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ABSTRACT

One of the key challenges to health care access in Canadian hospitals is growing overcrowding of the Emergency Departments (EDs), leading to the medical personnel overload, and the excessive waiting times to receive proper care. These adverse effects directly impact the patient satisfaction levels, the ability of the medical professionals to attend promptly to patients' health issues, and generate unnecessary costs. Addressing the sources of waste and improving the process provides better care and higher patient satisfaction, as well as increases operational efficiency and the ability of the medical professionals to intervene on time.

This paper describes an effort aimed at improvement of patients' experience over their ED stay. A combination of Lean tools were used to analyze, assess and improve the current situation. Simulation models based on current and future (desired) states were developed. Comparative analysis of both enabled verification of feasibility of proposed solutions, and provided quantifiable results.

1 INTRODUCTION

On at least a few occasions in their lifetime, an individual is very likely to visit a hospital. The serious issue concerning health care in Canadian hospitals is that they are very crowded and the waiting times are so long that it is rarely a smooth and satisfying experience.

Nearly 500 Emergency Departments operate in Canada (over 5,000 in the US) and provide care for patients around the clock. Canadians make annually 14 million ED visits, which result in 1 million hospitalizations (that accounts for 60% for hospital admissions overall). Canadians also rely more heavily (40%) on ED services than other nations (34% Americans).

Causes for ED overcrowding are well known (Derlet and Richards, 2002) and include hospital bed shortage, high medical acuity of patients, increasing patient volume, shortage of examination space and shortage of RN staff. Even though these issues are well recognized, alleviation of these problems in ED is not trivial and require addressing the complex systems issues. This, however, is not the focus of the paper; instead it concentrates on exploration of improving effectiveness of ED operations.

By creating a framework for eliminating waste in healthcare front-end processes, significant long term financial benefits can be gained – e.g., shorter lead times (meaning more patients served), less personnel required, more satisfied patients etc. All these benefits can be translated into financial figures.

The paper shows how a variety of Lean tools, such as Cycle Time Analysis, Work Combination Charts, Cause & Effect Matrix, Fish-bone Diagram, and Affinity Diagram, were utilized to assess and address the problem. The outcome helps to understand why the process system is creating long waiting lines and overwhelming delays. In addition, a simulation model software was used to convey this information in a visual form and perform comparative analysis. The modified process offers a better-managed, balanced and continuous patient flow through ED. Consequently, a comprehensive and feasible improvement appears that ultimately enhances the quality of health care services provided by the institution.

2 LITERATURE REVIEW

Since the concept of Lean thinking originated from manufacturing industry, it may be argued that the service sector and especially the health care sector may not gain from it. However, Womack and Jones (2003) advocate the application of Lean thinking in the medical systems. They argue that the first step in implementing Lean thinking in medical care is to put the patient in the foreground and include time and comfort as key performance measures of the system. Having multi-skilled teams taking care of the patient and an active involvement of the patient in the process is emphasized.

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Karlsson *et al.* (1995) argue that Lean product development, supply chain management, and Lean manufacturing are important areas also in healthcare. The focus on zero defects, continuous improvements and JIT in healthcare makes Lean concepts especially applicable. The establishment of customer interaction is equally important in the manufacturing industry as it is in the health care sector.

Young *et al.* (2004), see an obvious application of Lean thinking in health care in eliminating delay, repeated encounters, errors and inappropriate procedures. They suggest classification of conceptual issues, in particular which stakeholders can be identified as customers. Similarly, Breyfogle and Salveker (2004), advocate Lean thinking in healthcare and give an example of how Lean management principles can be applied to health care processes through the use of the Six Sigma methodology, which in many ways resemble the Lean production techniques.

Several case stories on Lean thinking initiatives in health care sector can be found in Miller (2005), and Spear (2005). In a recent publication by the Institute of Healthcare Improvement, two health care organizations in the US showed positive impact on productivity, cost, quality, and timely delivery of services after having applied Lean principles throughout the Measuring Lean Initiatives organization (Miller, 2005). Rogers et al. (2004), a medical director at the NHS Modernization Agency in the UK, claims that the key element of Lean thinking have been applied in service improvement programs for several years, and have shown successful outcomes in applying them among others to emergency flows and journey times in cancer care.

Due to the complexity of healthcare systems, discrete event simulation (DES) has proved to be an effective tool used for process improvement, particularly when combined with Lean manufacturing (TQM) and continuous quality improvement (CQI) techniques. An emergency department (ED) is the main area where thousands of patients flow every year. For this reason, several studies have been conducted to increase the efficiency of the ED using simulation tools. Most studies found in the literature aim at reducing waiting times and increasing service level (throughput) by improving the actual care process (Barnes and Laughery, 1998) or by increasing the size and the operation of the ED (Benneyan, 1997).

Komashie et al. (2005) conducted a study of an ED in a British hospital, with the objective to determine the impact of key resources (doctors, nurses, beds) on key performance measures (waiting times, waiting queues and throughput). The designed Arena model contains several features such as variable service times to model nurse and doctor ranking along with patient condition-based treatment durations. A different arrival process was used for each day of the week. Data was collected by means of Hospital log sheets, interviews, and on-site observations.

DES experiments show proportionality between waiting times and doctor utilization. Despite the good quality of the study, several essential elements of EDs were not explicitly included in the model such as lab tests, or triage codes. The highest reduction in waiting time appeared for a system without blockage, allowing admission of all patients. This scenario, however, is feasible only when a large bed capacity is readily available. While rare, such scenario remains of interest for simulating health crisis or epidemic circumstances, when system blockage must be avoided.

In an earlier study Saunders et al. (1989) proposed a model that contained several features such as triage priorities, lab tests, teaching aspects, result communication delays, and physicians' collaboration (concurring test results). Patients and lab specimens (blood samples, tests, and results) were modeled as entities flowing in the system. The main objective was to study the impact of key resources on waiting times and throughput. It was found that blood test turnaround time has a direct effect on patient throughput. Model logic was implemented using Siman and animation was performed using Cinema.

3 PROJECT WORK

The project was a joint effort involving hospital staff (nurses, doctors and administrators) and university research team. The hospital is a 278-bed facility that annually handles almost 140,000 patient visits, and cares for over 11,000 inpatients. Its Emergency Department logs over 57,000 visits a year and has 16 beds at its disposal. The hospital employs 1,859 staff, including almost 800 nurses and 413 physicians. The hospital has a Lean Transformation effort under way since 2005, but its focus and accomplishments have been limited. The work reported in here was aligned with broader Lean efforts in ED and was focused on the initial part of the ED, the triage process.

3.1. The ED Triage

In the ED triage procedures patients are categorized according to the severity level of their medical condition. Walk in patients, as well as emergency medical service (EMS) patients, are assigned a triage number of 1 to 5 (1 being most emergent, and 5 being the least) when they report to the triage nurse. Level one and two patients require immediate care from a physician. Level three patients are expected to see a physician within 30 minutes. However upon a number of visits to the ED, level three patients have been witnessed to be waiting over an hour in the waiting room. The number of those patients who seek medical care from the ER is significant, but due to resource deficiency they are given the lowest priority. Level four and five patients are typically serviced before level threes simply because they are usually discharged shortly after being seen by a physician.

3.2. Approach and Methods

The process was observed from the customer/patient perspective, and later combined with the observations and interviews that were carried out with the service providers/nurses in order to design a holistic view. Figure 1 shows a part of the ED with the area of focus for this particular paper.

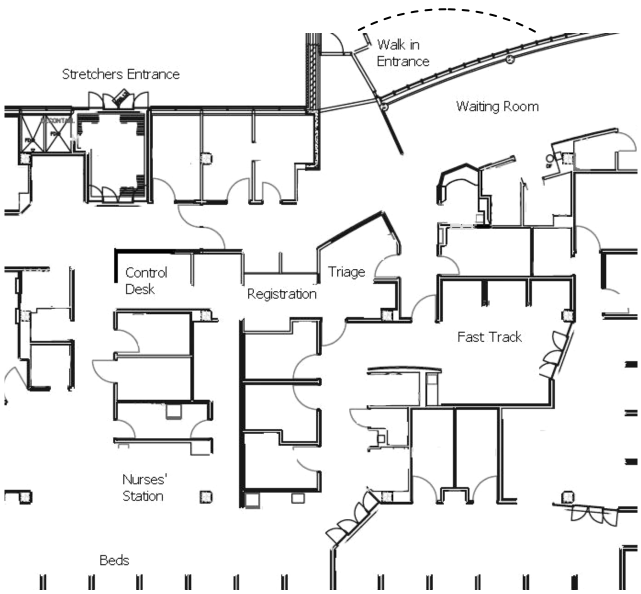

Figure 1: Floor Layout of Emergency Department

3.2.1. Data Analysis

All patients entering ED are logged into a census, which includes information about: date, census, hospital occupancy, beds available and waiting time. To understand the number of patients seen daily, the distribution of the data as well as any time related ED phenomena, a year worth of census data was used to construct various charts.

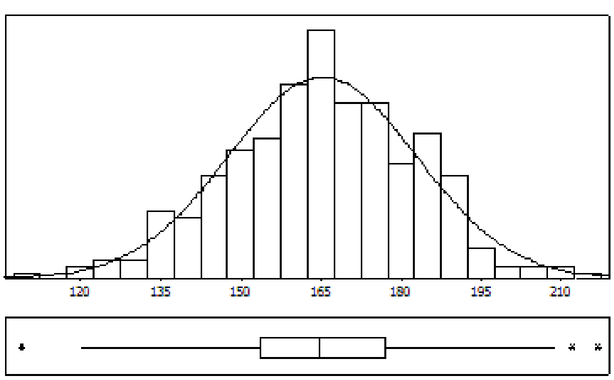

Figure 2: Statistical Summary of ER Census

Statistical summary charts and control charts were used in this analysis, (see Figs. 2 and 3). Figure 2 shows that the ER census data follow the normal distribution, with a mean of 165 patients/day, a standard deviation of 17.65 patients/day.

Analysis of the control chart in (Fig. 3) indicates that the hospital experiences an admission peak around the winter school holidays, and lowest admission levels occur around the spring school break. Figure 4 captures the difference between the weekends (average of 154 patients admitted) and the weekdays (average of 169).

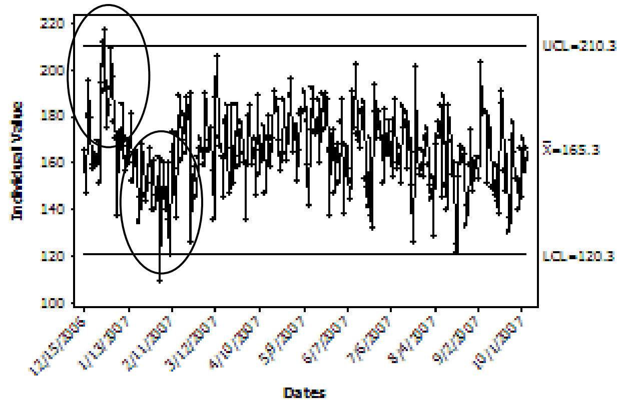

Figure 3: Process Stability

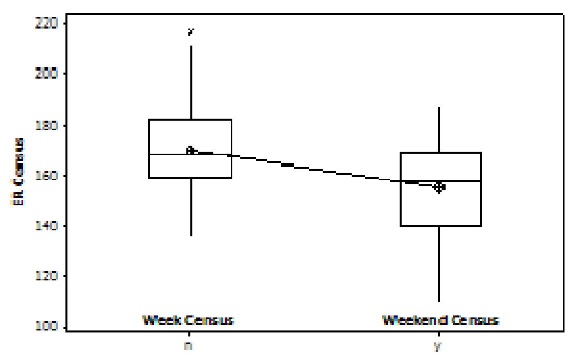

Figure 4: Weekday vs. Weekend Census

3.2.2. Lean Methods & Tools

Cycle time (CT) templates were created by observing the six fundamental staff positions in the ED. They included the security guard, charge nurse, triage nurse, patient liaison, and both registration clerks. A balancing chart was produced from this data (see Figure 5). Takt Time was found to be 523 seconds for a demand of 165 patients/day and again, 432 seconds for a demand of 200 patients/day.

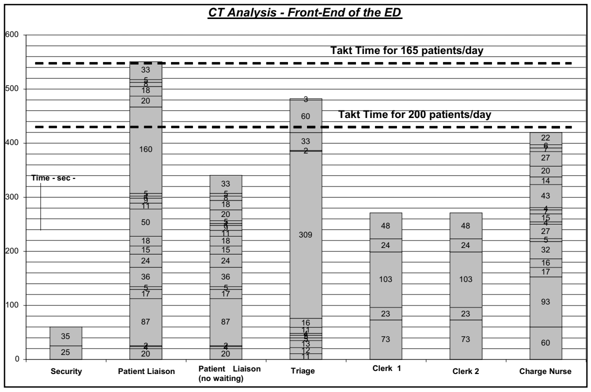

Figure 5: Cycle Time Analysis

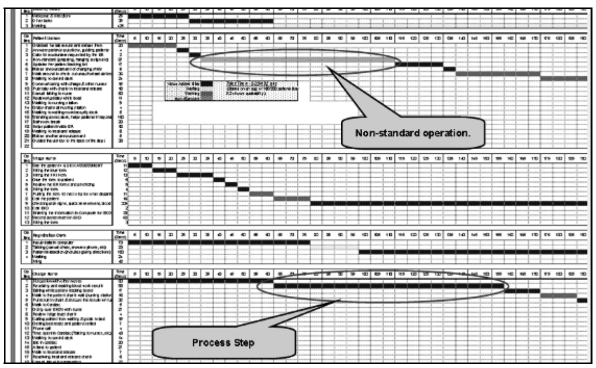

Figure 6: Work Combination Chart

Another way of displaying the sub-elements of the jobs was to show the time in seconds that each person spends during the subtasks in a Work Combination Chart (see Figure 6).

3.2.3. Brainstorming

These findings from the observations were presented and discussed in a brainstorming session. Improvement ideas generated in the brainstorming process were sorted into six categories and portrayed in an Affinity Diagram and a Cause & Effects (Ishikawa) Diagram, (see Figure 7).

The hospital staff evaluated (on a scale of 1 to 10) the significance of the suggested development opportunities based on cost, safety, quantity, time, and staff acceptance criteria. The outcome is summarized in a Cause and Effect Matrix (Fig. 11). The suggestions were ranked in a decreasing order of ease of application.

3.2.4. Layout Considerations

The improvement prospects for the layout were also discussed by the team members. Several alterations were made and the benefits of those changes were evaluated.

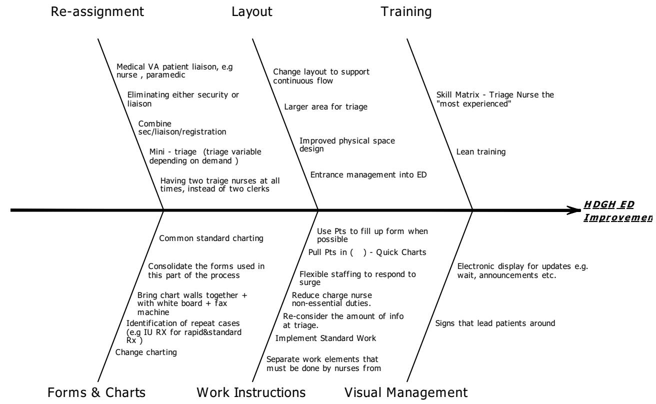

Figure 7: C&E Diagram

The Team analyzed the distance a patient needs to travel from the moment of entry to the ED until the point of admission. It turned out that the current process flow forces each patient to travel 184 ft (Figure 8).

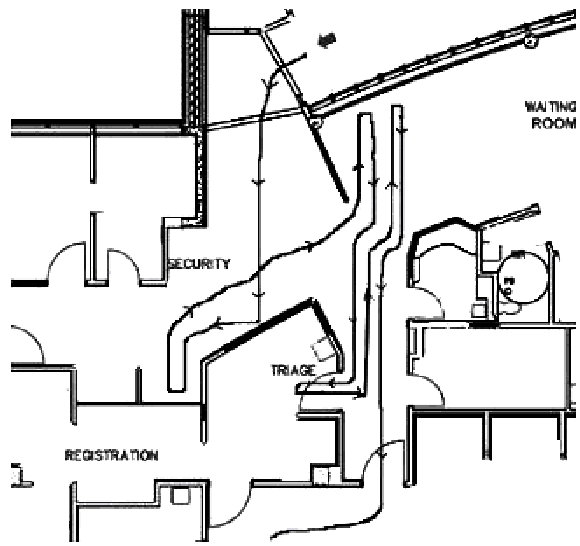

Figure 8: Trace of an individual patient travel in ED

3.3. Simulation

The current triage process was modeled using ProModel software. To obtain meaningful statistical estimates of the process characteristics, multiple randomized replications were run, under the assumption that patient arrival was following exponential distribution. The main input to the model was the inflow of patients, who were processed in the same manner throughout the system, but with priorities assigned in triage. Table 1 lists arrival probabilities of patients with different severity levels (according to The Canadian Triage and Acuity Scale Manual). The model gives Level 1 patient the highest priority to be "processed" and level 5's receives the lowest. Out of the average total of 165 patients/day obtained from the ED census, 110 arrive between 9 am and 9 pm (day shift), with an exponential distribution of E(390sec), the remaining 55 arrive between 9 pm and 9 am (night shift), with E(768sec).

Table 1: Arrival Probabilities of Patients

	Triage Level				
	1	2	3	4	5
Probability	0.01	0.07	0.33	0.43	0.16

From the stop-watch timing collected for each stage, the following average service times were assigned: 10 s for the 1st quick triage assessment, 145 s for registration, and 309 s for the 2nd vital signs triage assessment. A portion of the walk-in patients would go to the security guard or the liaison for help before going to triage. The major parameter the model was set to evaluate was the waiting time before the 2nd triage Assessment. According to the model, the patient would wait until the nurse was occupied with other tasks (doing 1st triage assessments and charting work); see Figure 10.

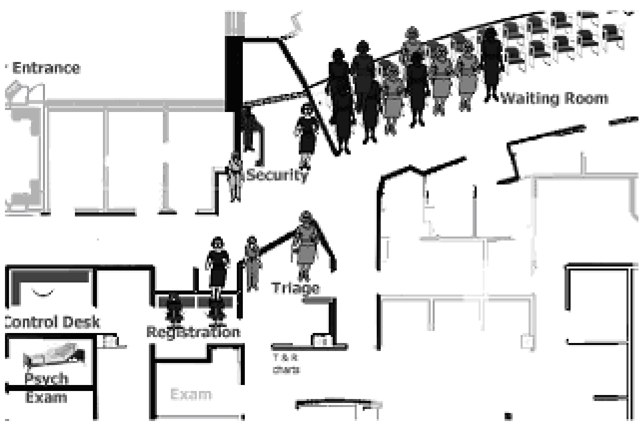

Figure 10: Process Simulation – Current State

4 RECOMMENDATIONS

In the course of the study the activities in the entrance and the lobby of the ED which include were thoroughly investigated, including:

- Security
- Registration
- Triage
- Waiting room.

4.1 Cycle Time Analysis Results

The result of recording cycle times (CT) for each of the staff members working in the above-mentioned areas produced an analysis that allowed the comparison between the processes. It was found that they differ greatly (see Figure 6). In terms of CT, the individuals are listed below in descending order of required work effort:

- Triage nurse
- Charge nurse
- Patient liaison
- Registration Clerks
- Security Guard

When waiting constraint was removed, the triage nurse cycle time significantly dropped. The security guard was idle most of the time. The modifications proposed in this regard are mentioned later in this section.

4.2 Brainstorming Results and Selected Recommendations

As a result of the brainstorming session held, the suggestions were grouped under the following headings:

- Reassignment
- Work instruction
- Layout
- Forms
- Visual management
- Training
- Communication

Analysis of the Cause and Effect Matrix points out that Visual Management and layout reconstruction were the two top-rated activities according to hospital staff (see Figure 11).

Cause & Effect Matrix

	Rating of Importance to Output	Cost	Safety	Quality	Time	Strategy	Staff acceptan	
		8	10	10	8	6	6	
		1	2	3	4	5	6	
	Improvement Opportunities							Total
3	Visual M. - Signs that lead patients around	9	9	9	9	6	9	414
8	Layout - entrance management into ED	9	9	9	9	6	9	414
23	Forms/Charts - bring chart walls together + with white board + fax machine	9	9	9	9	6	6	396
11	Work Ins. - Re-consider the amount of info at triage.	9	9	9	6	9	6	390
12	Work Ins. - Reduce charge nurse non-essential duties.	9	9	9	6	9	6	390
22	Forms/Charts - identification of repeat cases (e.g IU RX for rapid&standard Rx)	9	9	9	6	6	9	390
14	Work Ins. - Pull Pts in ( ) - Quick Charts	9	9	9	6	6	6	372
10	Work Ins. - Implement Standard Work	6	9	9	6	9	6	366
9	Work Ins. - Separate work elements that must be done by nurses from others	9	9	9	3	6	6	348
16	Re-assignment - medical VA patient liaison, e.g nurse , paramedic	6	9	9	6	6	3	330
19	Re-assignment - Mini - triage (triage variable depending on demand)	9	6	6	6	9	6	330
20	Re-assignment - having two traige nurses at all times, instead of two clerks	6	9	9	6	6	3	330
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 11: Cause & Effects Matrix – Prioritization of Improvement Activities

Visual Management suggestions included the following:

- Install a sign leading patients to triage.
- Provide more signs/maps guiding patients (explaining wait time situation) to save triage nurse or liaison time.
- Install a visual board (electronic display) to make waiting room announcements.

Since this matter was fairly simple to achieve and was highly prioritized by the Hospital, an effort was made to prepare signs that correspond to each of the points mentioned above.

Layout modifications included the following:

- Simplify the physical ED layout – current layout is confusing to patients, they are easily lost.
- Improve further physical space design to aid flow.
- Provide larger area for triage.
- Re-design the flow to avoid traveling and over-processing.
- Close access to ED through one of the existing entrance doors or make it exit only.

Keeping the desired ED state in mind, the team redesigned the layout to have only one point of entry to the ED, accessible to both walk-in patients and EMS patients. A smaller waiting room (having approximately 8 seats) leads to two triage rooms that can simultaneously receive and assess patients. From these triage rooms there are two separate waiting rooms (approximately two seats in each) adjacent to either side of the registration room. Patients are then directed from registration to the required care facility (for example, Treat and Release, ER beds, Cardiac, Fast Track, Trauma, Psychiatric care). The proposed layout is expected to decrease wait time and facilitate flow (see Figure 12).

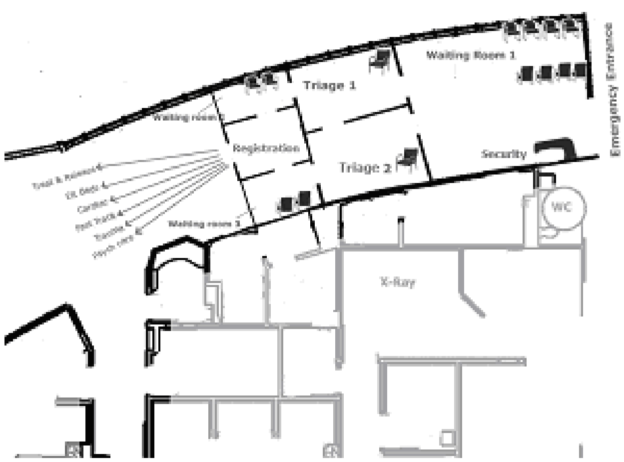

Figure 12: Proposed Layout

The proposed state with modified layout guides patients directly without confusion so the signs mentioned above will not be necessary anymore. It was estimated that the walking distance was reduced to 95 feet; a decrease of about 131 feet.

Some of the proposals related to re-assignment and work instruction issues, are listed as follows:

- Separate the work elements that can exclusively be carried out only by nurses, assuring that they have more time to carry out their essential (value adding) duties. For example: walking back to evacuate visitors from back of department can be done by either security or patient liaison.
- Standardize (to the degree possible) the tasks of the charge nurse (and liaison).
- Use flexible staffing to respond to patient surge (physician/triage/clerking).
- Carry out registration and triage simultaneously, where possible.
- Replace liaison with registered nurse to assist with triage.
- Place a nurse at the entrance (security outside)
- Introduce demand-dependent mini-triage.

After reviewing all suggestions, the team considered the top most promising recommendations:

- Merge the patient liaison and the security responsibilities into a single position.
- Have only one registration clerk instead of two, while employing a second triage nurse during the busy day shift.

Figure 13 shows the impact of these changes on the load of personnel involved in triage. Compared to Figure 5, Figure 13 below shows an extra triage nurse bar, the elimination of clerk two, and the transfer of the liaison's task times to the top of the guards' cycle time making them a single position. The workload clearly looks more reasonable, even with the elimination of two positions.

In the Training and Communications category, the key ideas were:

- Ensure that the profile of triage nurse is "most experienced" in her role, where assessment is made.
- Provide Lean training.
- Redesign perimeter of triage and registration desks (glass window around them dampens the sound and hampers communication).

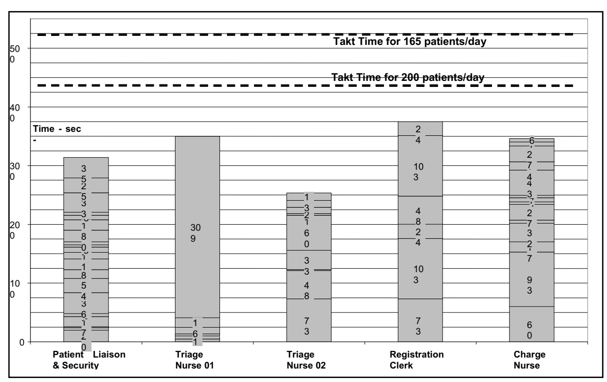

Figure 13: Cycle Time Analysis – Future State

Finally, ideas about Charts and Forms and the issue of excess paperwork expressed in the affinity diagram included the following points:

- Unify charting format and consolidate forms
- Eliminate excessive paperwork.

- Consolidate chart walls with the patients tracking whiteboard and the source of incoming lab results (fax machine).
- Allow patients to complete some parts of their registration forms.
- Reduce clerical work at triage.

The original objective of this paper was to increase the flow throughout the ED at the hospital by introducing Lean and process improvement methodologies. This was accomplished as depicted in the previous results. The techniques used were successful in answering the questions and drawing meaningful conclusions from the data since the work was done in collaboration with the staff members at Hospital. The staff extensively aided in ruling out non applicable proposals, alongside contributing to possible future practical applications.

4.3 Simulation Results

The data for patient arrivals per day was split into two shifts, a 9 am-9 pm (day) shift, and a 9 pm-9 am (night) shift. Two thirds of the patients arrive throughout the day (with shorter inter-arrival times), and the rest arrive at night and the early hours of the morning (with longer inter-arrival times). A generated list of arrival rates for 31 days(one month) was created and fed into both models, the current state and the future state models.

For the current state it was found that:

- During the day shift, the waiting time for the 2nd triage assessment reached up to 3.8 hours. 61% of the time, patients would wait for more than an hour. 26% of the time, patients would wait more than half an hour. The shortest waiting time turned out to be 10 mins.
- During the night shift, the waiting time for the 2nd triage assessment reached up to 2 hours. 10% of the time, patients would wait for more than an hour. 30% of the time, patients would wait more than half an hour. The shortest waiting time turned out to be 2.6 mins.
- On 60% of the days, a day patient would wait 2 to 3 times as long as a night patient. 30% of the time, day patients waits over 3 times as much.
- The triage nurse is very loaded with work, and her/his utilization as a resource 83% of the time exceeds 80%. It would go up to 99%, and down to 62%.
- On average, both registration clerks are busy 21% of the time, the liaison and the security guard are busy only 7% and 0.3% of the time respectively.
- The total cost of staff involved is $450,000.

For the proposed future state model, it was found that:

- During the day shift, the most a patient would have to wait to get into triage is 4.9 mins (3.7 hours less than the maximum waiting in the current state, and 5.9 mins less than the current minimum!). 54% of the time patient would wait less than 2 minutes, and 35% would wait between 2-3 minutes. The minimum wait is 1.1 minutes.
- During the night shift, the most a patient would have to wait to get into triage is 9.1 mins (which is a 1.92 hours improved difference compared with the current state, and it occurs only 0.03% of the time). 20% of the time a patient would have to wait between 4-6 minutes. 65% of the time, the wait would be between 2-4 mins.The minimum wait is 0.8 minutes (see Figures 14 and 15).
- On 93% of the days, a night patient would wait more than a day patient, due to low staffing levels (a single triage nurse in the night shift). On 68% of the days, the night patient would wait 1.5–2 times as long as a day patient.
- On average, Triage room 1's utilization, (which accepts patients throughout the 24 hours) is 49%. The maximum it would reach is 67%. As for the Triage room 2 nurse working the day shift, his/her utilization is 42% on average. The maximum this resource is utilized is 61%.
- The one and only one registration position has an average utilization of 40% (see Figure 16). The utilization of the security guard is on average 1%.
- The total resource (staff) cost is $350,000 and may save $100,000 annually when compared to the current state (this is a rather conservative estimate, based on salary data from Ontario Nurses Association website <`www.ona.org/faq#f17`>).

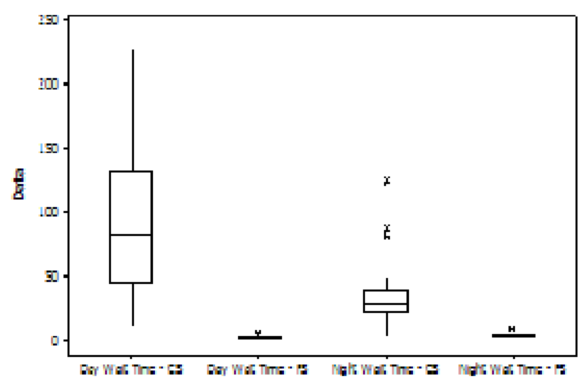

Figure 14: Box Plot Comparison of Waiting Times (current vs. future states)

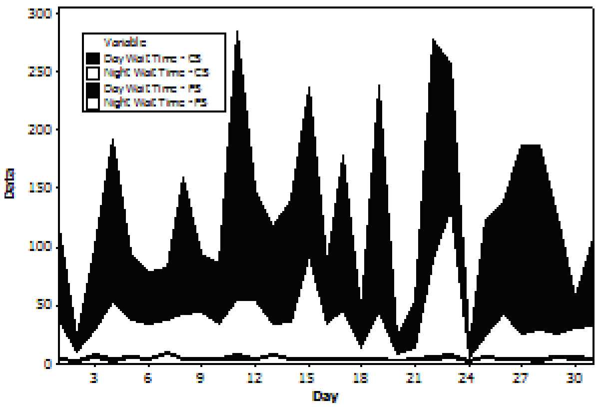

Figure15: Area Graph of Waiting Time

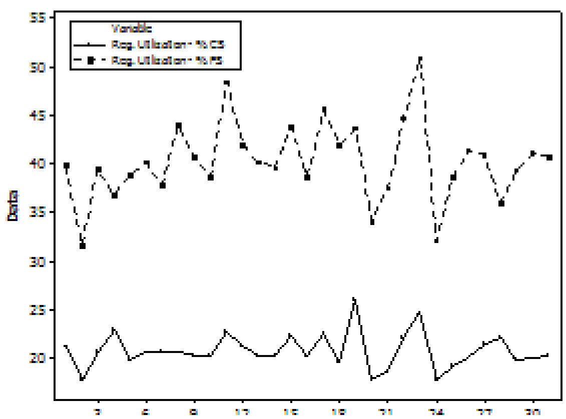

Figure16: Registration Clerk Utilization

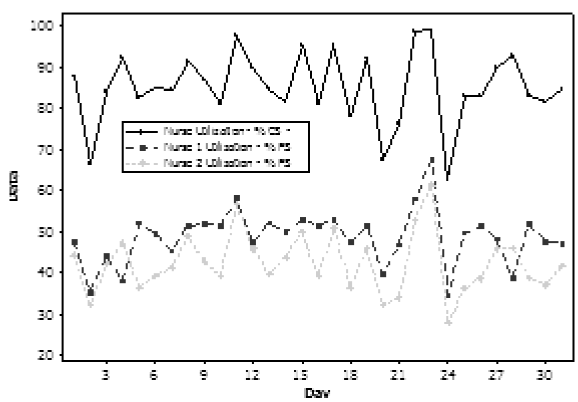

Figure17: Triage Nurse Utilization

In general, when comparing those results for both states, it can be noticed that for the suggested future state, the $100,000 worth of savings is very compelling for the hospital directly, and for the patients indirectly. The reduction in waiting time in either shift is significant. The radical reduction in triage nurse workload makes the future state much more flexible to accommodate a larger influx of patients in the cases of unfortunate exceptional circumstances such as in massive accidents or catastrophes (see Figure17). The closer utilization rates in the proposed future state indicate an improved balance, and that the existing intolerable bottleneck would be radically reduced.

5 LIMITATIONS

Although a lot of effort was invested in this study of Hospital Emergency Department, limitations attributable to multiple factors exist due to:

a. Limited timespan of the study.
b. Limited availability of resources. However, considering that the benefit of this type of Continuous Improvement activities is recognized, full time resources are required in order to provide continuity and sustain the gains.
c. Limited scope of the study: issues related to cultural, mindset and behavioral change were not covered.
e. The project did not consider any financial implications or commitments from the hospital management. While many improvements proposed can be implemented with virtually no budget, some require investment of money.

This paper will only be useful after validating its contents with future research and analysis. More work has to be done to discover the challenges currently facing many of the EDs in Canada and USA. At present, the hospital involved is studying and evaluating proposed process modifications and already has implemented ones that were relatively easy to implement (e.g., visual information cues).

6 CONCLUSIONS

The paper addressed some of the wastes in the front-end ED process, including transportation, over-processing, waiting, motion etc. To deal more effectively with different types of waste (Muda) in the process, the team applied Lean methodology techniques in order to understand the current state, develop an improved state of the process, identify the gaps and prioritize the activities.

The team succeeded in analyzing and proposing improvements in the front-end process of the Emergency Department at the hospital. Below is a summary of what in effort included/concluded the following:

a. Rebalancing of the front-end process that led to:
   - Re-assigning of one position by consolidating the patient liaison with the security guard;
   - Reducing the amount of work required from the triage nurse by:
     i. eliminating process waste (e.g. waiting, walking –

ii. re-defining one of the registration clerks' positions and replacing it with a qualified nurse position;
iii. dividing the work currently done by one triage nurse, to be done by two individuals, with the flexibility to provide support to the registration clerk when needed;

b. A Future State Layout that will:
- dramatically reduce the amount of travel the patient has to go though;
- simplify the whole triage process;
- reduce travel for the hospital personnel;
- make the whole process more intuitive –patients "flow" naturally from when they enter the ED to the point they are admitted;

c. Simulation of the overall process that made virtual changes more predictable.
d. Elimination of various wastes – e.g. over-processing of the forms, walking, transportation, waiting etc.
e. Improved Visual Management for the current state of the process;
f. Better understanding of the overall process, based on data.

Although this paper tackled only a diminutive part of the complete system, it certainly brought value to the already established internal Lean efforts.

7 FUTURE WORK

A logical continuation of this type of effort would be to elevate the level of work to the hospital level, rather than keeping it at the departmental levels. The reason for the long delays in the ED is not necessarily an internal flaw, the bottleneck might lie elsewhere. Some other processes down the line might be experiencing difficulties in admitting patients, automatically leading to an overcrowded ED.

At the point when a more comprehensive approach will be chosen, the most important part of Lean must be addressed with high priority, namely; people. No tools in the world can provide sustainability without a change in the culture, mindset and behaviors of the personnel. Unlike machines and processes that can be changed and improved relatively quickly, changing outlooks and mindsets (that would support Lean efforts) takes plenty of time and skill.

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