Analysing and improving the seven lean flows in a pathology laboratory

ABSTRACT

Purpose

This article examines the application and outcomes of applying all of the seven lean flows to pathology laboratory remodelling as part of a lean rapid improvement event.

Design/methodology/approach

Longitudinal case study of a lean rapid improvement event linking emergency and pathology departments focussing on the systematic application of lean’s seven flows to the physical environment.

Findings

Following the lean rapid improvement event, changes improving patient specimen, technician, supplies, and information flows avoided 187 km and eight days of unnecessary walking each year.

Research limitations

The difficulty of making accurate comparisons between time periods in a health care setting is acknowledged.

Practical implications

This research provides evidence that applying lean design concepts in a laboratory can make substantial improvements, particularly if the expertise of the people working in the laboratory is trusted to determine the most appropriate changes. Significant amounts of time and motion were saved by just one, easily quantifiable change.

Sociotechnical implications

The laboratory staff is processing increased numbers of time-critical tests, yet report a calmer working environment, without any increase in the pace of work. Laboratory personnel also experienced satisfaction in exercising control over their work environment.
Originality/value

To the best of the authors’ knowledge this is the first comprehensive report applying lean flows to pathology laboratory remodelling and one of the few applications of Lean Systems Thinking between departments and between separate health services organisations.

Keywords: health service, quality improvement, pathology, Lean Systems Thinking, health facility remodelling, spaghetti diagram
INTRODUCTION

Australia shares a challenge faced by many countries; to reduce health spending as a proportion of its economy (OECD, 2002). However, the challenge is more complex than just cost reduction. Concurrent needs exist to improve the quality of service delivered (Institute of Medicine, 2001) while coping with increasing demands for health care (Department of Health and Aging, 2009) and lowering the per capita cost of health care (Institute of Medicine, 2012). In the Australian state of New South Wales large amounts of public money are being invested in rebuilding existing health facilities, and creating new buildings to support improved service delivery. Remodelling health facilities presents particular challenges: health facilities are open 24 hours a day, 365 days a year, often involve the use of specialised diagnostic equipment which cannot be relocated without significant effort and recalibration and, clinical and ethical imperatives dictate minimal disruption to patient care.

This research focuses on one physical change in a pathology laboratory that was initiated by laboratory personnel during a Lean Rapid Improvement Event (RIE). This work extends the lean health literature in several ways. It explicates the seven lean flows of manufacturing in a health services setting, and in doing so challenges previous adaptations of factory flows to medical settings. It also provides a quantified example of the benefits achievable through application of Lean Systems Thinking to the physical remodelling of pathology laboratories, especially when the expertise of ‘operators’ is trusted to provide solutions to challenging problems. It explicitly addresses a cross-departmental improvement program and provides an agenda for future research.

It also considers the impact of senior management involvement. In this case study, and usually for lean implementations in health services to date (de Souza, 2009), senior executives were drawn from two departments within a hospital, and from two separate health
service organisations (a state laboratory network and one hospital of a local health district). The director of the emergency department and the laboratory manager of the pathology sector laboratory co-located in an Australian public hospital, the hospital’s general manager and the director of the pathology service participated in the Rapid Improvement Event with a range of personnel from the emergency and pathology departments.

**Origins of Lean Systems Thinking and its application in health care**

Lean Systems Thinking (or philosophy) is the name commonly given to the manufacturing methodologies developed by Toyota as the Toyota Production System (TPS). TPS developed into a system of workplace organisation, built upon Toyota's Managing Director’s observations of the fundamentals of mass production during a tour of the Ford Motor Company's Rouge River plant in the 1950s. The TPS satisfies customer needs by using high value-add processes optimised to meet customer needs, and reducing the time elapsed and costs incurred between paying for raw materials and being paid (Womack and Jones, 2003). Lean achieves this by enlisting the knowledge and skills of people who perform the process in identifying and removing eight types of process waste, through the use of continuous improvement methods (Womack and Jones, 2003). Adaptations of lean manufacturing process techniques (Liker, 2004) appear more frequently in health services than any other public service context (Radnor and Boaden, 2008). Over the last twenty years the number of lean public health projects has rapidly increased and a recent study (Burgess and Radnor, 2013) shows lean process improvements continue be popular in the UK and hospital managers are using Lean Systems Thinking (LST) in more sophisticated ways in organisation-wide programs that support organisational strategy. The pace and spread of lean techniques in public health services is likely to continue accelerating as governments either mandate or encourage their adoption as part of quality-improvement and cost-reduction
Flow and applications of Lean Systems Thinking in pathology service improvement

While some pathology disciplines, such as anatomical pathology retain strong craftwork elements (Friedberg and Pantanowitz, 2009), the automated, high volume processes used for clinical chemistry and haematology tests are reminiscent of factories. Perhaps for this reason pathology laboratories have been attractive sites for early adaptations of Lean Systems Thinking from manufacturing to health-care settings. Reported applications of LST to pathology operations include: a four month consultant led project resulting in improved turnaround times (TATs) with decreased variability and a 20% increase in test volume (Rutledge et al., 2010), a pursuit of zero errors in anatomical pathology (Condel et al., 2004), finding ways of coping with skilled workforce shortages (Zaleski, 2011) and, reducing TATs and inappropriate demand, creating cost savings and avoiding unnecessary admissions (NHS Improvement Programme, 2010).

When flow has been considered in the scholarly literature to date concerning hospital design, the focus has generally been placed on patient flow and creating conditions that support continuous flow (Reijula and Tommelen, 2012; Ben-Tovim et al., 2008), avoiding technological obsolescence (Leonidas, 2011) and designing smaller, more flexible health care facilities (Noble and Lee, 2010). With one partial exception (Nicholas, 2012), which does acknowledge the benefits available from examining all seven flows in the context of emergency department redesign, but does not explicate each, there has been no comprehensive consideration of all seven flows to date, and none in the context of pathology laboratories or processes that cross departmental boundaries.
The seven flows of Lean Systems Thinking

The implementation of lean organisational cultures and working environments requires adherence to the five guiding principles of Lean Systems Thinking, also called the five pillars of lean. The five pillars of lean philosophy espoused by Womack and Jones (2003) are well established in the lean health literature. The pillars are: 1) Specify value as defined by the customer, 2) Identify the value stream and remove waste, 3) Cause the remaining steps to flow, 4) Flow occurs at the pull of the customer and 5) Pursue perfection.

Each process undertaken in a manufacturing environment can be viewed as the confluence of a number of flows from different domains. Some of these flows are obvious, such as the movement of equipment. Other flows, for instance the flow of information, are less so. The seven flows of lean manufacturing refer to: 1. the flow of raw material, 2. the flow of work-in-progress, 3. the flow of finished goods, 4. the flow of operators, 5. the flow of machines, 6. the flow of information, 7. the flow of engineering (in the form of equipment maintenance and support personnel (Black, 2008).

Tracking each of these flows while a factory is operating makes waste, such as delays and rework, easily identifiable and supports problem solving by the people who do the work, at the place where the work is done. Although using the seven flows to identify wastes is well established in manufacturing settings, to date they have not been clearly understood or widely adopted in health services settings. A methodical adaption of physical and other flows from a factory to health services settings, with a particular focus on pathology laboratories follows.

“Flow” is the process of smoothly adding value at the appropriate time for the patient. The mapping of the seven flows within a manufacturing environment allows us to see how people and materials interact to add value to the product. This type of analysis is useful for examining patient journeys as hospitals can be seemingly chaotic places with bouts of
frenetic motion interrupting long periods of waiting. Using the seven flows to study an area identifies the wastes and any conflicts between various flows in that area. The opportunity for breakthrough solutions often exists in these conflicting areas. It is simplistic to say that the patient should not move because this would mean all the other flows have to compensate (the flow of clinicians is likely to be increased if we keep the patient static). A team based approach, together with some flexibility in the physical layout of the area, may allow the best solution to be identified and agreed upon through relying on the knowledge and insight of the people that do the work.

A central tenet of lean methodology is that it is most important to identify waste. Once we see the waste it is comparatively easy to remove it. In his seminal work Ohno (1988) identified seven types of waste (transportation, inventory, motion, waiting, over-processing, over-production and defects) which have since been supplemented by an eighth waste, that of wasted human potential. Guides (Graban, 2008) and toolkits (Hadfield and Holmes, 2008) have now been written specifically for health services organisations to provide practical approaches to identify and reduce each of these wastes.

This work extends the application of Lean Systems Thinking beyond the identification and reduction of the seven wastes. It uses the seven lean flows to see waste and interruption to flow for all the processes that contribute to the patient journey. Previous conceptualisations of the seven lean flows in health care identify the importance of the flow of people, products, supplies, materials and information (Nicholas, 2012) and the flow of patients, clinicians, medication, supplies, information, equipment and process engineering (Black, 2008). We assert these are inadequate because they do not take into account the purpose of analysing flows, which is to reveal waste, and if followed slavishly will miss important opportunities to identify waste in healthcare settings. Table 1 compares factory flows with those than can be observed in a hospital department and demonstrates the need to focus on the specific tasks
being performed in a particular physical environment. In some cases only five flows may be involved, in others there may be more than seven.

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Using each of these flows to map overall workflow allows people to see waste. Reorganising the area to optimise all the flows simultaneously is achieved by using the insight and experience of the team responsible for and working in this area.

**Context and Impetus for the Pathology Lean Rapid Improvement Event**

This research took place at Campbelltown Hospital, a major metropolitan hospital in the South Western Sydney Local Health District (SWSLHD) at the outer edge of Sydney, New South Wales (NSW), Australia. The SWSLHD provides services to a population of around 1.5 million, representing just under 20% of the total NSW population. In addition to a high influx of migrants in the area, the birth-rate is significantly above the NSW average. Notwithstanding this young and family-oriented demographic, people of 65 years and over are responsible for more than 45% of all acute hospital bed days (SWSLHD Media and Communications Unit, 2011).

The research reported in this manuscript followed an earlier radiology project (Fitzgerald et al., 2011). Over five years Campbelltown Hospital’s use of Lean Systems Thinking has been growing in acceptance and complexity of context, and has continued despite changes in the hospital executive.
Campbelltown Hospital’s emergency department is one of the busiest departments in the State, with over 55,000 presentations per year. Emergency department patient presentations are steadily increasing by approximately 3.5 % each year, although the monthly rate of increase in 2012 compared to the same month in 2011 varied from 1.6 to 8.7%. The pathology sector laboratory situated at the hospital primarily services the hospital’s Emergency Department (ED). However the rate of increase in demand for pathology testing has outstripped the increase in emergency patient presentations. In twelve months the pathology department has experienced a 29.5% increase in the number of test requests originating from the ED. September is a busy month of the year for Australian emergency departments, representing the end of the winter peak and testing a hospital’s ability to cope with community demand. In September 2010 the pathology laboratory performed over 2,600 Electrolyte and 2,400 Full Blood Count tests. In September 2012 this had increased to 3,800 Electrolyte and 3,900 Full Blood Count tests (increases of 46% and 62.5% respectively).

While physically located in the hospital, organisationally the pathology laboratory is part of a hub and spoke pathology network known as the Sydney South West Pathology Services (SSWPS). A hub and spoke network is needed because not all the facilities in the Local Health District have sufficient pathology demand to justify their own full service pathology departments. Also, the high cost and volatility of reagents used in some tests necessitate transporting blood samples to the central, hub laboratory located at Liverpool Hospital, 20 kilometres away from the hospital in which this research was conducted.

The impetus for a Lean RIE originated not in the pathology laboratory, but in Campbelltown Hospital’s emergency department. Routine communications between the emergency and pathology departments consist of blood, urine and sputum specimens being transported by a vacuum tube system from the emergency department to the pathology laboratory, telephone calls made by emergency department clinicians in attempts to expedite results and test results
being delivered electronically to the emergency department using the Cerner FirstNet/PathNet electronic test ordering and laboratory information systems. However, a new message was about to be delivered.

The emergency department, like all public hospital emergency departments in Australia is under pressure to increase the percentage of patients treated, admitted, discharged or transferred within four hours (Emergency Care Institute NSW, 2012), to meet state targets for timely access to care which started in 2012. The explicit intent of the four hour target is to create systemic change across the whole hospital system, and provide a measure of progress (Baggooley et al., 2011). Meeting the National Emergency Access Targets could translate into increased federal health funding for the state. Campbelltown Hospital’s General Manager asked the research team to discuss barriers to meeting four hour targets with the emergency department director, who explained that current pathology TATs contributed to delays in the treatment of individual patients, slowed patient flow and contributed to access block. While not all emergency patients require pathology tests, when they do blood tests can take up to 80% of the total emergency department length of stay for non-admitted patients (Bradley, 2011). The relationship between the emergency department and pathology laboratory leaders was good, with the pathology laboratory manager scientist being described as, “… a friend to the emergency department”, but current performance was unsatisfactory.

The hospital’s pathology laboratory was operating with few staff; all staff worked three to four shifts of overtime each week, and was described as “struggling” by the SSWPS pathology service business manager. SSWPS performance reports showed that the hospital’s average in-laboratory Full Blood Count test turn-around time (TAT) was routinely over 10 minutes, and at times as high as 20 minutes compared to a target of 10 minutes. In September 2011, the combined “drawn to laboratory” from ED, and in-laboratory TAT performance ranked sixth out of the seven hospitals in the Local Health District. The laboratory had
already been approved to move to 24 hour operation, and was in the final stages of planning to install a new analyser. At this time the SSWPS business manager commented that in his opinion new technology, in the form of faster analysers with larger capacity, would solve the problems at the laboratory.

**Challenges in Measuring Improvements in Hospital Settings**

The difficulty of making comparisons between time periods in a health care setting is acknowledged, as are the confounding effects of upgrading the laboratory analyser and preparing to move to 24 hour operation. For these reasons this article focuses on just one of the changes resulting from the RIE. This is in part because its effect cannot be conflated with concurrent changes in technology and laboratory operations, and in part because it provides an excellent illustration of the benefits available when the expertise of people performing each role is welcomed into facility redesign.

**METHOD**

The method used to organise and run the ED-pathology RIE is next described, followed by the methods used by the research team to study the event.

**Organisation and Content of the ED-Pathology Rapid Improvement Event**

The Senior Hospital Scientist at the hospital’s pathology laboratory, knowing of Lean Systems Thinking, invited the university-based research team to organise an improvement event to support ED/pathology process improvement. A Lean Six-Sigma Black Belt practitioner from a local medical device manufacturer was recruited to design and facilitate the Rapid Improvement Event (RIE). The RIE method chosen adapted techniques designed for service rather than manufacturing businesses (Rother and Shook, 2003; Keyte and Locher,
and was designed to take only two elapsed days of clinician time in contrast to manufacturing RIEs which generally take four to eight days to complete. After agreeing upon a shared ED-Pathology goal, “We deliver quality results in a timely manner to provide the best possible care to our patients” voice of customer interviews were conducted with pathology and emergency department personnel to understand how the two departments worked together to deliver value, which notions of value were consistent and which diverged between pathology and emergency departments. Internal stakeholders rather than patients were interviewed, and the techniques used to identify influential stakeholders and conduct Voice of Customer interviews have been described in previous publications (Hayes et al., 2011; Hayes et al., 2012).

Delivery of the RIE was delayed by eight weeks when one of the executive’s schedules was altered at short notice, making it impossible for her to attend the start and finish of the event. A joint decision was made by the hospital, pathology service and the research team to reschedule the meeting rather than proceed without executive representation from one of the organisations. This decision was made due to the agreed importance of having executive involvement from both organisations at the beginning of the event, to communicate support and at the end to review and approve, or explain reasons for delay or rejection of changes the ED-Pathology team proposed as RIE outcomes.

The RIE was conducted over four half-days, with staff returning to their work in the hospital each afternoon. On the first morning members of the pathology and emergency departments were trained in LST, “walked” the physical route of the emergency department request–pathology test-report results process, and reviewed pathology demand and performance data for the previous month. Explanations of the eight wastes were given in terms of pathology laboratory operations – this was made possible by the earlier voice of customer interviews (Hayes et al., 2012). The waste of over-production was exemplified by emergency
department doctors requesting tests that were not needed for the diagnosis and the waste of over-processing was illustrated by having to enter patient details twice. The waste of motion was illustrated by staff walking across the laboratory to find a pipette while transportation waste was discussed in terms of the need to send samples more than 20 km to Liverpool for processing after midnight when the on-site pathology laboratory closed. It was easy for the team to volunteer examples of the waste of waiting; one was specimens waiting to be logged-in at specimen reception when the laboratory was overloaded during peak demand periods. Inventory waste was discussed in terms of excess stock in store rooms but not always having everything to hand when needed. Defect wastes included having to repeat the process of collecting a specimen from a patient because the sample was too small or had deteriorated during transportation to the laboratory. The final waste, unused human talent was described in terms of decisions being made without enlisting the experience and knowledge of subject matter experts. As planned, the first morning was attended by the hospital general manager and the director of the emergency department and their role was explicitly and publicly identified as being to support the implementation of ideas generated by the pathology and emergency department staff. The emergency department director issued a cross-departmental challenge to the attendees: for both groups to work together to provide Full Blood Count test results within 30 minutes, and chemistry tests within 60 minutes from the specimen being collected from the patient. The focus of the event was to improve the *timeliness* of results while maintaining quality, consistent with the impetus of the recently announced National Emergency Access Target (NEAT) policy. During preparatory interviews for the RIE (Hayes et al., 2012) members of the emergency department had made it clear that the quality and safety of the services provided by the on-site pathology laboratory were good, but that the timeliness of the laboratory's performance was not. For this reason attention was focussed on reducing wastes, particularly wasted time as a key way to improve the patient experience.
On the second morning, the RIE participants completed the emergency department request–pathology test-report results process Value Stream Map, including measurements of value add and non-value add (waste) steps in the process. They discussed whether the concept of takt time (time unit used in lean production to synchronize the rate of production with the rate of demand) was applicable in their setting. Pathology personnel completed the majority of the work, with emergency department explaining what happened on the “other side” of the vacuum tube.

The third morning focussed on flow through the laboratory, inventory and desired future states. Examples of completed spaghetti diagrams were shown to the participants. Spaghetti diagrams or maps are so called because the finished product often resembles a tangle of spaghetti strands recording the routes walked and locations visited while working in a particular physical environment. Interestingly spaghetti diagrams do not appear in Sobek and Lang’s (2010) categories of high, moderate or low-use lean tools reported in health care improvement work. The value of combining spaghetti diagrams and the seven flows of Lean Systems Thinking in a pathology laboratory are explained and illustrated in the results section.

The fourth and final morning was spent on workplace organisation, visual management and preparing the list of ranked improvement ideas, showing owners and time to complete to the hospital and Sydney South West Pathology Services executives.

**Methods used by the research team to study the event**

The Rapid Improvement Event was observed by three academic researchers. Their role was to observe the group, study the language and the interactions amongst members of the group (Creswell, 2013) and assess how this may create an environment conducive to achieving positive dialogue about opportunities for improvement. The researchers are interested in the
use of social action as an effective implementation strategy aimed at improving health outcomes for patients (Eccles et al., 2012). This research about the role of social action will be reported in another paper at a later date and will add to existing implementation research.

Observations made at the rapid improvement event included observations about interactions between professions and occupations, (doctors, nurses, laboratory technicians and executive managers), which are usually hierarchically distributed. We observed patterns of behaviour blending group behaviours, each group understood their own role well, but were unaware of each other’s roles. We observed the group coming together in a joint understanding of each other’s roles and observed a specific tipping point, where the understanding of the unintended negative consequences of the current process changed into a willingness to subscribe to new processes to improve effectiveness. This tipping point is the subject for further research.

RESULTS

As described in the method section, the third morning of the rapid improvement event focussed on flow through the laboratory, inventory and desired future states. During this time the participants were introduced to the idea of tracking people’s movements on a floor plan using a spaghetti diagram and were shown an example of a completed spaghetti diagram. At the end of the morning floor plans of the existing laboratory were provided to the pathology attendees and the request made that they draw the movement of staff in the laboratory. One staff member volunteered to complete the spaghetti diagram and returned the next morning with two diagrams showing the path followed during week days (Figure 1) and on weekends when there were fewer staff working in the pathology laboratory (Figure 2).
Figures 1 and 2 clearly show the routine patterns walked, including traversing the laboratory to a location distant from where the rest of the work occurs (top of the diagrams) and repeated back-tracking between benches and equipment. It was clear that the task of mapping the standard routes around the laboratory had been easy to complete, with all the pathology attendees agreeing that the spaghetti diagram showed an accurate representation of the movement of specimens from specimen reception through the laboratory. This shows that the tool was easy to learn and use and produced accurate representations of work patterns in the laboratory. Examining the routes repeatedly walked on weekdays and weekends raised comments about the number of times people turned and crossed between benches and how being aware of people standing behind you was a necessary skill to work in that particular laboratory.

The seven flows within the ED and pathology labs were discussed during the creation of the ED – Pathology Value Stream Map. For example, at the specimen reception area of the pathology laboratory the following flows are visible: information (lists of tests requested for each patient, printed on paper and in electronic form), patients (represented by one or more specimens), supplies (specimen tubes contained in plastic bags), equipment (time-stamp
clocks, the canister used to protect specimens during their journey in the vacuum tube from ED to pathology) and hospital personnel in the form of laboratory technicians.

The group then directed its attention to the proposed floor plan for the remodeled laboratory, which had largely been designed around the need to add a new analyser with a large footprint. Staff had seen this floor plan previously. The attendees were split into two teams, invited to consider how they would move around the laboratory when the remodelling was complete, and asked to redesign the laboratory layout using Lean Systems Thinking principles they had learned such as one way flow, and multiple, local repositories for supplies rather than one central location. The group became very quiet after one pathology participant commented that a new wall shown on the plan was going to necessitate extra motion in the laboratory and although they were getting a faster analyser, the new floor plan split the laboratory and would impede flow in the workspace.

The spaghetti diagrams now formed the basis for an interesting discussion. The Lean Six Sigma Black Belt facilitating the rapid improvement event did not offer any solutions or ideas. Instead he encouraged the team to think about what they could change to solve the problem they had identified. The atmosphere became quite tense, and the two groups merged back into one to look at the floor plan and express their concern about the positioning of the wall. Discussion in the group continued. All pathology participants quickly agreed that the wall had to be built in that position, and there was clear consternation about the impact this would have on pathology staff. Again the facilitator and research team kept quiet. Then one of the hospital participants mentioned the word “window” and the team quickly (and with evident relief) took up the idea, agreeing that a window in the wall would permit specimens to be passed through without wasting motion to work in the remodelled laboratory. A member of the research team then asked if benches could be placed on each side and at the same height as the window to allow samples to be slid through the window. This was accepted as a
further improvement; not only would the waste of motion be reduced but the risk of dropped samples, necessitating returning to the patient to collect another specimen (waste of rework) was considerably lessened.

Discussion of other ways to remodel the laboratory continued, including dividing the work into separate gas and chemistry lines to create two loops of motion in the laboratory eliminating the need to cross back and forth between benches, and positioning computer terminals in the most beneficial locations for conducting and reporting pathology tests (see Figures 1 and 2). The new floor plan developed by the rapid improvement event attendees (see Figure 3), recorded the group consensus and was displayed in the laboratory, then given to the builders in the rough form shown in Figure 3. Initially the builders resisted the change because it necessitated cutting pipes that were in the wall, but the need for the window was now understood and judged to be important. The builders were convinced to make the extra effort in order to avoid building wasted motion and delay into the remodelled laboratory.

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Figure 3: Plan created during RIE to split laboratory into two lines (chemistry and gas) and insert window into wall

Limitations of the research design

One limitation of this research, and case studies in general, is that several changes resulting from the Rapid Improvement Event were made at the same time; emergency department doctors changed their pathology test ordering behaviour, the equipment in the pathology laboratory was re-organised into separate gas and chemistry lines, and the laboratory was preparing to move to 24 hour operation and being remodelled in preparation for the arrival of
the faster analyser. These changes took place against the constant background of variability in the emergency and pathology laboratories. Variation in the number of type of patient presentations, the number, skill level and specialisation of clinicians working on each shift, the impact of seasonal changes, mini-epidemics and a multitude of other factors combine to make meaningful comparisons difficult. To avoid some of these issues of comparison, the impact of putting the window into the wall is now analysed in isolation from other modifications resulting from the RIE.

When the new wall was built and tables placed on either side of the window a researcher returned to pace out the route that would have been taken if the rapid improvement event had not occurred and the window idea had not been thought of, and accepted by the pathology laboratory participants.

The window was being used 60 - 70 times each eight hour day shift, from Monday to Friday. On weekends there was only one person working in the laboratory so they had to walk from specimen reception area around to the analyser and although the risk of dropping specimens was reduced the extra motion could not be avoided. If the remodelling had continued without input from the people who do the job, each trip from specimen reception to the analyser would require 24 steps, (12 metres). Each of these trips would take 15 seconds to complete. While the extra distance and time taken for one trip to the analyser appear small they add up dramatically over time. Roughly 65 trips of 12 m would be made each eight hour shift, resulting in 780 m of walking per day, and 3.9 km of wasted motion per 5 day week. Time is required to waste this motion. Sixty-five trips taking 15 seconds each would require 975 seconds (16.25 minutes) per day shift, accumulating to 1 hour and 21 minutes for the Monday to Friday week.
Over longer periods the numbers, of course, increase. In one month, 15.6 km of walking is avoided and 5 hours 20 minutes of time is saved. In a year 187 km and eight full working days of wasted walking and wasted time (delay) is avoided. When the hourly rate of the person working at specimen reception is applied to these numbers it becomes clear that in addition to reducing the wastes of waiting, motion, rework and human potential, over A$1,400 has not been spent paying someone to suffer these conditions in order to compensate for the delays that would have been inserted into the process. It is not known how long it will be until the laboratory is next remodelled but it is likely that had the window not been added to the plan, these wastes would have continued for a number of years.

**Sociotechnical impacts of the Emergency Department - Pathology lean rapid improvement event**

Cost savings and time savings are easy to measure exactly, but important intangible benefits have also been experienced by the laboratory staff. Reduced physical fatigue, satisfaction in exercising control over their work environment and having the opportunity to identify and avoid problems rather than having unsatisfactory work environments imposed on them all have a motivating effect. The impact of a range of changes made within the pathology laboratory and alterations to how emergency department doctors order pathology tests have resulted in a calm and steady work pace in the laboratory, even though test numbers have increased. Comparing the same month of the year, in two years the emergency department pathology workload has increased from 1,900 to 2,600 tests per month. The ability to absorb this increase without increasing the pace of work in the laboratory is identified by the laboratory staff as the biggest impact of the lean rapid improvement event. Even on weekends, traditionally a challenging time because there are fewer technicians in the laboratory, the flow of work is experienced as routine and manageable.
Before the rapid improvement event the pathology staff knew their workload was increasing each month and they were expending greater effort in order to cope. Their experience of being better able to cope with demand, and under less pressure is interesting in the context of claims of work intensification as a consequence of lean systems thinking (Lloyd and Seifert, 1995), but is consistent with other reports of motivation and increased staff morale after using Lean Systems Thinking in public sector organisations (Radnor and Boaden, 2008).

Furthermore evidence of concurrent sociotechnical and operational improvements in the laboratory support conceptualisations of lean as an approach that has potential to improve both operational and sociotechnical aspects of the work environment (Joosten et al., 2009). The beneficial impact of the lean rapid improvement event is judged by the pathology department to be greater than that of the new analyser, and the group’s performance has been acknowledged as outstanding by the business manager at SSWPS and recognised by a Local Health District Quality Award.

DISCUSSIONS/CONCLUSIONS

Before the RIE, discussions between the pathology laboratory manager and the builders contracted to remodel the laboratory had focused on finding room for the new analyser. No other considerations were taken into account. It was not until the RIE that the physical flow of specimens through the request-test-report cycle was investigated and questions raised about the desirability of physically separating the gas and chemical processes and reducing wasted time and transport at the specimen reception area. This oversight occurred, and in all likelihood continues to occur across Australia and the world, because the approach taken to remodelling health facilities does not routinely consider all seven flows.

Limitations of the Rapid Improvement Event method
RIE participants have been asked repeatedly to identify adverse consequences of the event but none have been nominated. This could be due to an unwillingness to criticise the conduct or the outcomes of the RIE to the researchers who organised the work. However no criticisms of the event or outcomes have been made even when the researchers explained that they would welcome knowledge of unintended results or ways to improve the RIE. We posit that the extensive work preceding the RIE (individual and group interviews, discussion of the RIE’s focus on processes and systems rather individuals and four years of working with the emergency department on other research projects) combined with the positive relationships between the pathology and emergency departments and clear executive support from both organisations, provided a particularly conducive environment for the work.

Two limitations are inherent in the RIE method. The first is scalability. Developing a VSM of cross-department processes requires intensive work with the people who perform the tasks every day. This requires an investment of time (albeit only two days in total for the method used in this research) and a skilled lean facilitator for each event. A VSM for the pathology request-test-report cycle in another hospital could differ because of differences in layout, equipment (e.g. some facilities do not have vacuum tube transport systems) and variations in clinical practice patterns (e.g. in some facilities doctors collect the majority of pathology specimens, in others nurses do). This represents a strength and a weakness in the RIE method; the outcomes are highly applicable to the facility, but improvement actions may not always be directly transferred to other sites, hindering the diffusion of potentially useful process innovations. Variation in hospital settings, the content and the application of lean interventions have been posited to explain reports of varying success in hospital settings, and prevent generalisation from one organisation to another (Andersen et al., 2014). However, given the speed and ease with which personnel used spaghetti diagrams to track each of the seven flows in the pathology laboratory it is
likely that the spaghetti diagram tool and flow mapping techniques described in this research could be applied as a separate activity from a RIE in other pathology laboratories in Australia and overseas.

The second limitation concerns the use of RIEs as a form of “spot kaizen” rather than part of a systemic transformation. This work reports the first use of a RIE at Campbelltown Hospital and while it did span organisations and departments, it did not address the many connections and interdependencies that exist within the organisation such as clinical information, pharmacy and individual inpatient wards. However as has been reported in other countries (Burgess and Radnor, 2013) the use of Lean Systems Thinking has since spread in the hospital and is now being adopted as a systemic approach to support learning, safety and innovation strategies at the hospital.

**Implications of the research**

In the years 2012-2013 the Australian state of New South Wales spent A$1.16 billion on health services capital works, and capital works expenditure will grow at a faster rate than recurrent funding for salaries (NSW Health, 2012). Pathology laboratories are frequently remodelled (every three to five years in the case of the Campbelltown laboratory) due to new testing technologies being developed and delivered.

Given the impact that thoughtful application of the seven lean flows can make when combined with the expertise and tacit knowledge of the people who work in health facilities, taking the time to analyse the seven flows in healthcare settings would seem a worthwhile investment. It can release capacity in a strained system, and importantly, allow people to exercise control over their work environments in productive and creative ways.

In most health care settings the primary customer is the patient requiring diagnosis and treatment, but in a pathology laboratory the blood, sputum or faeces specimen is the only contact between the patient and the laboratory. As Nicholas has noted (2012) hospital physical redesign project teams typically include architects, builders and the facility owners,
but the patients and clinicians who populate the built environment are frequently absent from discussions and decisions, or their involvement is limited to reviews of floor plans once the key decisions have been made. This paper demonstrates some of the practical and social benefits of involving staff who work in the facility in methodical, end-to-end and cross-departmental Value Stream Mapping, including analysis of all seven flows. A short time spent using a very simple tool, produced spaghetti diagrams which not only revealed issues with the current laboratory layout, but further demonstrated that the planned changes would make matters permanently worse. Providing the laboratory staff with the training to see waste, and executive support to make changes, produced benefits for patients, clinicians and hospital managers.

How then can the seven lean flows become incorporated in health facility design and remodelling? One option could be to supply firms bidding for contracts to build or remodel health facilities with a “tool-kit” to support informed engagement with clinical and administrative staff in each facility. Simple tools such as spaghetti diagrams provide a quick way to record and communicate current flows, and can be used to capture more than one flow on one diagram. For example, Figure 4 shows the task disruption caused when a doctor has to interrupt the process of drawing a blood specimen to search for supplies (in this case a small needle indicated by the “S” on the floor plan) and repetitive walking between the patient’s bed (P₁) and the computer terminal (I₁).
The speed with which clinicians and technicians can be trained to create spaghetti diagrams and their value in making wasted motion and interruptions to all seven flows visible suggest opportunities exist to increase their use in improving the seven flows in health care facilities.

A second idea is to incorporate patients and clinicians in reviews of plans and use walk-through techniques (Broberg and Edwards, 2012) to answer the vital questions “Is this AT LEAST as good as our current floor plan, and does it support seamless physical and information flow?” Perhaps most important is the need to ensure an eighth flow, the flexibility to support continuous improvement, is incorporated to support future improvements in clinical protocols, equipment used and physical changes needed to create effective care delivery environments.

The complexities of instigating any changes to workflow in a hospital laboratory are not to be underestimated. Whilst it is seemingly simple to make changes to the organisation of work in service industries, improving the provision of clinical care in health care settings is much more complex. This can be caused by reasons as diverse as: resistance to decreed, managerially mandated change, inability to unfreeze existing routines, time constraints preventing opportunity to learn new routines, and strong divides between professional and functional influences. In our experience, it can be difficult to achieve the necessary support for change from managerial and professional hierarchies. Therefore one area for future research is to examine exactly why this particular project was so successful. What is the tipping point for change when working with competing, diverse, difficult to manage professional identities? How do we facilitate uptake of suggestions for improvement and are the strategies used transferable to other contexts? It is our belief that the use of social exchange strategies resulting in social action at the starting point, through involvement of all stakeholders, facilitates the uptake of new ideas and supports change.

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Making issues visible through Value Stream Mapping, tracking the seven flows and working together to find meaningful solutions for problems identified greatly assisted in generating collective subscription to the proposed changes. Future research will focus on unpacking the behaviours that assisted with the uptake of change, adding to organisational behaviour theory, change management theory and implementation science.

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<table>
<thead>
<tr>
<th>Manufacturing Flow</th>
<th>What it lets you see</th>
<th>Hospital Flow</th>
<th>What it lets you see</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Material</td>
<td>Material: where it's stored, how it's replenished, how often, and how much?</td>
<td>Medicines and other supplies</td>
<td>Where are the drugs stored, how much, how far away, how often are they restocked. Who can get them, how long does it take?</td>
</tr>
<tr>
<td>Work-in-progress</td>
<td>How does the product move as it's being built. Does it stop? How long it is stationary? How often it is moved? How far it is moved?</td>
<td>Patient</td>
<td>How many locations the patient must attend in order to complete treatment? How far does the patient travel?</td>
</tr>
<tr>
<td>Finished Goods</td>
<td>Where are products stored when they're complete? How many are stored, and for how long are they stored?</td>
<td>Patient (treatment complete in this area)</td>
<td>Where do patients go when treatment is complete? Do they wait? How long do they wait, and how many wait together?</td>
</tr>
<tr>
<td>Operators</td>
<td>The motion during work, reaching, bending, superfluous motion</td>
<td>Clinicians, Technicians, Administrative and Support Staff</td>
<td>The motion during delivery of therapies. The interactions of the various people during therapy delivery.</td>
</tr>
<tr>
<td>Machines</td>
<td>Utilisation of machinery, set-up times, out-of-location maintenance.</td>
<td>Equipment</td>
<td>Storage of often used equipment. How many are stored? How many are needed? How far</td>
</tr>
<tr>
<td>Manufacturing Flow</td>
<td>What it lets you see</td>
<td>Hospital Flow</td>
<td>What it lets you see</td>
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<tr>
<td>Information</td>
<td>Records of how and</td>
<td>Records of how and when patients are moved, diagnoses, treatment received. What is recorded? Where it is recorded?</td>
<td>Where information is generated? How it is recorded? Who records it? How much does recording activity reduce the time for patient contact?</td>
</tr>
<tr>
<td></td>
<td>when product is</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>transferred? What is recorded? Where it is recorded?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Process Engineering</td>
<td>What tooling is</td>
<td>Maintenance and non-clinical staff needed for the process</td>
<td>How is equipment maintained, in-situ or off site? How is the area maintained? How do cleaners move through the area?</td>
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<td>required? How is</td>
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<tr>
<td></td>
<td>it maintained? How is it serviced? How is it changed/modified? How often the line is rebalanced?</td>
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<td></td>
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</table>

Table 1: Comparison of lean flows between a manufacturing environment and a hospital environment.
Figure 1: Spaghetti diagram of technician movements in pathology laboratory on week days

Figure 2: Spaghetti diagram of technician movements in pathology laboratory on Saturday/Sunday
Figure 3: Plan created during RIE to split laboratory into two lines (chemistry and gas) and insert window into wall

Figure 4: Spaghetti diagram of doctor’s movements in acute area of emergency department while collecting pathology specimens from patient