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CASE STUDY

Applying Lean Six Sigma methods to reduce length of stay in a hospital's emergency department

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ABSTRACT
Operational excellence is critical to throughput and patient flow in an emergency department. This case study applied the Lean Six Sigma DMAIC methodology to improve throughput as measured by reducing patients' length of stay by 30% in just 3 months, and reducing the percent of patients leaving without treatment from 6.5% to .3%. The patient satisfaction, as measured by patient satisfaction surveys, had increased by 24% to 89.9%. This allowed the ED to achieve the top 1% level of hospitals nationally. This case study demonstrates the value of engaging healthcare providers in improving their processes through application of Lean Six Sigma methods.

KEYWORDS
DMAIC emergency departments; emergency services; Lean Six Sigma; nonparametric methods; process improvement; quality-management systems; Six Sigma method

Introduction

Overcrowding of patients in Emergency Departments (EDs) throughout the United States is occurring more frequently due to increased patient volume. Several reasons for the increased patient volume in EDs include higher patient acuity, protracted emergency evaluations, reduced bed capacity, nursing shortages, inefficiencies related to connecting to on-call specialists while patients are in the ED, and use of the ED by those with no other alternatives, such as those without medical insurance. Some of this overcrowding is also attributed to the inability of patients with insurance to be able to access their primary care physicians quickly, causing them to access emergency services (American College of Emergency Physicians, 2002).

Healthcare as an industry has begun to adopt Lean Six Sigma methods and tools in the last decade or so. Furterer (2014) provided several examples of how Lean Six Sigma was used in community-based hospitals to improve throughput in the ED, reduce Operating Room turnaround time between surgical cases, improve operating room organization, reduce linen loss, reduce unnecessary CT scans in an ED, implement evidence-based sepsis protocols in an ED, lean the surgical outpatient screening process, and design women's center processes (Cudney and Furterer 2012) (Cudney, Furterer, and Dietrich 2014). Six Sigma has been used to improve processes including ED cycle time reduction, clinic patient preparation, and medication safety (Christianson et al. 2005), reducing medication errors (Castel, Franzblau-Isaad, and Paulsen 2005), improving the patient discharge process (Allen, et al. 2010), and expediting CT scan throughput (Klein and Khan 2017). Wang, Li, and Howard (2013) proposed a system model to study patient flow in an ED. Stanton et al. (2014) applied Lean Six Sigma resulting in significant improvement in an ED in Australia. However, they questioned whether the improvement was related to the Lean Six Sigma methods and tools or instead related to leadership leveraging resources to create desirable outcomes through the project. Deblois and Lepanto (2016) found that Lean and Six Sigma are better adapted to processes that have a linear sequence of events. Hussein et al. (2017) combined the Six Sigma methodology and discrete event simulation to identify improvements to reduce overcrowding in an ED.

This case study describes the use of the Lean Six Sigma methodology and tools in a hospital's ED.

Methodology

The hospital has about 500-beds and is a community-based acute care facility. This hospital is accredited by the Joint Commission. The hospital is affiliated with over 700 physicians representing 27 medical specialties (Furterer 2014). The hospital had recently built a new and much larger ED, which they believed would improve patient capacity and throughput. However,

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they did not know how to change the processes to incorporate the following critical Lean Six Sigma principles:

- Design processes focusing on the critical needs of the patients. There was limited ability to identify critical needs of patients and translate those into process design requirements. The ED facility was designed without considering patient flow and best practice processes.
- Optimize cross-functional processes, with a system-wide view. The hospitals' processes were not designed; so much as, they evolved over time. New requirements based on new technology, or regulations would be introduced, and process changes would be introduced without understanding best practices for process design, especially with regard to how a process in one department affects other connected processes in another department. For example, the inpatient floors may implement staffing changes that affect the ability of the patients who are admitted from the ED to be placed in a bed on the inpatient floor.
- Eliminate wastes to improve processes and throughput. Waste is the non-value added activities that cause unnecessary activities and delays, such as travel, and additional tests. The staff did not know how to identify and eliminate wasteful activities in their processes.
- Focusing on process variation and the root causes of variation to understand the impact to the processes. The ED staff did not understand how to perform root cause analysis and focused only on symptoms of problems, not the root causes.
- Empowering teams and subject matter experts to improve their processes. Incorporating team-based problem solving with subject-matter experts to improve their processes engages stakeholders and reduces resistance to change.

This ED Lean Six Sigma project was the first of its kind in the hospital. The author's role in the project was as project and team facilitator, as well as the Lean Six Sigma Master Black Belt mentor for the team. The author also performed the statistical and data analytical analysis.

Define phase

The Define phase activities and tools are shown in Figure 1.

Activities	Tools
1. Create Project Charter and Stakeholder Analysis	▪ Project charter ▪ Stakeholder analysis
2. Perform initial VOC & Identify CTS	▪ SIPOC ▪ VOC, CTS
3. Select Team & Launch Project	▪ Project plan

Figure 1. Define phase activities and tools.

Create project charter and stakeholder analysis

The cross-functional team developed the project charter, shown in Figure 2.

The project charter helps the team to understand the problem to be solved. Many times the process improvement team is anxious to jump to solutions, before thoroughly understanding the problem that needs to be solved, to the level of detail that is necessary to start the project. The hospital recently renovated the ED, which provided much more physical space to provide emergency services to the patients. They believed that this would improve flow, but without re-designing and streamlining the processes, the patient length of stay got worse. The ED staff had been involved in prior process improvement efforts that were not actually implemented successfully.

Project Overview:	This project is focused on improving patient throughput in the ED. About 40% of the patients seen are admitted to the hospital, vs. 60% seen are discharged.
Problem Statement:	The Emergency Department is experiencing delays in moving the patients through the ED in a timely manner. From January through April, patients took an average of 5.8 hours for a patient to be seen, treated, tested and discharged and an average of 8.7 hours for a patient to be seen, treated, tested and admitted. There are excessive delays and an average 6.5% of the patients left without being seen. The total bypass hours for the past year were 341 hours.
Goal(s):	Improve ED throughput time to 3 average hours for discharged patients and 5 average hours for admitted patients. There could be an improvement in patient satisfaction and quality of care due to the synergistic relationship between throughput, quality and satisfaction.
Project Scope:	The scope includes the ED processes starting from patient entrance, to triage, treat, transport, test/diagnose, disposition and discharge/admit. This project will include identifying the major constraints to throughputs, the root causes and improvement recommendations.

Figure 2. Project charter.

Suppliers	Inputs	Process	Outputs	Customers
▪ Patient ▪ EMS ▪ Physicians ▪ Other facilities	▪ Request for ED Care ▪ Referrals ▪ Patient information	**Triage patient**	▪ Acuity level ▪ Triage decision	▪ Medical staff ▪ Patients
▪ Patient ▪ Medical staff	▪ Patient information ▪ Acuity level ▪ Triage decision	**Register patient**	▪ Registered patient	▪ Registration ▪ Medical staff ▪ ED Physicians
▪ Patient ▪ Medical staff ▪ ED Physicians	▪ Patient information ▪ Acuity level ▪ Triage decision	**Treat patient**	▪ Patient information ▪ Physician orders	▪ Patient ▪ Medical staff ▪ Ancillary staff ▪ ED Physicians
▪ Patient ▪ Medical staff ED ▪ Physicians ▪ Ancillary staff	▪ Patient information ▪ Physician orders ▪ Patient medical record	**Test / Diagnose Patient**	▪ Test results ▪ Specimens ▪ Diagnosis ▪ Patient medical record	▪ Patient ▪ Medical staff ▪ Ancillary staff
▪ Patient ▪ Medical staff ▪ Ancillary staff	▪ Test results Diagnosis	**Disposition Patient**	▪ Diagnosis ▪ Patient medical record	▪ Patient ▪ Medical staff ▪ ED Physicians ▪ Admitting & Consulting Physicians ▪ Ancillary staff
▪ Patient Medical staff ▪ ED Physicians ▪ Ancillary staff	▪ Diagnosis ▪ Patient medical record	**Transport Patient**	▪ Transported patient ▪ Patient medical record	▪ Patient ▪ Ancillary staff ▪ Medical staff
▪ Patient ▪ Ancillary staff ▪ Medical staff	▪ Patient ▪ Patient medical record	**Discharge or Admit Patient**	▪ Discharged or admitted patient ▪ Bill	▪ Patient ▪ Insurance companies ▪ Medicare/Medicaid

Figure 3. SIPOC.

Critical to Satisfaction (CTS)	
Title	**Description**
Patient throughput time	The length of stay, or time from when the patient arrives until they are discharged from the Emergency Department.
Patient wait time during visit	The time that the patient waits between major steps of the process.
Quality of care	The quality of care that the patient receives, especially from a diagnosis perspective.
Patient satisfaction	The satisfaction of the patient as determined through patient satisfaction surveys.

Figure 4. Critical to Satisfaction (CTS) criteria.

However, they had a very good idea of the goals of the project, and how much they believed that it was possible to improve the length of stay. Although, in a typical Lean Six Sigma project, the goals wouldn't yet be numerical at the Define phase due to not yet understanding the current state of the process.

Project charter

Project financial benefits for this project included increased revenue from reduction of patients leaving without treatment, increased volume and revenue through increased capacity and performance, and increased inpatient revenue by admitting additional patients that are seen through the improved ED. There will also be the potential for reducing operating costs through improved efficiency related to staffing resources.

The stakeholder analysis identifies the patients and stakeholders impacted by the Emergency Services' processes. It defines the stakeholders' type (primary or secondary), their primary role related to the process, their potential impacts and concerns, and receptivity to the project now and in the future.

For this project, we prioritized the stakeholders into primary, and secondary stakeholders. The primary stakeholders, are more involved and "touch" the process. We identified the primary stakeholders as the ED patients, ED physicians, medical staff, hospital administration, and ED registration staff. The ED patients are concerned with the quality of care, having low waiting times and patient satisfaction. They would

Activities	Tools
4. Define the Current Process and Voice of Process (VOP) Performance	▪ VOP ▪ Data collection plan ▪ Process maps
5. Define Detailed Voice of Customer (VOC)	▪ VOC
6. Validate Measurement System	▪ Measurement Systems Analysis (MSA)

Figure 5. Measure phase activities and tools.

Figure 6. Value chain for emergency services.

be neutral to the project, since they are not directly involved on the improvement project, other than completing patient satisfaction surveys, although they are most certainly impacted by the process activities and outcomes. The ED physicians are critical to the processes, and provide healthcare and diagnostics for the ED patients. The ED physicians want efficient processes, high patient satisfaction, and to improve the patient throughput and capacity of the ED. They strongly support the project now and should also do so when the team implements improvements. The medical staff includes nurses, technicians, transportation, lab, radiology, pharmacy, and other patient areas who provide care. As a stakeholder group, they generally are moderately supportive at the start of the project, however, need to strongly support the improvements as the team implements improvements. They are concerned about efficient processes and patient satisfaction. The hospital administration are primary stakeholders that manage the hospital, and will provide necessary resources for the project. They are strongly supportive of the project, and requested the project to be performed. Administration is concerned with the efficient use of resources that patients are satisfied with the healthcare services and patient throughput, which equates to costs in the ED.

The secondary stakeholders "care" about the project and process, but are not involved at the critical level of the primary stakeholders in the ED processes. The secondary stakeholders are the Emergency Medical Services (EMS) who transport the patients to the hospital when they are critically ill. They also include the admitting physicians who admit the patients to the hospital, the regulatory agencies who ensure adherence to the regulations, and ancillary support services who provide meals, supplies, and clean the ED rooms.

The SIPOC is used to ensure that the team has identified the suppliers and customers of the inputs and outputs of the process activities. It provides a check and balance to ensure that the scope of the processes are understood and all of the stakeholders have been identified, so that they can be engaged in the project. The SIPOC is shown in Figure 3.

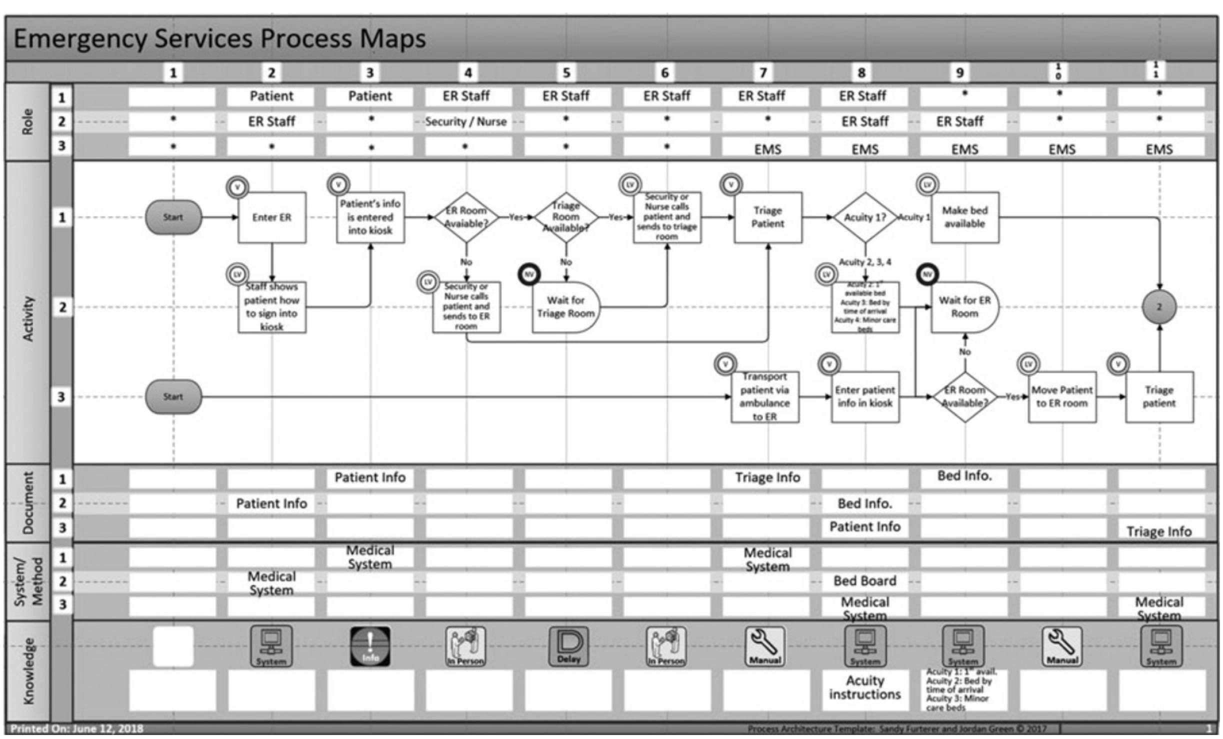


Figure 7. Emergency services process maps example.

Data Collection Plan		
Critical to Satisfaction (CTS)	Metric (short title)	Operational Definition (metric description)
Patient throughput time	Total LOS	Time from patient arrives to discharged from ED (physically leaves)
	Triage time	Time from arrival until patient is triaged
	EDP Time	Time from when the patient is seen by the ED Physician to when they complete their disposition
Patient wait time during visit	Wait time for ED	Time after Triage until the ED physician sees the patient
	Orders to leave ED	Time from when orders are received to when the patient physically leaves the ED
Patient satisfaction	% Left Without Being Seen	The number of patients left without being seen / Total number of patients signed into ED.
Quality of care	Lab time	Time to perform labs: time from ordered by physician to results provided to physician
	Diagnostic time	Time to perform diagnostic tests: time from ordered by physician to results provided to physician
	Register time	Time from arrival in ED to the patient is registered
	Admit time	Time from diagnosis to when the patient is admitted to inpatient floor

Figure 8. Data-collection plan.

Perform initial VOC and identify CTS

The working project team developed the initial Voice of the Customer (VOC) based on their knowledge of the patients and the patient satisfaction survey results. The Critical to Satisfaction (CTS) criteria are shown in Figure 4. The critical elements from a process output perspective are patient throughput time, or the patient length of stay in the ED; the patient wait time during their visit; the quality of patient care; and overall patient satisfaction.

Select team and launch project

The hospital's Chief Executive Officer (CEO) selected the project working team representing the primary stakeholder groups. The Lean Six Sigma project team members included: Nurses and Physicians that provide care in the ED, staff that admit and register the patients in the ED, compliance personnel, imaging technicians and radiologists who provide results, lab personnel, inpatient floor and unit nurses, the Chief Nursing Officer (CNO), finance personnel, pharmacists, environmental services and hospital administration. Extremely aggressive milestones were encouraged by the Hospital's CEO. The project kicked-off at the end of May. The DMAIC process was conducted across a 3-month period. The improvement ideas were piloted in late July until November. Improvement levels and control mechanisms were implemented in late November. This was very quick for a project of this size and scope.

Measure phase

The activities shown in Figure 5 were performed in the Measure phase.

Define the current process and voice of process performance

The Master Black Belt facilitated the project team and subject matter experts through documenting the ED processes using process maps with swim lanes. The Emergency Services Value Chain was developed and used as a guide for ensuring that all of the processes were understood and documented. The Value Chain for Emergency Services is shown in Figure 6.

A sample process map is shown in Figure 7 for the patient arrival, triage and ED bed assignment process. The remaining ED processes were also documented, which included lab processes, imaging diagnostics, patient registration and testing, transporting patients, inpatient hospital bed assignment, and admitting process from the ED.

The Voice of the Process (VOP) encompasses collecting data to understand the current state of the processes. The data collection plan identified the data to collect to understand the current state processes. The data collection plan is shown in Figure 8.

The ED Bed Board, an in-house developed Business Process Management System, records the time that the patient moves through each major step in the ED care process. We leveraged the ED Bed Board to capture the process times.

Figure 9 shows the baseline ED process time line for the data collected from January through April.

The current state baseline average metrics (minutes) by process activity for admitted and discharged patients are shown in Figure 10. Notice that the average times do not add up due to the variation and differences in patient categories in the data.

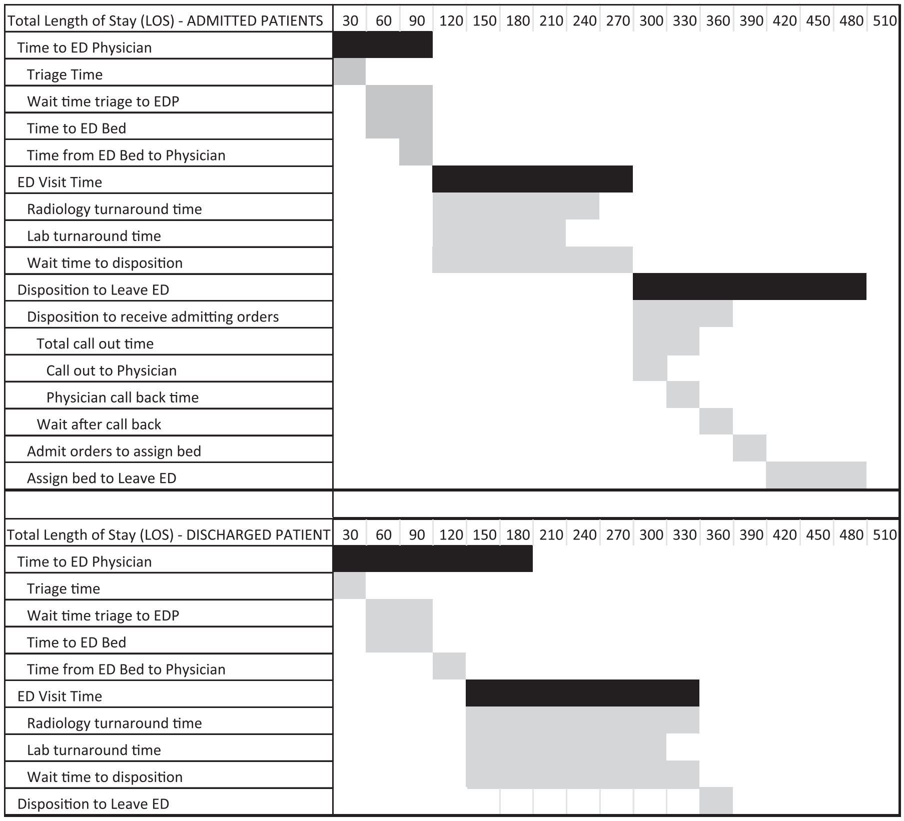


Figure 9. Current state ED process time line (average minutes)—admitted and discharged patients.

Define detailed voice of customer

The subject matter experts on the project team represented the internal VOC based on their knowledge of the patients' needs. The patient satisfaction surveys already collected by the hospital were used to represent the patients' voice.

Metric	Baseline	
	ED Admitted	ED Discharged
Total LOS:	8.7 hours	5.8 hours
% LWBS:	6.50%	
Total Time to EDP:	93	109
- Triage Time:	34	34
- Wait time triage to EDP:	65	79
- Time to ED Bed:	61	81
- Bed to Physician	34	55
Treat/Diagnose to Disposition Time:	192	175
- Radiology Diagnostic Time:	138	270
- Lab Time:	119	
- EDP Time: Visit	192	175
Disposition to Leave ED	223	64
- Disposition to get admit orders	103	
- Total Call out Time	41	
- Call out to Physician	13	
- Physician Call Back	29	
- Wait after call back	37	
- Admit Orders to Assign Bed	42	
- Assign Bed to Leave ED	112	

Figure 10. Current state average metrics (minutes) for admitted and discharged patients.

We developed histograms from the ED Bed Board for the patients' length of stay by admission type, using Minitab statistical software. The histograms for the admitted and discharged patients are shown in Figure 11.

The distributions of the Length of Stay data are non-normal distributions. They have long tails with a few patients having long lengths of stay. These occurred either when patients are held in the ED when critical care beds are not yet available, due to high inpatient census, or holding patients while a transfer to another facility is set up. The standard deviations were quite high, 3.9 h for patients admitted to the hospital and 3.0 h for patients who were treated and discharged from the ED.

Validate measurement system

We validated that the ED Bed Board data was consistent with the operational definitions and that the data was collected consistently. We observed the ED processes to understand how the data was collected. The only issue that was discovered about three months into the project, was that the time that the patient physically left the ED was not recorded precisely when they left the ED, but when the record was closed by the ED nurse. We added

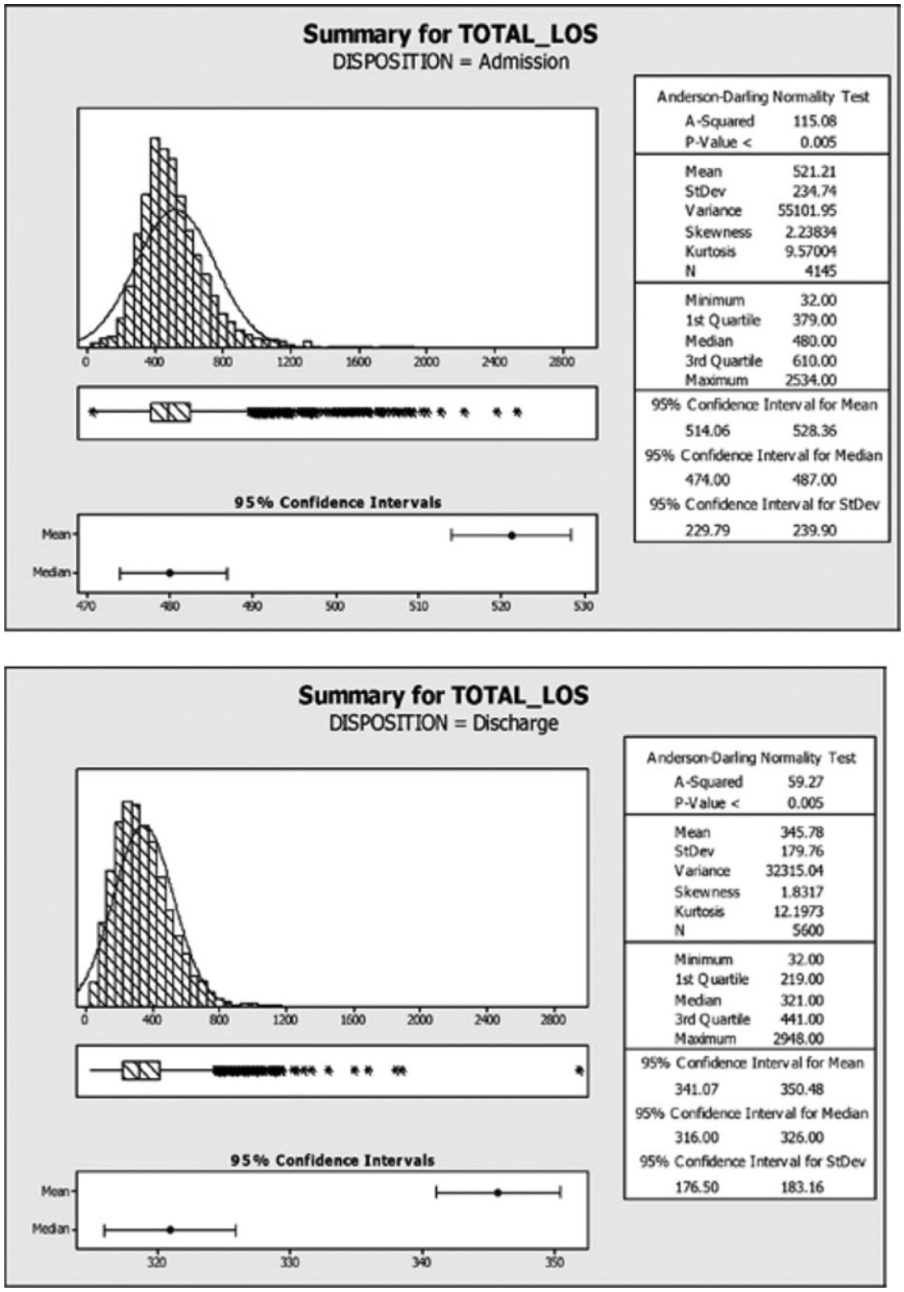


Figure 11. Total length of stay histogram of admitted and discharged patients.

another field that the ED nurses used to know when the patient left the ED, and trained the nurses how to use this newly added field.

Activities	Tools
7. Develop cause and effect relationships	▪ Root cause analysis ▪ Why-why diagram ▪ Correlation analysis
8. Determine and validate root causes	▪ Statistical analysis ▪ Graphical analysis
9. Develop process capability	▪ Takt time, capacity analysis, bottlenecks ▪ Process capability

Figure 12. Analyze phase activities and tools.

Analyze phase

The activities shown in Figure 12 were performed in the Analyze phase.

Develop cause and effect relationships

We performed the five Why's analysis and developed several Why-Why diagrams for the following process problems regarding:

- Understand why patient flow is not continuous, and fraught with multiple delay types

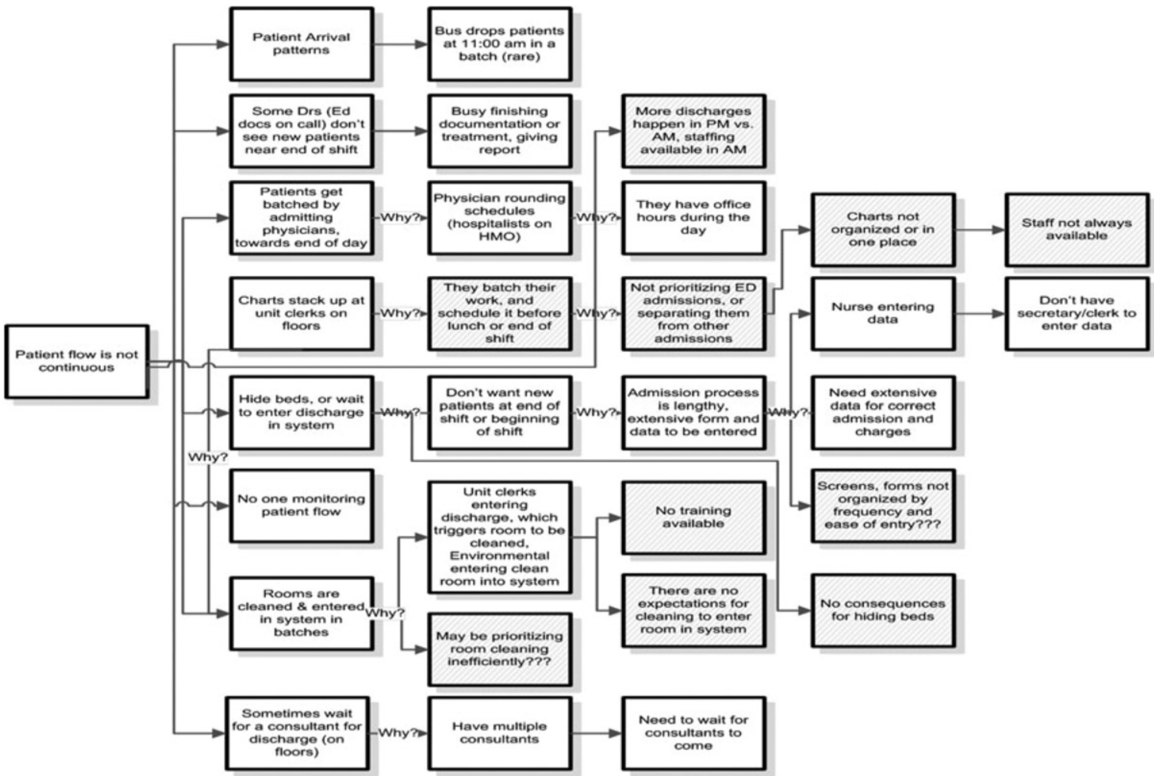


Figure 13. Why-why diagram for "why is the patient flow not continuous?"

- Reasons for why the admitting physician call back takes an average of 43 min
- Causes for why patients wait in minor care
- Reasons that the triage time is an average of about 34 minutes for admitted and discharged patients, and 53 minutes for patients that leave before being seen by a healthcare professional
- Understanding the delays in getting patients registered for ED services

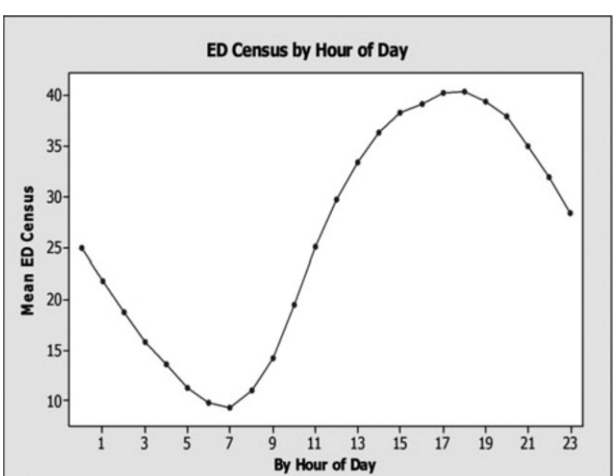


Figure 14. Patient census and patient arrivals/departures by time of day.

- Root causes for delays in getting the nurses in the ED rooms to provide nursing care to the patients
- Causes for delays in getting physicians to provide care for patients in the ED rooms
- Reasons for delays in scheduling and delivering radiology diagnostic tests for patients
- Causes of delays in lab tests and results
- Reasons for delays in discharging patients from the ED when care is complete
- Causes for delays in providing bed assignments for admitted patients
- Reasons for delays in quickly getting patients moved by patient transport to inpatient rooms when they are admitted to the hospital.

An example of the Why-Why diagram for "Why is the patient flow not continuous?" is shown in Figure 13.

Determine and validate root causes

We analyzed the ED Bed Board system data to understand the factors that impacted the patient throughput. We stratified the ED Bed Board data in many ways, such as patient demographics, diagnosis, the

Activities	Tools
Design future state with costs and benefits	▪ Improvement plan ▪ Cost/benefit analysis
Establish performance targets and project scorecard	▪ Performance targets ▪ Project scorecard/dashboard
Gain approval, train, and pilot	▪ Hypothesis tests

Figure 15. Improve phase activities and tools.

way patients arrived in the ED, the number and types of diagnostic tests performed, and acuity levels.

The patient census, arrival and departure data had very interesting and predictable trends, as seen in Figure 14.

These graphs show that as the arrivals increase around 11 am, it takes until almost the end of the day for the departures to catch up and the census to be reduced. The patient left without being seen pattern reaches the maximum level when the highest level of patients departing from the ED occurs. However, there is a several hour delay in removing patients from the ED Bed Board system that may have physically left the ED two to three hours prior. The ED Staff removes the patient after they are called in the waiting room, which is when they notice that the patient has left. Patients will tend to leave without treatment if they have to wait longer to be triaged, on average 20 minutes longer than those who do not leave without treatment.

A goal would be to improve the patients' experience early in the process by triaging them more quickly, and retaining them in the system.

From the data, we also see that the average length of stay varies slightly for different days of the week. The average ED census also varies some across the days of the week. It also is apparent that the more patients that are in the system, the length of stay increases, especially once it exceeds the normal system capacity of about 85 patients for the day.

Develop process capability

The takt time, is the time required to complete each unit, or getting each patient through the steps of the

	Baseline		Target		Improved		% Improvement	
	Admitted	Discharged	Admitted	Discharged	Admitted	Discharged	Admitted	Discharged
Total LOS:	8.7hrs	5.8 hours	5 (43%)	3 (48%)	5.6	3.9	36%	33%
% LWBS:	6.50%		3.50%		0.51%		92%	
Total Time to EDP:	93	109	35	35	26		75%	
- Triage Time:	34	34	15	15	11		68%	
- Wait time triage to EDP:	65	79	20	20	20		73%	
- Time to ED Bed:	61	81	35	42	13		82%	
- Bed to Physician	34	55	20	20	13		72%	
Treat/Diagnose to Disposition Ti	192	175	109	91	161		11%	
- Radiology Diagnostic Time:	138	270	154	154	N/A			
- Lab Time:	119				N/A			
- EDP Time:Visit	192	175	109	91	160		13%	
Disposition to Leave ED	223	64	127	33	155	47	30%	27%
- Disposition to get admit orders	103		59		77		25%	
- Total Call out Time	41		23		N/A			
- Call out to Physician	13		7		N/A			
- Physician Call Back	29		17		N/A			
- Wait after call back	37		21		N/A			
- Admit Orders to Assign Bed	42		24		25		40%	
- Assign Bed to Leave ED	112		64		64		43%	

Figure 16. Sample scorecard.

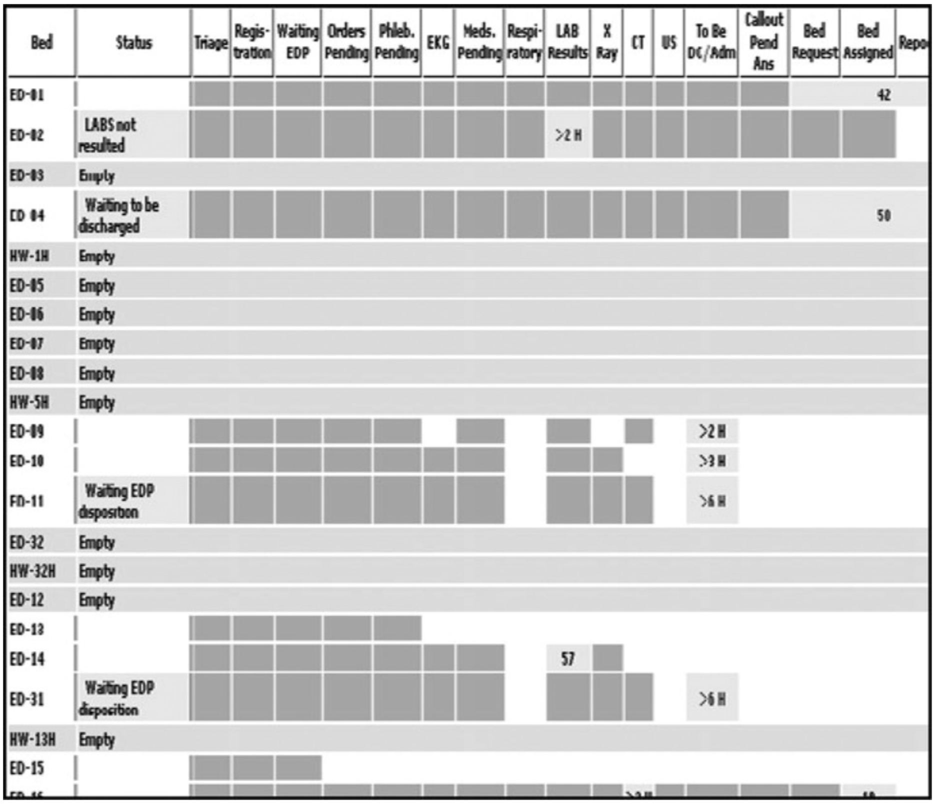


Figure 17. Sample flow dashboard.

process, aligned to patient demand. The takt time helps us to understand the target length of stay based on the current patient volumes. This also helps us to identify key bottlenecks, so we know where best to focus improvement efforts.

Takt Time = Total Available Time/Number of ED Visits
Total Available Time = Number of ED rooms * minutes per day
Takt time = Total Available Time/Patient Demand
Patient volume capacity = Total Available Time/System Cycle time

Where Number of ED rooms = 32
Minutes per day = 1440
Patient Demand = 90
System Cycle time = 409 (6.8 h)
Total Available Time = 46,080
Takt time = 512 min per day = 8.5 h per day
Patient volume capacity = 113 patients

The ED is working at 80% of its desired capacity, or 90 (actual) divided by 113 patients (desired). When the ED patient census exceeds 85 patients in a day, the number of patients leaving the ED without treatment skyrockets.

The takt time is calculated for each major activity, so the constraining or bottleneck activities are identified. The triage and registrations processes are the key bottleneck processes.

The ED processes are currently not statistically stable, so a long-term process capability is not yet feasible.

Improve phase

The activities and tools were developed in the Improve phase, as shown in Figure 15.

Design future state with costs and benefits

The Lean Six Sigma process improvement team generated improvement ideas to eliminate the root causes of process problems.

The ideas were organized into the following themes:

- Assignment of Inpatient Hospital Beds for ED Admitted Patients
- Processes for triaging patients and waiting room
- Call out and call back procedures for admitting physicians
- Transporting patients to inpatient floors and to diagnostic tests
- Managing patient flow

Metric	Before	After	% improvement
% LWBS	6.5%	.6%	91%
Time to Ed bed:			
Discharged:	61	13	79%
Admitted:	81	18	78%
Triage time	34	13	62%
Total LOS			
admitted:	8.7	6.1	30%
Discharged:	5.8	4.1	29%
Bed assigned to leaving ED	112	67	40%
Total time to EDP	93	32	66%
Diagnostic time	184	166	10%
Improved admit orders to assign bed time	42	32	24%
Disposition to get admit orders	103	70	32%
Time to assign inpatient bed	42	24	43%
Assign bed to leave ED	112	67	40%

Figure 18. ED improvements.

- Staffing in the minor care area
- Improving diagnostic testing
- Inpatient reporting procedures
- Improving the ED discharge process
- Incorporating dashboards and scorecards to manage and assess patient flow and throughput
- A description of each follows: (Furterer 2014)

Assignment of inpatient hospital beds for ED-admitted patients

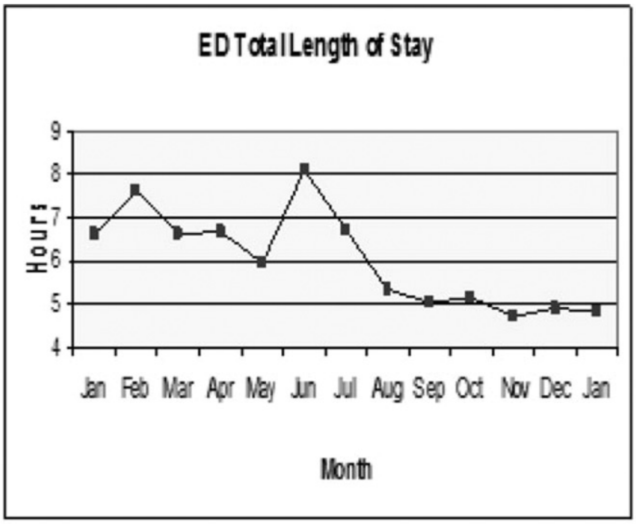
The assignment of inpatient beds for approximately 40% of the ED patients that needed to be admitted to the inpatient floors would improve patient flow. The true status of the inpatient beds was not consistently being updated in the inpatient bed board system. Beds would be cleaned and available, and not marked as ready to occupy in the system. The patients would also be discharged, and the beds would not be timely marked as ready to be cleaned. This could waste precious time that a patient could be admitted and moved to the inpatient floor, instead of waiting in the ED and adding to the ED census. More timely updates of the inpatient bed board could improve the time to assign inpatient beds for admitted ED patients. As a further improvement, the team proposed a new idea to have the Nurse Supervisors on the inpatient floors assign the inpatient beds, instead of the Admitting department. This could reduce the time to assign a bed, by better connecting the knowledge of the bed status to the nurses who are assigning the beds. Many times the admitting clerks had to call the floors to attain the bed status and the preferences of the nurse managers for bed assignments. This change eliminated the admitting department as the "middle man" between the ED and the floors. They also implemented a pre-emptive bed assignment, where beds would be tentatively assigned when it was likely that an ED patient would be admitted. The bed could be assigned when the ED nurses initially received the admitting orders, but prior to all of the report activities being completed.

Processes for triaging patients and waiting room

The team revised the triage and waiting room procedures to improve patient flow and getting patients into ED beds more quickly. When patient volume surged, the ED added a triage nurse to alleviate the triage bottleneck. When ED beds are available, patients were placed into the ED beds, and then triaged there, instead of waiting for a triage room to become available. They also did the patient's medication reconciliation in the ED room, instead of within the triage room.

Call out and call back procedures for admitting physicians

The team added a dedicated communication secretary that would be responsible to call the admitting physicians to obtain the admitting orders for the ED patients that needed to be admitted. This person would be added during the highest ED census time from 2 pm to 10 pm. The current medical call out policy required that the admitting physician be called



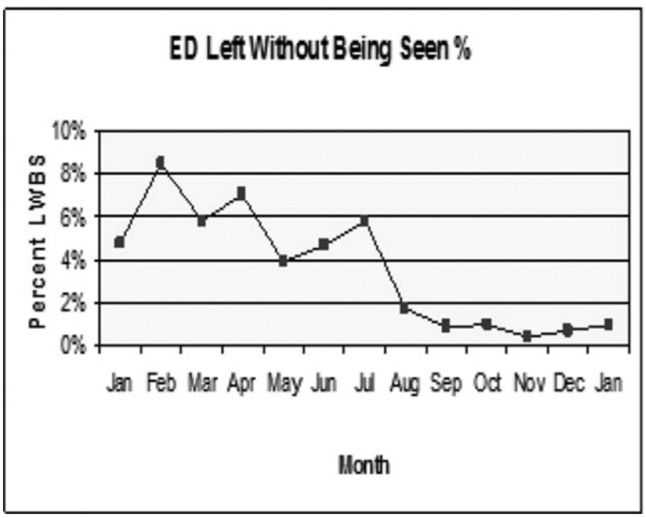


Figure 19. Improvement in total length of stay and percentage Left Without Being Seen (LWBS).

three times, within 15-min intervals. After the three times, if the admitting physician did not call back, the on-call physician could be called. In the current state, this policy was not adhered to consistently, and the 15 min would often be surpassed, adding time to the admitting process. The average time to call out to physicians was 13 min, with a 20-min standard deviation. The admitting physician call back time averaged 29 min with a 34-min standard deviation, exceeding the specification times. The average number of call attempts was almost 2 (1.8), before the admitting physicians returned the hospital's call to request admitting orders. The team developed a cost/benefit analysis to ensure that the additional revenue related to the communication secretary was justified compared to the employee cost. The cost/benefit analysis also included the cost of a dedicated ED patient transporter, and an additional ED nurse. The revenue was

Activities	Tools
Implement improvement recommendations and manage change	▪ Change management plan
Incorporate process control plans and scorecards	▪ Control plan
Implement continuous improvement cycle, plan do, check, act (PDCA)	▪ Replication opportunities ▪ Future plan

Figure 20. Control phase activities and tools.

based on the increased number of patients, from a daily average ED visits of 89 in the baseline period, to 101 average ED visits 2 years after initial improvements were implemented. This resulted in an increase of 13% ED visits. The revenue numbers were based upon ED visit revenue, and inpatient revenues for the nearly 40% of the ED patients admitted as inpatients.

Transporting patients to inpatient floors and to diagnostic tests

The team added a dedicated patient transporter in the ED during the highest ED census times of 3 pm to 11 pm. We estimated a rate of return based on both reducing patients leaving the ED without being seen and the additional volumes of patients by increasing ED capacity by reducing the length of stay. The benefits far exceeded the costs by a ratio of 13.4 to 1 (benefits to cost), much higher than the break-even ratio of 1 to 1.

Managing patient flow

The team developed additional ED Bed Board alerts for when the patients exceeded the desired process time targets. These alerts were used to enact a surge plan, which included special activities and resources that are put in place when the patient alerts and volume exceed predefined limits.

Staffing in the minor care area

The ED added a minor care physician to staff the minor care area when volume warrants. This greatly reduced the length of stay for low acuity patients that used to have to wait for an ED physician from the higher-level acuity area to sign off on the patient chart.

Improving diagnostic testing

Both lab and imaging test improvements were implemented. A fast track pregnancy test required for radiology was implemented for women of childbearing age. A new Lean Six Sigma team was formed to reduce the number of CT scans. Since the radiation exposure for one CT scan is roughly equivalent to 1000 X-rays, it is important to safeguard that all CT exams are the best modality to use for the medical issue presented. We also added an electronic alert to the ED Bed Board to track the time required to draw lab specimens.

Inpatient reporting procedures

Information technology automated the transfer form that was previously being re-written by the ED nurses to share with the inpatient floor nurses. This greatly enhanced the communication between the ED and the floors and units.

Improving the ED discharge process

Yet another new process improvement team was created to improve the inpatient discharge process. This would help to ensure that inpatient beds are available when needed to admit ED patients. This would alleviate some of the crowding in the ED.

Incorporating dashboards and scorecards to manage and assess patient flow and throughput

The Information Technology department developed a Flow Dash Board within the ED Bed Board system that could be used to monitor each and every patient in the ED, and to identify patient bottlenecks. We also developed scorecards that helped to ensure the ED was achieving their performance targets.

The Chief Information Officer (CIO) was a critical team member on the process improvement team. She developed requirements based on the input of the process improvement team's development of the improvement ideas and action plans. The dashboards were developed in-house through the Information Technology (IT) department and implemented within the ED Bed Board System. The dashboards were automatically generated from the ED Bed Board System on a monthly basis, and on demand.

Establish performance targets and project scorecard

A sample scorecard is provided in Figure 16.

An example of the Flow Dash Board is shown in Figure 17.

The flow dashboard helped to keep the patient moving through the process by identifying the status of each patient within the value chain of activities.

Gain approval, train, and pilot

The team began to pilot improvements at the end of July.

We applied the scorecards to track weekly improvement. We enhanced some of the improvements and continued to develop additional improvement ideas.

For all of the process improvements that were implemented, we updated the process maps and developed the future state process maps.

Remarkable improvements were made in the percent of patients that left the ED without being seen (LWBS) by a healthcare professional. The LWBS percentage decreased by 3%, from 6.5% to 3.5%, and eventually to .3%. The time to get the patient into an ED bed improved by 50% for admitted patients and 51% for discharged patients (reduced by 30 and 42 min, respectively). Within 3 months significant momentum was achieved in many of the process times, as shown in Figure 18.

The technical aspects of changes are sometimes the easiest to implement. It is the culture change that can be difficult, if not nearly impossible. However, this was not the case for our ED improvement project (Furterer 2014). A renewed focus was applied to reduce the percent of patients leaving without treatment. An ED physician assistant called a patient on their cell phone after they left the ED due to a long wait. The patient was still in the parking lot, returned to the ED and was treated. That is culture change! Another example was of a long-time ED physician that had reduced his schedule due to the chaos in the ED. He saw the incredible difference, and returned to the ED full time (Furterer 2014). Figure 19 shows graphs of the improvement in the Total Length of Stay and the percent LWBS.

Training for the new processes and procedures was incorporated as needed. Training ranged from formal training sessions for how the nurses needed to update the inpatient bed board, for how to assign hospital beds and how to monitor the ED Bed Board for bed requests. On-the-job training was received for many of the improvements. Additionally, simple communication mechanisms were incorporated, such as "the focus of the day," to train staff on simple process changes.

Hypothesis tests and improvement metrics

patient throughput. We performed a nonparametric test, due to the distribution of the total length of stay (LOS) data not being normally distributed. We used the Mann–Whitney one-sided test (Test of $\eta 1 =$

$\eta 2$ vs. $\eta 1 > \eta 2$) for the LOS metric for the January through April baseline data and compared the data to the July data after 1 year of the initial implementation of the process improvements. The baseline median length of stay was 384 minutes (6.4 hours) compared to the improved median length of stay of 269 min (4.5 h), at a significance level of 0.0000. This resulted in a 30% improvement within three months of the initial improvement implementation.

Left without being seen. The percent of patients Left Without Being Seen (LWBS) improved from 6.5% to .3%, at a significance level of 0.000, using a 2-proportion test.

Patient satisfaction

The patient satisfaction results were probably one of the most significant measures exemplifying how well the improvements worked. The baseline patient satisfaction prior to implementing improvements was 65.9%. After implementing the process improvements, the patient satisfaction for the third quarter improved to 73.5%, which was statistically significant at the 95% confidence level. The ED placed in the 90th percentile for patient satisfaction nationally, and second within the region. In the prior year, the patient satisfaction was higher at 68.9%, but had dipped shortly prior to the pilot. By the end of the project, patient satisfaction achieved the top 1% of hospitals nationally, rising to 89.9% (Furterer 2014). Quality of care was not an explicit Key Performance Indicator (KPI) measured as part of this project. However, the patient care was monitored continuously as part of the hospital's quality-management system.

Financial impact

The patient capacity, measured in number of ED visits, increased by 12 ED visits per day, or 4380 higher ED visits after the improvements were implemented. This was measured 2 years after the initial improvements were deployed. This resulted in an estimated $3.4 million dollars net margin, from both increased ED visits and inpatients admitted from the ED.

Control phase

The control phase activities and tools are shown in Figure 20.

Implement improvement recommendations and manage change

The team used several change management tools throughout the project (Furterer 2014). A stakeholder analysis was performed in the Define phase that helped to understand the needs of each major stakeholder group, and engage the team members by hearing their "voice." The CEO spoke to the team at the project kick-off and conveyed the criticality of this project to the viability of the hospital.

Incorporate process control plans and scorecards

The improvement team remained together to monitor improvements and ensure targets were met. We communicated effectively with the executive team through status reports and metric scorecards. The ED Director monitored the control plan weekly, to ensure that the process remained in control. The team developed detailed control plans that identified control mechanisms and metrics to assess and control improvement. The ED Bed Board alerts became the control mechanisms to control the processes.

Implement continuous improvement cycle, plan do, check, act (PDCA)

A continuous improvement culture was generated in the ED. The team continued to hold monthly ED process improvement meetings where they developed and implemented new improvement ideas. The Lean Six Sigma method and tools were replicated throughout the hospital. Lean Six Sigma Green Belt training and certifications were implemented. Many of the same or similar improvements could be replicated in EDs throughout the country, adapted for each organization's unique factors and cultures.

Conclusions

The project was extremely successful, but challenging at the same time. The project scope was large and the processes were complex.

The team achieved great success in improving the Emergency Services processes (Furterer 2014). The length of stay, the percent of patients leaving without being seen, the door to doctor time and patient satisfaction all improved significantly (Furterer 2014).

There were many factors that contributed to the success of the ED Lean Six Sigma project, as follows:

- The CEO was highly visible throughout the project and extremely engaged. He provided gentle encouragement towards the targets and goals.
- Highly valuable and knowledgeable team members participated on the Lean Six Sigma team.
- The facilitator was highly experienced with both technical and change management skills.
- Information Technology was a key participant on the team, and made required technology changes quickly and with high quality.
- The ED Bed Board provided a Business Process Management System level of data and metrics that provided in-depth analysis and identification of root causes.
- Hospital Administration monitored performance weekly, and provided resources and approvals when needed.
- The ED Director and Nurse manager were engaged and willing to make change happen
- The ED staff was willing and able to pilot improvement
- The ED physicians were key process innovators leading the way to improvement and change.

Future research

Lean Six Sigma methods and tools can be applied to other EDs to identify process problems, their root causes and improvements. Some of the identified improvements that were implemented successfully in this project could be replicated, however, the LSS methodology should be used to ensure that the improvements apply to problems and root causes of each ED. The data-based approach of Lean Six Sigma is powerful in healthcare where data is available, yet not always used to measure, improve and control healthcare processes. More training, education, and applications of Lean Six Sigma in healthcare should continue in this patient-centered industry.

About the author

Dr. Sandy Furterer is an Associate Professor at the University of Dayton, in the Department of Engineering Management, Systems and Technology. She previously was a VP of Process Transformation for a community bank in Columbus, Ohio. She also was the Enterprise Performance Excellence leader that deployed Lean Six Sigma in a hospital system in south Florida.

She received her Ph.D. in Industrial Engineering with a specialization in Quality Engineering from the University of Central Florida in 2004. She received an MBA from Xavier University, and a Bachelor and Master of Science in Industrial and Systems Engineering from The Ohio State University. She has over 25 years of experience in business process and quality improvements with multiple service industries, including healthcare, retail, consulting, information systems, and financial services. She is an ASQ Certified Six Sigma Black Belt, a Certified Quality Engineer, an ASQ fellow, and a certified Master Black Belt. She is an author or coauthor of four reference textbooks on Lean Six Sigma, Design for Six Sigma, and Lean Systems, including her latest book: Lean Six Sigma Case Studies in the Healthcare Enterprise by Springer publishing in 2014. She is an author or coauthor of several journal articles, and refereed conference proceedings publications on process modeling, Lean Six Sigma, process improvement, and engineering education. She has over 80 conference presentations on operational excellence, process improvement, Lean Six Sigma, business process architecture, and engineering education.

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