patient LOS from admission to discharge (distinguished according to method of delivery). Secondary metrics included the average time elapsed from when a discharge order was written until the patient was actually discharged, the on-time performance of the first scheduled C/S of the day, the proportion of patients that were discharged by 11:00 AM, 12:00 PM and 1:00 PM, and the average time spent in L&D or PACU postpartum recovery before being transferred to the MIU. The baseline values for each metric are listed in Table 1 below. (Note that there is no baseline for the rate of discharges achieved by specified times—prior to the engagement no data were collected to measure this.)

Table 1. Metric Baselines

Metric	Baseline Value
C/S Rate	42.2%
LOS (Vaginal Delivery)	2.68 days
LOS (Delivery via C/S)	4.39 days
C/S On-Time Performance	32.4%
Discharge Delay	3.71 hours
1st C/S On-Time Performance	44.4%
Discharge by Time Rates	n/a
Postpartum Recovery Time	5.5 hours

4.2 *Method Changes*

Throughout the first half of the project and as a result of defining performance metrics and conducting process observations, the VSM session and data analysis, we identified a number of opportunities for process or method changes that would support the defined objectives. This list grew to well over sixty opportunities, and a preliminary improvement scenario was developed for each. The opportunities were then assessed and prioritized according to the level of effort required to implement the proposed change and the expected impact on operations. From these assessments we developed a shorter list of approximately fifteen that we would implement over the remainder of the project, once each was vetted by the affected staff. Furthermore, we identified a staff member to be the "change champion" for each recommendation. By doing this, the staff took ownership of the process changes, greatly aiding the successful implementation and sustainment of each. Among the proposed process changes were short-, medium-, and long-term opportunities, referring to how quickly they could be implemented at the hospital. The short-term opportunities, or quick wins, were those that could be implemented within a week of their identification and approval.

Several of these quick wins were identified during the early stages of the project and in the VSM session; these included opportunities that would affect overall process efficiencies, but also some that might be considered more 'quality of life' changes. The most significant in terms of process improvement revolved around the use of hospital laborists to support various operations. The laborists had indicated that they were willing to assist with patient triage and the discharge process (e.g. writing orders) when available, but were not being asked to do so. In fact, the other (private practice) providers were unaware that they were 'allowed' to request the laborists' assistance. By simply opening the lines of communication and informing the providers of the laborists' ability and willingness to support, there were immediate improvements in both areas of the BC.

Two impactful quality of life changes were the addition of a second computer at the charge nurse's station, preventing the need for the charge to find an empty room to make updates in each of the two information systems, and restricting the providers from using the nurses' break room for meetings, as the nursing staff felt uncomfortable entering the room if the providers were holding a meeting.

Among the medium-term changes, the two with the greatest effects were a change to scheduled C/S start times and a method to monitor discharges from the MIU. The purpose behind these was to increase the on-time performance of scheduled C/S and to reduce patient LOS by smoothing the distribution of discharges. In each case, significant data analysis was conducted to form the foundation for the recommended changes.

By matching electronic records of procedure start times to paper copies of procedure schedules, we found that the on-time performance of scheduled C/S was approximately 30%. A procedure was considered on-time if the patient's arrival in the operating room was within ten minutes of the scheduled time. (Hospital policy recommended that a procedure be considered delayed if it began more than five minutes late; for the purposes of this project BC management agreed to use ten minutes as the indicator.) The BU scheduled up to four procedures each day, with start times of 8:00 AM, 9:30 AM, 11:00 AM and 1:00 PM. A fifth slot, at 2:30 PM, was available but rarely used (one occurrence in a three-month period).

To address the challenge of getting scheduled procedures to start on time, several steps were required. Anecdotally, hospital staff indicated that scheduled procedures were often 'bumped' by unscheduled procedures, although actual delay causes were not regularly recorded. To verify that claim, our first step was to implement a method change in which the operating room staff agreed upon and documented the reason for delay, when applicable, during a regular huddle just prior to surgery start used to verify such things as mother's name, C/S indication, etc. Next, we conducted a thorough analysis of times surrounding C/S (e.g. start times, procedure lengths). Through that analysis, we discovered several pieces of information that suggested a change in start times was necessary. First, the average length of a C/S was just over one hour, and approximately 20% were more than 75 minutes. Since the same scrub technician and anesthesiologist were present for each procedure, and the same anesthesiologist was also responsible for placing and removing epidurals in L&D, it was often difficult to get subsequent procedures started on time if the previous one had been delayed for any reason. In fact, over a three-month period there were 50 C/S that had a delayed start and another procedure scheduled in the subsequent slot—48 of those subsequent procedures were also delayed. All of this information gave rise to the recommendation of changing the scheduled start times to be two hours apart, at 8:00 AM, 10:00 AM, 12:00 PM and 2:00 PM. Although only limited data have been collected under the new schedule, preliminary results from this method change are encouraging. Additionally, informal evidence collected during the first week of implementation suggests a higher degree of satisfaction with the new schedule: if one procedure is late there is still an opportunity for the subsequent procedures to get back on schedule, giving providers greater confidence in their ability to complete their procedures on time and still see other (non-laboring) patients throughout the day.

In the MIU, the nursing staffed believed that there were significant delays in discharging patients who were scheduled to go home on a particular day. Standards for patient LOS are 48 hours for a vaginal delivery and 96 hours for a C/S from time of delivery until time of discharge. However, due to inefficiencies in the discharge process, many patients were waiting until late afternoon or early evening to leave despite having been ready (from a clinical perspective) early in the morning. The impacts of these delays on the back end on the patients' stays included a higher than expected average LOS for the unit, bottlenecks that led to boarding of patients in the BU (delivered patients remaining in L&D or the PACU beyond the standard period before transfer to the MIU), and a decrease in the effective capacity of the unit due to the unavailability of both beds and nurses.

The greatest challenge in addressing the discharge issue was a lack of awareness. Staff members on the MIU were unsure how effective they were at getting patients discharged by specified times, nor were they collecting any information to develop an understanding of the reasons why so many discharges were happening so late in the day. Three related process changes were therefore implemented to identify and alleviate these delays. First, hospital laborists were empowered to write discharge orders for other providers, when appropriate. This eased the burden on other providers who often treated discharges as their lowest priority task during the day. Second, a formal process was put in place for recording the reasons behind any discharge delays. A form recording the time of discharge and indicating reason for delay, if any, was created and required for all discharges. Finally, a time tracking tool was implemented to collect and analyze the times of discharge, which is discussed further in the following section.

Several long-term changes were also identified and implemented, with each of these having considerable impacts on the overall project objectives. The most significant of these was developed through continued data analysis of C/S and induction rates, in conjunction with observation of induction processes. Through additional research and discussions with the provider staff and OB leadership, we discovered that the group of C/S that were most susceptible to improvements were those categorized as nulliparous, term, vertex, singleton (NTSV) procedures. This includes only procedures in which the mother is giving birth to her first child (nulliparous), whose pregnancy is full term (term), with the fetus presenting in a normal (head down) position (vertex), and there being only one fetus in the womb (singleton) (Main et al., 2006). Using this knowledge, we were able to determine the manageable C/S rate for the hospital and individual providers over a 14-month period beginning in April 2010. With this information, the Director of Obstetrics was armed with the data needed to discuss clinical decisions one-on-one with providers.

Further analysis of NTSV C/S deliveries indicated that the majority of these procedures were done as a result of a patient's 'failure to progress'. In other words, the mother labored for a significant period of time without delivering, and the resulting fatigue made it unlikely that she would be able to deliver the baby vaginally. In order to avoid putting the mother or baby at risk, the decision was made to perform a C/S. Subsequent analysis showed that many of these deliveries began with an induction, in which the mother was given medication to initiate the labor process rather than allowing it to occur naturally. In fact, over 25% of inductions resulted in deliveries via C/S, similar to findings at other hospitals (Kaul et al., 2004).

Based on all of this information, several process changes and clinical requirements were put in place to better manage inductions. These ranged from procedures that restricted inductions from being scheduled until after the baby had reached a minimum gestational age, to standardization of induction management, to a peer review of the need for a C/S when the primary physician determines that a patient has stopped progressing.

While the findings described here represent only a few of the method changes implemented throughout the course of the project, they provide a sampling of the mix of techniques—both LSS and analytics—that were used to obtain the desired results. Without using both sets of tools, it is unlikely that many of the gains achieved throughout the course of the project would have been realized.

4.3 Change Monitoring and Sustainment Tools

As addressed previously, one of the main purposes behind the development of DSTs was to provide the hospital with the means to help sustain the recommended changes long after the conclusion of the engagement—it is only through this sustainment that the hospital is able to achieve long-term success. Therefore, we created three leave-behind tools, developed in Microsoft Excel® to facilitate their use by hospital staff, designed to aid in operations and performance monitoring.

The first of these is a discharge tracking system used by the MIU, related to the medium-term method change described above. Our analysis identified a significant opportunity to reduce overall patient LOS and also noted that oftentimes patients were being boarded in the L&D unit rather than being transferred to the MIU after delivery because beds were not available. Although discharge times varied significantly, over two-thirds (67%) occurred after 1:00 PM and nearly 90% occurred after 12:00 PM. After vetting our findings with the Nurse Manager in the MIU and explaining our intentions, a target of 30% by 11:00 AM was set as an achievable goal; that is, 30% of all patients scheduled to go home on a particular day should be discharged by 11:00 AM. Secondary goals of 50% by 12:00 PM and 70% by 1:00 PM were also established. In order to meet or exceed the target, the manager had to be armed with appropriate tools to measure progress, issues, and results. Developed to provide that support, the maternity discharge tracking system is a simple tool that is used to collect basic data on how many patients were discharged before 11:00 AM, etc. It also captures the reasons for any discharge delays, providing insight into which activities or processes should be the focus of future improvement efforts in helping to achieve the stated goals.

To further improve patient flow, a similar tool was also designed for the BU. Data showed that extensive boarding was occurring, holding resources and beds for excessive periods of time. For example, a patient would arrive two hours prior to her scheduled procedure; the procedure itself would take approximately one hour; and the average postpartum LOS in the PACU was 5.5 hours. This resulted in both a PACU bed and dedicated nursing care being held for an average of 8.5 hours per C/S—at least three hours longer than expected.

To address this inefficiency, a postpartum LOS tracking tool was developed to both track delay reasons for why patients were not transferred to the MIU sooner and to record postpartum LOS times in order to monitor progress over time. Initial thresholds of 2.5 hours for a C/S and 3 hours for vaginal births were deemed acceptable by the Nurse Manager based on clinical evidence and existing processes. If a patient remains on the BU after delivery above those limits, a nurse is required to fill out a form that captures the primary reason for the delay as well as the postpartum time on the unit, from delivery to transfer. The Nurse Manager collects that information and enters it into the tracker on a regular basis, and is responsible for monitoring progress towards eliminating excessive postpartum stays.

Another decision aid is a provider performance monitoring tool that tracks deliveries by specific providers and provider groups. It allows departmental leadership to look at the C/S rates by each physician on a continuing basis, comparing those rates to his or her group's rates and the overall hospital rate. Further, it allows the user to parse the data according to a number of criteria (e.g. NTSV criteria, gestational age). These data can also be viewed over a user-specified time frame to see how providers are trending over time.

Finally, we developed a computer-based tool to support the scheduling and information archiving of inductions and C/S. These schedules had previously been kept on paper forms. Procedure cancellations were managed by simply erasing the line on the form, when it was reported that the procedure had been cancelled (typically due to an early delivery). This tool captures the same information that was previously reported in terms of scheduling, but adds elements of control and automation that were previously absent. For example, a request for a C/S requires the estimated due date of the baby be entered. The tool will then calculate the acceptable date range of the procedure based on hospital regulations, and will automatically schedule the procedure so as to maintain a balanced schedule. It also provides a method to archive any cancellations, so that data may be analyzed, if necessary, at a later time. (This tool was designed as an interim solution to be used until the hospital's information systems department could develop an integrated, automated scheduling system for BU procedures; this effort has been initiated and is expected to be completed in the very near future.)

5 PRELIMINARY RESULTS

Once implemented, each method change was monitored to measure its impact. A preliminary set of cumulative results observed from the beginning of the project in May 2011 through its conclusion in August 2011 was compared with the baseline data in Table 1. Furthermore, results are updated on a monthly basis to continue to monitor progress over an additional twelve-month period.

Although reducing the C/S rate was very much driven by clinical and behavioral changes, the data analysis completed and process improvements implemented throughout the course of the project provided invaluable support to effecting these changes. By arming a devoted leadership team with detailed data, providers were made more aware of the impact their practice was having on the hospital as a whole, and changes to clinical processes followed. Induction protocols were revamped, elective procedure criteria were modified, and vaginal birth after Cesarean (VBAC) attempts were increased. As a result, the C/S rate from May through July 2011 was down to 38.1%, better than a 3% reduction from the seasonally-adjusted baseline. This degree of improvement observed during the highest volume months suggests that the hospital will continue to experience improvement over the remainder of the year.

On-time starts in the OR affect each group of practitioners in the BU: nurses, providers, anesthesiologists, laborists, and scrub technicians, but is also a driver of patient satisfaction and overall LOS. If a C/S is delayed, the patient's stay is extended by the length of that delay, at a minimum. Oftentimes these delays were the result of a scheduled procedure being bumped by an emergent or non-emergent case. In these situations not only was that particular scheduled procedure delayed, but so too were all subsequent procedures scheduled for that day, thereby causing an even greater impact on both patient satisfaction and LOS. When the C/S schedule was modified and the requirement to document delay causes was implemented, on-time performance saw an almost immediate improvement. Over the three-month period of the engagement, the proportion of scheduled C/S that started on time increased to over 45%—more than a 40% improvement over the baseline; the goal is to achieve a 50% improvement, with an on-time start percentage of 48.6%.

The other primary metric for this engagement, overall LOS, is impacted by both the C/S rate and the on-time start performance. It is also affected by other improvement efforts aimed at patient flow, such as postpartum delays and MIU discharges. Preliminary data from May through July 2011 show marginal improvements in overall patient LOS—there was no noticeable change to LOS for vaginal deliveries, but average C/S LOS decreased by approximately 2.65 hours, or 2.5%. Secondary metrics, however, showed greater improvements which should, over time, lead to more significant savings in patient LOS.

Among the secondary metrics addressed, three are tied to the MIU. The first is the elapsed time between when a maternal discharge order is written and when the patient physically departs the unit. By allowing laborists to support the discharge process and capturing delay reasons, this period has decreased by 5% from 3.71 hours to 3.52 hours. It is expected that this trend will continue as discharge processes continue to be a focus of the sustainment effort. The second is the rate at which patients are discharged by specified times. Over the first three weeks that discharge performance was tracked, the MIU met its 11:00 AM goal of 30% only once; during the next three weeks that goal was met eight times. (Discharges by later times had better initial percentages, but showed similar improvement.) While the overall performance is still not at the preferred level, there is a noticeably improving trend that promises the desired results will be achieved in time. Third among the secondary metrics linked to the MIU is postpartum recovery time. Although this time is accrued in either L&D or the PACU, delays tend to be driven by a lack of resources available in the MIU to accept new patients. Since the tracking of these delays was not initiated until the last week of the project, results are not yet available for analysis. The final secondary metric that we assessed—on-time performance of the first scheduled C/S of the day—has also shown improvement, increasing to over 57%. The primary benefit of this is the trickle-down effect on other scheduled procedures. History indicates that as soon as one C/S is begun late, for any reason, there is little success in getting subsequent procedures back on schedule. By improving the on-time starts for the first procedure, the BU is aligned for success over the remainder of the day.

Finally, although not stated as an explicit objective for this project, the nature of process improvement efforts within the healthcare industry dictates that patient satisfaction must be a consideration. To that end, we investigated MIU Press-Ganey scores to determine the extent to which the implemented method changes were impacting patient satisfaction. Press-Ganey scores are reported quarterly, but there is some visibility on a rolling, weekly basis. Comparing the first quarter of 2011 (January, February, and March) and the preliminary scores from quarter three (1 July through 21

August), the overall discharge score improved by 4%. Because the project started during the middle of quarter two, the scores from April through June would not show conclusive evidence of improvement due to changes implemented by our team; however, the data do indicate that the upward trend began during the second quarter. The most notable improvement recognized by patients was "Speed of discharge process", which increased 7%. In addition to measuring patient satisfaction within an organization, Press-Ganey scores also allow a hospital to compare itself against its bed-count and state peer groups. With the improved ratings, the hospital currently ranks among the top 63rd percentile within the state for OB discharge satisfaction, a significant jump from ranking at the 21st percentile during quarter 1.

6 CONTINUING EFFORTS

In addition to the DSTs described previously that were created and delivered to the hospital staff for its use, other quantitative modeling tools were conceptualized to form the foundation for future performance improvement efforts. These included a delivery forecasting tool and a patient flow simulation model. Development of these tools has been initiated and is expected to continue over the next six to nine months.

Historically, the hospital saw an increase in monthly deliveries during the summer months, but did not always staff accordingly; however, this anecdotal trend did lead to some rudimentary forecasting to support future staffing efforts. These forecasts were based on the estimated due dates of the patients of each provider affiliated with the hospital. Essentially, each patient was grouped according to her expected delivery month, and the numbers assigned to each month were summed to predict the number of deliveries expected by month. This provided a reasonable estimation of the number of deliveries to expect within a particular month, but was a fairly static prediction.

By adding some statistical rigor, we intend to formulate a more robust and dynamic forecasting tool that will be used to support future staffing and scheduling efforts. Similar to the hospital's predictions, ours are also based on patients' estimated due dates. However, the challenge is that babies are rarely born on their due date (even when scheduled via C/S)—they arrive when they are ready. Using historical data we have fit gestational age at birth to a binomial distribution and are using this to probabilistically estimate the delivery date of current patients. Although we considered other demographic factors, such as mother's age, previous births, etc., we believe that gestational age alone is an adequate predictor and plan to test our prediction algorithm to determine if it will be sufficient.

In addition to the forecasting effort, we felt that a model of patient flow could provide significant benefit to the hospital staff. Throughout the course of the project, we were able to collect a vast amount of data concerning patient 'processing' times, or the time patients spent within each area of the BC (e.g. Triage, L&D). We also developed a thorough understanding of the paths that were available to each patient upon entering the BC. For example, many patients would arrive at Triage for a scheduled procedure, such as a non-stress test or a labor evaluation, and then were discharged home. Others might be in labor or scheduled for a C/S and therefore be admitted directly to the L&D floor. Utilizing this information, we developed a simulation model of a patient's journey through the BC. Using traditional OR modeling and analysis techniques, we incorporated appropriate probability distributions to ensure that the model was an accurate representation of BC paths and processes. Once validated, we intend to use the model to investigate potential or expected impacts of additional method changes prior to their implementation.

7 CONCLUSIONS

Much success has been achieved within the healthcare industry by applying LSS tools and methodologies to process improvement efforts. In an attempt to build on these achievements, it was our argument that incorporating more advanced data mining, modeling, and analytic techniques than have been traditionally used in LSS applications could only improve the overall results of a process improvement project. Over the course of this engagement, we believe that the results have justified our hypothesis. At the conclusion of the project the preliminary results have already indicated noticeable improvements in each of the stated objectives, with the promise of greater savings to come as the impacts of implemented changes are expected to be fully realized after one full year of sustainment.

Using LSS we were able to identify a number of process constraints, inefficiencies, and resource bottlenecks that were restricting workflow. By applying a variety of LSS techniques, we developed and implemented several process changes that had immediate impacts on operations. We also provided OB management and staff with monitoring tools to support the sustainment of these changes and resulting gains.

With data analytics and OR methodologies, we were able to take the next step in successful performance improvement within the hospital. By providing both leadership and front-line staff with the underlying data to support proposed changes, we obtained their buy-in and ownership, key factors in change management and sustainment. Furthermore, the analysis we performed and the tools and models we developed have armed leadership with the information and mechanisms needed to maintain this success through the ability to continuously monitor performance within the unit at both the group and individual levels and to assess the feasibility, reasonableness, and expected impact of other changes prior to their implementation.

Based on our previous experiences in applying LSS techniques and OR models independently to various efforts, we feel that the marriage of the two has been a huge success. Particularly within the healthcare setting, where clinical decisions and patient safety drive procedures and operations, the combination of the two methods provided a means for improvement that did not infringe upon the providers' decision-making processes nor on patient outcomes. In fact, it was expressed by provider staff that, despite their skepticism, improvements within patient flow challenged them to re-evaluate their clinical decisions. Providers were more aware of the impacts a decision will have on the rest of the unit, their patients' satisfaction, and most importantly patient safety. These realizations and staff participation will help to sustain the initial changes for lasting and rewarding effects.

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