STEPS: Lean Thinking, Theory of Constraints and Identifying Bottlenecks in an Emergency Department

Abstract:

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Abstract
This study aimed to identify the bottlenecks in patientsâ journeys through an emergency department (ED). For each stage of the patient journey, the average times were compared between two groups divided according to the four hour time frame and disproportionate delays were identified using a significance test. These bottlenecks were evaluated with reference to a lean thinking value-stream map and the five focusing steps of the theory of constraints. A total of 434 (72.5%) ED patients were tracked over one week. Logistic regression showed that patients who had radiological tests, blood tests or who were admitted were 4.4, 4.1 and 7.7 times more likely, respectively, to stay over four hours in the ED than those who didnâ t. The stages that were significantly delayed were the time spent waiting for radiology (p=0.001), waiting for the in-patient team (p=0.004), waiting for a bed (p<0.001) and ED doctor turnaround time (p<0.001).

Introduction
Overcrowding has become a problem in emergency departments (ED) in Ireland, primarily due to exit block. It can compromise clinical care, patient access, patient satisfaction, patient dignity, staff morale, surge capacity, safety, cost efficiency, teaching and research [1-6]. In the UK, the National Health Service (NHS) set a target to achieve the disposition of 98% of patients within four hours of arrival at an ED [7]. In Ireland a target of 6 hours has been adopted [8]. The international literature has identified a number of ways to alleviate ED overcrowding and facilitate flow by tackling input, throughput and output factors [1,9]. The choice of intervention depends upon which delaying factors are particular to the ED and the improvement process should begin by identifying exactly what these delaying factors are.

Lean thinking and Theory of Constraints (TOC) are process improvement methodologies that aim to facilitate flow. These methodologies can be applied successfully to the unpredictable needs of healthcare [10-12]. They have both been used successfully in the NHS [13-16] and in EDs elsewhere [17,18]. In TOC terminology, according to Umble and Umble, the work being processed through a healthcare system can be defined as the patients themselves [15]; so there are constraints wherever patients are found in queues. While TOC aims to increase the throughput by focusing on the main constraint in the system [11,19], lean thinking aims to reduce the flow time by reducing waste at every point throughout the process [10,19]. The five focusing steps tool (5FS) provides the foundation for the TOC improvement process and the first of these five steps is to identify the constraints [11]. The remaining four steps are to exploit the constraint, to subordinate everything else, to elevate the performance of the constraint, and to identify the next constraint. The aim of this study was to identify and prioritise the bottlenecks in the patientâ s journey through the ED in a regional general hospital from the time of arrival to the time of admission or discharge by using a method based on the NHS four hour rule [7] and a significance test.

Methods
Process maps of patientsâ journeys through the ED and Radiology Departments and of their blood samples through the Pathology Department were developed in consultation with staff. Based upon this, a value-stream map10 was drawn. Following this, patients who were seen by an ED doctor during a seven day period in June 2006 were tracked from initial registration to their disposition (admission or discharge from ED). Non-routine data were collected for this study by hospital staff using data collection sheets attached to the patientâ s clinical notes and x-ray request forms. The UK four hour target was used for the purposes of this study to split the sample into two groups with patient journeys of under and over four hours; i.e. between patients who were seen and managed in a timely manner (under four hours) and those whose journey through the ED could be considered â too longâ (over four hours).

The sample size calculation estimated that a sample size of 400 subjects would be required to detect a difference of 20 minutes total ED journey time (i.e. 15% difference) between the two groups with a power of 90% and at a 5% significance level. The population under study was defined as the total number of patients seen in the ED during the calendar year 2005, i.e. 29,412 patients. In 2005, there were on average 80 ED attendances per day at Sligo General Hospital (29,412/365=80). At this rate of attendances it would take five days to achieve 400 attendances. It was decided to extend the study period to seven days to overcome the expected problem of missing data. In this study, the term â turnaround timeâ (TAT) is used to describe the time a healthcare worker spends with the patient from the start of the assessment or investigation to the finish. This does not include the time from the request for assessment to the start of the assessment which is termed the â waitâ .

The SPSS (version 14) statistical software package was used for analysis. All variables found to be significant predictors on univariate analysis (Pearson Chi-square tests) were included in a logistic regression model and backward stepwise logistic regression analysis performed using likelihood ratios. This was carried out to establish which variables were predictive of total journey times longer than four hours. In order to identify where bottlenecks appeared when the system was under pressure, each stage of the journey was compared between the two groups. The assumption was that when a patientâ s total journey time exceeds four hours, the time intervals at the bottlenecks would stretch to a greater degree than the stages that are not bottlenecks. By definition, some time component was going to be longer in the over-four-hour group, however, the aim was to see if some segments of the patientâ s journey lengthened disproportionately while others stayed the same. Mann-Whitney tests were used because data were not normally distributed.

Results
During the study period, a total of 599 patients passed through the ED, of whom 336 (56.1%) were males and 263 (43.9%) were females. The disposition time was non-routine data that was collected manually for 434 (72.5%) patients so the total patient journey time could be calculated for these patients only (72.5% of total). The remaining 165 patients (27.5%) left the ED without the time being recorded. Of the 434 patients, the total patient journey from registration to admission or discharge took under four hours for 321 (74%) patients and over four hours for 113 (26%) patients. Of the total sample of 599 patients, laboratory tests were ordered for 190 (31.7%) patients and radiological tests were ordered for 332 (55.4%) patients. One hundred and nineteen (19.9%) patients had both laboratory and radiological tests.

Figure 1: Mean time spent in each stage for the under and over four hours groups

Logistic regression was carried out to identify which factors were associated with patients who were more likely to stay more than four hours in the ED. It showed that patients who had radiological tests were 4.4 times more likely to stay over four hours in the ED than those who didnâ t; patients who needed blood tests were 4.1 times more likely to stay over four hours in the ED; and those who were admitted were 7.7 times more likely to stay over four hours in the ED. The time interval for each stage of the patientâ s journey is compared for the under and over four hours groups in figure 1.

TAT= Turnaround time
*Significant

There was a significant difference in the mean times between the under and over four hours groups in four variables: wait for radiology, wait for the in-patient team, wait for a bed and the ED doctor TAT (Table 1). A value-stream map of the patient journey was developed, (Fig 2). The value adding stages are placed above the line and the non-value adding stages below the line10. The non-value adding stages of the patientâ s journey are the periods spent waiting for medical assessment (by ED doctor or in-patient team), for diagnostics (X-ray or laboratory) or for a bed.

Figure 2: Value-stream of the ED patient journey

Discussion

The lean thinking value stream map in (Figure 2) shows how the non-value adding stages overlap with the bottlenecks identified in this study. The bottlenecks were identified as the four stages in the patientâ s journey that were significantly longer in the over-four-hours group. These were the ED doctor TAT; the wait for radiological tests; the wait for assessment by an in-patient team and the wait for a bed. Since the ED doctor TAT stage incorporates the time spent waiting for diagnostics results to come back and since that may be where the true delay occurred, this bottleneck was not included in the prioritisation process. The remaining three bottlenecks can be prioritised by looking at the significance test results. The most significant difference seen between the two four-hour groups was in waiting for a bed which had a p value of <0.001. This was followed by wait for radiology and then by wait for in-patient team assessment.

Lean thinking and TOC both aim to facilitate flow. According to the core lean thinking principles [10], flow can be

facilitated by minimising or eliminating all of the non-value adding stages (Figure 2), but it is not clear from the value stream map which non-value adding stage should be addressed first. The TOC approach to this question is to identify the most restricting bottleneck (the â constraintâ) and to address this first. The methodology used in our study allows the identification of which stages expand disproportionately when a patient is delayed i.e. which services become bottlenecks when the system is under pressure. These bottlenecks can also be quantified which helps to prioritise which bottleneck should be addressed first and provides an evidence base to support any such change project. Once a bottleneck is freed, some other stage in the system will emerge as a new bottleneck and this may be unpredictable and not immediately apparent. If the ED has a fit-for-purpose information system in place, then the impact of the change can be evaluated and the next bottleneck can be prioritised.

Since this study was carried out, a number of process changes have occurred in this hospital. A twelve-bed Acute (Medical and Surgical) Assessment Unit has been opened. This unit shares a common entrance with the ED as recommended in the Acute Medicine Programme [section 5.5] [20]. The introduction of both the Integrated Patient Management System (iPMS) and the National Image Management Information System (NIMIS) allow the Radiology Department to co-ordinate work-flow with other departments. Efforts have been made to free medical in-patient teams from out-patient department duties while on-call and an increasing number of nurses in the ED are now authorised to request x-rays.

This study was limited in that it examined patient factors only, ED factors such as workload and rostering were not examined. Two other limitations stemmed from the fact that non-routine data had to be collected i.e. missing data and performance bias. It was assumed in the analysis that there was no systematic pattern in the missing data. The staff were aware that this study was being carried out and this may have led to performance bias. This study combined the four hour timeframe with a significance test to identify the bottlenecks in the patient journey through the ED. This four hour timeframe methodology pinpointed and quantified the bottlenecks by showing which steps stretch out and cause delays for patients and which steps seem to remain the same regardless of how long the patient spends in the ED. The bottlenecks were long waits for radiology, for in-patient team assessment and for an inpatient bed. Both lean thinking and TOC informed the interpretation of these bottlenecks and the implementation of improvement measures.

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