Title

Doing more with less: Ways to improve patient flow in hospital settings

Word Count

Abstract word count: 264 words

Body text word count: 4,545 words

Abstract

BACKGROUND: Recent reports suggest that public hospitals are unable to respond to changing population needs. It is critical that innovative approaches be developed to assess and improve the management of hospital resources, and improve patient flow. This article presents findings from a study that applies process management principles – typically used in the manufacturing industry – to healthcare services.

METHOD: An interactive visual software program, Tecnomatix Plant Simulation®, was used to map processes within sonography in the imaging department of a public hospital. The map was informed by data, which included the department layout; number of diagnostic rooms available; available equipment; staff rosters; procedure times; scheduling processes; and patient-wait periods. Using the software, data were integrated to provide a visual animation, superimposed on the lay-out of the department.

RESULTS: To assess opportunities for improvement, parameters influencing patient flow were manipulated using the software program. These included variables that influence room use, including staffing, room availability and scheduling procedures. Simulating improvement strategies within a virtual environment had several benefits – strategies were tested instantaneously; they could be viewed as a visual animation; there was no disruption to existing hospital processes; and there was no risk of resistance to change among clinicians.

CONCLUSIONS: This article demonstrates the potential value of process management tools in improving patient flow in hospital settings. It indicates that, using interactive animation, innovative ways to manage and deploy hospital resources can be tested virtually, devoid of the many challenges typically associated with trialling changes in the physical setting. This finding has important implications for hospital managers charged with the responsibility of doing more with less.

Keywords

Patient flow, process management, emergency department, lean thinking

Introduction

The Australian public hospital system is facing a myriad of challenges that collectively hinder its effectiveness and its efficiency [1, 2, 3, 4]. This is perhaps most apparent in the emergency department (ED) [5]. According to the recent Garling [6] report:

> Most problems or stresses… observed in the NSW [New South Wales] public hospital system find expression, in one form or another, in Emergency Departments, be it a lack of senior doctors, ineffective bed management practices, widespread use of locums or poor communication with patients or their families [6, p. 716].

Among the reasons for this is an increased demand for emergency services which, according to Garling [6], is 'in excess of what you would expect by reason of population growth alone' [6, p. 716]. For instance, while the NSW population grew by only 3.8 percent from 2001 to 2006 [7, 8], the number of people presenting to NSW EDs increased by over eighty percent over a similar timeframe (2002-03 to 2007-08) [6]. However, public hospitals have a limited capacity to meet this demand [5].

Limited hospital capacity is evidenced by ED access block [9, 10]. Access block occurs when a patient remains in an ED for over eight hours, consequent to the limited availability of an inpatient bed [2]. Although Australian statistics are limited, a recent survey of Australian EDs indicated that more than 40 percent of patients receiving care in emergency departments were waiting for ward beds, and 77 percent of those had been in the department for over eight hours [11]. Given that bed occupancy rates in most Australian hospitals exceed the accepted maximum for efficient care and surge capacity [3], this statistic constitutes a serious concern.

The consequences of access block are costly. In addition to increasing risk to patient health [12, 13, 14], it affects the allocation of limited public resources and the management of healthcare services. More specifically, it is associated with decreased efficiency in the ED [15, 16, 17, 18] and increased inpatient stays [19]. Given the interconnected nature of hospital departments, access block is likely to hinder patient flow throughout a hospital [20]. It can thus reduce the efficiency of the surgical, intensive care, pharmaceutical, and diagnostic imaging departments, among others.

The causes of access block are multifaceted. In addition to an insufficient number of inpatient beds [9], access block is attributed to:

- Limited workforce capacity;
- The health needs of an ageing population;
- The increasing number of young patients (under 25 years) who access EDs as a substitute for primary care [5, 21];
- The increasing number of patients requiring intense and/or continued hospital treatment [22], thus overcrowding hospital departments [23];
- A decline in community services including nursing homes [9] and mental health services [22], which in turn adds further strain on the hospital system – for instance, the average length of hospitalisation among patients with mental health issues is approximately 14 days longer than those requiring acute care [24];
- Changing patient expectations – improved access to health information has enabled patients to access healthcare services earlier, and to intentionally access hospitals that provide an array of different services [5];
- Changing referral patterns – according to a recent Australian report:

> There is a strong trend towards patients bypassing their GP in the decision to attend an ED, with up to 86% of patients self-referring to the ED and relying on their family and friends for advice. A significant proportion of all patients cited GP accessibility as the reason for attending an ED and only 34% thought they really needed hospital or emergency treatment [5, p. 5].

- Increased use of ambulance services, which has risen by 10 percent annually in the last two years [5];
- The limited access of day clinics and private practitioners [25];
- The decline in bulk billing among general practitioners [26, 27, 28, 29], particularly in rural areas [30, 31, 32], which in turn may encourage access to bulk billed hospital services;
- Funding arrangements that focus on elective surgery and outpatient care [9], limiting resources available to EDs; and
- The over-bureaucratisation of the public health system [33], leading to the use of staff time for administrative actions rather than clinical care.

Although there have been some attempts to improve access to hospital services, these may have exacerbated access block. For instance, efforts to improve the skill level of ED staff and allow access to specialists within the same ED visit may have promoted the use of EDs [5].

Given the associated costs of access block and the associated impact on service quality, it is necessary to identify ways to improve patient flow in the ED, and thus, the interconnected departments. One approach that holds promise for healthcare services is *lean thinkin*g [34]. Typically applied to private industries – notably, manufacturing [35, 36, 37, 38], lean thinking aims to provide products or services ‘in the most efficient manner by improving flow and eliminating waste from processes’ [39, p. S39]. This is achieved by understanding current processes, identifying areas for improvement, and implementing necessary change. The application of lean thinking to private industry has helped to improve productivity, reduce waste and lower costs [40] – and it is these strengths that hold promise for healthcare services.

The potential value of lean thinking for the healthcare sector is recognised by Australian government departments. Government policies for instance, allude to the role of process management principles – normally applied to the manufacturing industry, to the management of healthcare services [41]. This potentially includes the identification of value-adding processes as well as wastage.

Lean thinking can be applied using visual analytics. Visual analytics represents a marriage between computation, visual representation, and interactive thinking [42]. According to Thomas and Cook [43]:

> visual analytics… [is] the science of analytical reasoning facilitated by interactive visual interfaces. People use visual analytics tools and techniques to synthesize information and derive insight from massive, dynamic, ambiguous, and often conflicting data; detect the expected and discover the unexpected; provide timely, defensible, and understandable assessments [43, p. 10].

Techniques that are simultaneously visual and interactive can be helpful for four key reasons [44]; namely:

1. They can help users to understand complex data and situations where models alone are inadequate;
2. They readily detect ‘trends and anomalies, evaluate hypotheses, and uncover unexpected connections’ [44, p. 15];
3. Through the use of contextual cues, they help the user to interpret the information he/she is presented; and
4. They encourage users to engage with and explore large datasets that might otherwise be daunting [45].

To demonstrate the way visual analytics can aid the management of healthcare services, the aim of this article is to reveal the application of visual analytics to a hospital department. It outlines an approach to understand current sonography processes with an imaging department, identify areas for improvement, and pilot improved management strategies within a virtual environment. Sonography uses ultrasound-based equipment to produce real-time diagnostic images of soft tissues, including foetal images. The imaging department was selected because, akin to other hospital departments, it is closely associated with the ED and has a bearing on patient flow, and as such, access block.

Methods

The department to which visual analytics was applied is situated in a NSW public hospital that serves a highly populated and ethnically diverse community [46]. The sonography department is situated within the Imaging Department, on the same level and approximately 50 meters from the ED. It contains three fully equipped, dedicated sonography rooms and presently handles around 4,000 patients per year. There were 3 full time sonographers in the department size of department when the study commenced. Along with ED patients the sonography department services the other departments in the hospital (see Table 1 for relative usage) along with a small number of outpatients primarily to enable necessary sonographer training to occur

Following ethics approval by the relevant academic institution and the Area Health Service, Business Process Modelling (BPM) and visual analytics were used to map the processes of sonography and the layout of the department, identify improvement areas, and simulate innovative strategies to improve patient flow. BPM is a management activity that helps to improve efficiency by allowing the user to observe current processes visually and identify the factors that both help and hinder [47, 48]. To effectively manage the wealth of data required for the study, visual analytics software, the interactive visual software program, Tecnomatix Plant Simulation®, was used to integrate information about departmental functions, resources, events, relationships between components, communication links, and information flow. Tecnomatix Plant Simulation® software is a tool that facilitates discrete event simulation and the creation of digital models of logistic systems [49]. This allows users to investigate system characteristics; test modifications without disrupting the system; and identify ways to optimise system performance. Following the simulation of the department's current operations, this software enabled the rapid simulation of solutions suggested by the imaging personnel.

Data collection to enable the simulation involved the following stages:

1. Workflow practices – that is, the sequence of connected steps, were observed in person by members of the research team over different hospital shifts on both weekdays and weekends; mapped using operations flowcharts; and then verified by staff from the medical imaging department;

2. Sonography patient case-mix and activity data were collected over three months to measure frequencies and gauge work movements – this information included patient-logs, staff rosters, and machine-use times;
3. Official hospital records – in the form of the bookings record and schedules, were collected over three months. This information included patient demographics, wait-times, procedure durations, test-specifics and procedure delays. The observations of both the researchers and the hospital staff indicated that inpatients who had arrived in the department prior to their scheduled time entered the sonography room on the scheduled time. For this reason, wait-time was calculated from scheduled time until the patient was collected by a sonographer;
4. To gauge the use of the sonography rooms – and ensure the accuracy of hospital records, time measuring points were collected over three months – these included patient arrival time to the waiting room; scheduled appointment time; patient arrival after the test; and patient departure time from the department;
5. Staff rosters were collected and constraints were determined – these included skill requirements for positions as well as particular diagnostic procedures; training time; teaching time; and award conditions;
6. The quantitative data collected were cleaned to ensure completeness and accuracy;
7. To refine and validate interpretations of the data collected, 10 semi-structured interviews were conducted with staff members who were familiar with sonography, its processes, and its relationship with other hospital departments. Themes explored during the interviews included work processes as well as the factors that helped and hindered patient flow;

8. Collected data were regularly cross-checked with the manager of the imaging department and the senior sonographer for verification; and

9. Further verification was received from sonography staff members who perused and provided feedback on the collected data and the models developed of current departmental processes.

To avoid the inconsistencies typically evident during December and January [50], data were collected between March and April in 2008; it was therefore reasonable to extrapolate the data to full-year results. Furthermore, extrapolated totals were consistent with full-year treatment statistics.

Results

Once cleaned, the dataset contained 314 patient records. Relative to the mean, the standard deviation of the sonography procedure times was high. To reduce the standard deviation, the diagnostic procedures were categorised. All procedures that appeared over 15 times were evaluated as a single procedure with their own procedure times – this resulted in seven categories, including abdominal, carotid doppler, lower leg, obstetrics (between 18 and 22 weeks of pregnancy), pelvic, renal, and other. The frequency and distribution of each category were then determined. Curve matching was used to obtain the best fit function to model these distributions, and the gamma distribution [51, 52]; was found to be the most appropriate statistical function.

Collectively, the data helped to understand current practices and processes within sonography. For instance, sonography patients came from three sources – 43 percent were referred from the ED; 36 percent were inpatients; and 21 percent were outpatients. Collectively, these patients waited an average of over four minutes – yet room utilisation was over fifty percent during conventional business hours – that is patients and attending sonographers were only present in the room for just over half of the available time. (See Table 1).

Table 1: Selected data describing sonography department (March-April 2008)

Outcome measure	Current situation
Average patient waiting time	4:39 min
Patients	
Inpatients	1,784
Outpatients	994
Emergency patients	1,149
Total patients	3,927
Average staff overtime	8:43 min
Room use (09.00-17.00)	54 %
Room use (incl. weekends)	13 %
Use of sonography staff[1]	85 %
Timeslot duration scheduled	60:00 min
Average procedure time	48:34 min

[1] Refers to staff capacity

Having understood the operation of the sonography department, three parameters were identified for potential manipulation – the procedure frequency; procedure sequence; and timeslot duration. Procedure frequency refers to the amount of times certain procedures were undertaken during the data collection period. Procedure sequence refers to the succession in which the procedures are booked and scheduled, and timeslot duration refers to the time set aside in the booking schedule for the booking of a single procedure.

Given the unpredictable demand for services, particularly from the ED, it is difficult to control procedure frequency. Hence, this parameter was deemed not suitable for manipulation. It would have been possible to manipulate the sequence of procedures. According to scheduling and sequencing theory, the total wait-time of many tasks or procedures is minimised when these are sequenced using shortest processing time (SPT) rule [53]. As such, procedures are best scheduled from shortest to longest duration. However, sonography staff were of the opinion that differences in procedure times were too unpredictable, and that short or long procedure times depend mainly on individual patient characteristics. For this reason, procedure sequencing was largely deemed to be inappropriate to improve processes, as individual case characteristics can not be determined before the procedures commence. Manipulating the timeslot duration was deemed appropriate. This was because, although timeslots of sixty minutes were allocated for each procedure, on average, only 48.34 minutes was required (*SD* = 17.34 mins,). Hence, it was possible to reduce timeslot duration.

In addition to timeslot manipulation, sonography staff proposed additional strategies to improve patient flow. These included dedicating one sonography room to emergency patients; increasing staff capacity; and terminating all services provided to outpatients.

Simulations

In each of the following strategies the following assumptions were made in the simulations: 1) That the current case-mix of patients from ED, inpatients or outpatients would not change; 2) That all available sonography slots would be filled; and 3) Additional sonographers could be found to staff any additional capacity generated in the situation simulated. These assumptions appear reasonable as the case-mix has been stable over the data collection period, during this time all available sonography slots were generally utilised and excess demand has been reported. The staffing was perhaps the most uncertain assumption, but subsequently this has been achieved.

Strategy 1: Dedicated sonography room for emergency patients

The first simulation model assumes that regardless of the number of rooms available, one room will always be assigned to emergency patients.

At time of fieldwork, three sonography rooms were not always in use – this was largely due to staff shortages, but also arose through equipment maintenance, staff training and other irregular interruptions. All predictable blockages to room use or staff availability identified (eg routine maintenance, scheduled staff leave or training, historic patterns of equipment breakdown or staff illness) have been included in the simulation. Consequently, dedicating a room to emergency patients may prevent inpatients and outpatients from accessing sonography services. Nevertheless, compared with current practices, this improvement strategy can assist approximately an increased number of patients. As indicated in Table 2, this strategy enables 173 additional patients to be provided with sonography services – it also reduced wait-time by over two minutes. This is largely because the dedicated emergency room is not scheduled, resulting in higher use. The strategy would also increase the number of emergency patients treated by over 800 annually; this is because, under current scheduling practices, the same number of emergency patients is treated regardless of the number of rooms available, resulting in fewer inpatients and outpatients being treated. The reduced number of inpatient appointments may pose little concern because inpatients admitted from the ED may have received their tests in the ED; however, the potential for inpatient bottleneck would require monitoring. Other benefits associated with this strategy included reductions in staff overtime.

Table 2: Dedicated sonography room for emergency patients

Outcome measure	One room for emergency patients each day	Current situation (6 emergency timeslots if 3 rooms available)
Waiting time	2:16 min	4:39 min
Total patients	4,100	3,927
Inpatients	1,361	1,784
Outpatients	753	994
Emergency patients	1,986	1,149
Staff overtime	6:22 min	8:43 min
Room use (09.00-17.00)	56 %	54 %
Room use (incl. weekends)	13 %	13 %
Use of sonography staff	85 %	85 %

Strategy 2: Fifty-minute timeslots

At time of fieldwork, seven timeslots were available each day per room when bookings were made at 60 minute intervals. This is increased to eight when these timeslots are reduced to fifty minutes. Consequently, the number of patients treated increases to 4,488 (see Table 3). Although patient wait-time and staff overtime also increase, so too does the utilisation of staff – this is largely because of the tighter schedule.

Table 3: Changing timeslots

Outcome measure	50-minute timeslot	Current situation
Waiting time	11:23 min	4:39 min
Total patients	4,488	3,927
Inpatients	2,042	1,784
Outpatients	1,137	994
Emergency patients	1,309	1,149
Staff overtime	12:38 min	8:43 min
Room use (09.00-17.00)	61 %	54 %
Room use (incl. weekends)	14 %	13 %
Use of sonography staff	96 %	85 %

Strategy 3: Increased staff capacity

The use of relevant sonography staff members can be increased by:

1. Including the hours that staff members currently work in other departments, like the x-ray department, in the model; or
2. Increasing staffing by, for example, recruiting one fulltime equivalent sonographer.

At time of fieldwork, two of the three sonographers sometimes worked in x-ray rooms of the imaging department. The continued presence of both workers in sonography would increase the number of available procedure days by 78.

Under the staff roster system that was used at time of fieldwork, the three sonography rooms were fully staffed only 84 (of 260) days (excluding weekends), over a 12-month period. On the remaining 176 days, there were occasions when no sonographers were scheduled because two staff members were not always available. The employment of 3.6 fulltime equivalent staff members would enable all three sonography rooms to operate simultaneously all year.

Increasing staff capacity increased room use (see Table 4); this is because it allowed all three sonography rooms to be operational more often. With increased room use, patient flow also increased. However, the utilisation of staff remained unchanged.

Table 4: Increased staff capacity

Outcome measure	Sonography staff remain in sonography	Extra sonographer	Current situation
Waiting time	4:25 min	4:23 min	4:39 min
Total patients	4,459	5,166	3,927
Inpatients	2,026	2,351	1,784
Outpatients	1,133	1,308	994
Emergency patients	1,300	1,507	1,149
Staff overtime	8:43 min	8:45 min	8:43 min
Room use (09.00-17.00)	61 %	72 %	54 %
Room use (incl. weekends)	14 %	17 %	13 %
Use of sonography staff	85 %	87 %	85 %

Strategy 4: Not scheduling patients who do not require preparation

Over one-quarter of all patients (25.4%) do not require preparation prior to ultrasound, like the need to fast or the need to have a full bladder; this equates to approximately five of the 21 appointments per day (23.81%). Using this information, a model was devised whereby patients not needing preparation would *not* be scheduled, and this strategy simulated. As such, two appointments, of a possible seven (25% per room), would be scheduled in each room in the morning and the remaining time would remain unscheduled. The scheduled appointments consisted of a ratio of inpatients (without preparation) to outpatients of 48.36 (48 = 64%*0.75). The simulation also involved dedicating one of the three sonography rooms to emergency patients. However, when fewer than three rooms are available, a room will not be assigned to inpatients; this is because of insufficient appointment time for inpatients and outpatients that require preparation.

Simulation of this strategy showed increased room use and the average patient wait-time decreased (see Table 5). This was largely because the model assumes that non-scheduled patients do not need to wait for their procedure. Although this might not always be the case, efficient coordination of the department could minimise wait-time among non-scheduled patients. Yet, in this scenario, one room was dedicated to emergency patients and the schedule of patients (without preparation) reduced inpatient and outpatient procedures at the cost of increased emergency services.

Table 5: First-come-first serve for patients not requiring preparation

Outcome measure	No schedule for patients not requiring preparation	Current situation
Waiting time	1:40 min	4:39 min
Total patients	4,127	3,927
Inpatients	1,500	1,784
Outpatients	649	994
Emergency patients	1,979	1,149
Staff overtime	6:20 min	8:43 min
Room use (09.00-17.00)	58 %	54 %
Room use (incl. weekends)	13 %	13 %
Use of sonography staff	91 %	85 %

Strategy 5: Terminating outpatient services

The fifth strategy involved removing all outpatient treatments from the department and treating inpatients and emergency patients using sixty-minute timeslots in sonography rooms that were *not* dedicated to emergency patients – as such, outpatient services were terminated within this model. Average patient wait-time and staff overtime both increased (see Table 6). This was because inpatients and emergency patients are typically treated for slightly longer periods. Although the number of treated patients remained unchanged, the number of treated inpatients and emergency patients increased. The utilisation rates remained unchanged.

Table 6: Sonography provides inpatient services only

Outcome measure	No outpatients	Current situation
Waiting time	5:05 min	4:39 min
Total patients	3,927	3,927
Inpatients	2,394	1,784
Outpatients	0	994
Emergency patients	1,533	1,149
Staff overtime	9:58 min	8:43 min
Room use (09.00-17.00)	54 %	54 %
Room use (incl. weekends)	13 %	13 %
Use of sonography staff	85 %	85 %

Discussion

Due to the disparity between supply and demand, the healthcare system in many Western nations is far from ideal [2, 5, 54] and access block is symptomatic of this [9, 10]. Although access block might be addressed by attending to a number of systemic issues [21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 55], there is an immediate need to improve patient flow within the hospital system. Failure to address this problem risks the health of healthcare services and the health of patients [12, 13, 14, 15, 16, 17, 18, 19].

In this article, one approach is demonstrated to inform strategic decision-making, and as such, improve patient flow and alleviate access block. By using visual analytics within sonography, this study reveals one way that complex processes within a hospital department can be understood; improvement can be identified; and viable options to improve these areas can be simulated. Given the interconnected nature of hospital departments [20], improved efficiencies in one department are likely to have beneficial effects on surrounding departments.

The results of this study indicate that, within the research site, patient flow might be improved by:

- Reducing procedure timeslots from sixty to fifty minutes;
- Increasing staff capacity; and
- Separating outpatient services from the imaging department.

Given that these strategies have the potential to improve patient flow, they are also likely to increase demand on patient transport and administrative services. This is because increased patient access to healthcare services is likely to require auxiliary hospital services, including (but to limited to) transport within the hospital and administrative support.

The results also indicate that patient flow might be hindered by:

- Dedicating one sonography room to emergency patients – although this was associated with greater throughput for emergency patients, it also decreased staff ability to perform tests on inpatients. Hence, while the bottleneck might be alleviated in the ED, it might also obstruct patient flow in the wards. This can affect the availability of beds for emergency patients, thus creating a new bottleneck. Furthermore, the ED would have to ensure the dedicated sonography room is used at a constant pace – that is, the room cannot be idle. This may prove difficult due to the unpredictable nature of demand; and
- Not scheduling patients who do not require preparation – this had a negative result for both inpatients and outpatients.

The ability of this study to map departmental processes and identify feasible improvement strategies was largely contingent on *bona fide* collaboration with hospital staff. This helped the researchers to understand a complex system and identify options that were appropriate, feasible, and met the priorities of both the hospital and its staff. Visual analytics is largely dependent on context – without the engagement of, and validation from individuals who might benefit from it, the application of simulated models is likely to be limited.

In addition to the potential for greater efficiencies, visual analytics offers the hospital setting three further benefits; namely:

1. Change can be piloted without the need for environmental (including policy) change;
2. Visual analytics allows hospital staff to observe the potential benefits associated with an altered process, which in turn, can increase confidence; and
3. Visual analytics provides a platform for discussion and a better understanding of the inter-connectivity of processes across different departments.

Although this study helped to test solutions without changing the hospital setting, it is limited by providing a theoretical solution only. A theoretical solution cannot accommodate daily variations that affect patient flow, like telephone calls, limited hospital infrastructure, the limited availability of patient information, as well as Occupational Health and Safety issues, like repetitive strain injury (RSI).

Implications for practice

Within two weeks of simulating the seven strategies presented in this article, staff from the imaging department reported their recommendations to the General Manager. These included:

- Reducing procedure timeslots from sixty to fifty minutes;

- Increasing staff capacity to ensure all three sonography rooms are operational simultaneously; and
- Dedicating one sonography room to emergency patients.

According to the simulated models, these strategies are likely to effect several changes, which collectively have the potential to improve patient flow (see Table 7).

Table 7: Solutions Recommended by Hospital Staff

Outcome Measure	50-minute timeslots 3 sonography rooms 1 emergency room Staff increase 1.0 FTE	Current situation (6 emergency timeslots if 3 rooms available)
Waiting time	8:10 min	4:39 min
Total patients	5,554	3,927
Inpatients	2,276	1,784
Outpatients	1,284	994
Emergency patients	1,994	1,149
Staff overtime	9:20 min	8:43 min
Room use (09.00-17.00)	75 %	54 %
Room use (incl. weekends)	13 %	13 %
Use of sonography staff	85 %	85 %

The interest among hospital staff in some of the simulated improvement strategies suggests that visual analytics holds promise for improving patient flow in hospital settings. Despite the complexity of healthcare services, visual analytics can accentuate opportunities for improvement. It can manipulate critical parameters; test a range of options through animated simulation; and present results visually to ease interpretation. Considering the prime role of EDs, it is essential to develop and provide the means that optimise their processes – visual analytics represents one way to achieve this.

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