From Hospital Plans to Computer Simulation:

A Case Study of the Alfred Centre.

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Abstract

The work reported in this paper was commissioned by The Alfred Hospital, one of Melbourne’s major public hospitals. The brief was to build a simulation model from the plans for the Alfred Centre, which would be an elective ‘walk-in, walk-out' investigative, diagnostic and treatment facility. The client wished to know whether the three Post Anaesthetic Care Units proposed for the new Centre would cope with the flow of patients from the Theatres, Endoscopy Rooms and the Cardiac Catheter Lab. There were two important factors to be considered. The first was that, whereas these three streams of patient care had previously had their own PACU facilities, in the new centre they would be combined. Secondly, the greater operational efficiencies expected of the new Centre made estimating patient flow difficult. The model indicated that under certain scenarios PACU capacity was insufficient to deal with expected patient flow.

Introduction

This paper is a preliminary examination of findings that have arisen from a System Dynamics model that has been derived from the initial plan for the Alfred Centre. The Alfred Centre was designed as a stand-alone short stay day procedural centre integrated within the Alfred, one of Melbourne's major hospitals. The model is a patient flow model that links the surgical procedures, medical interventions, and endoscopy interventions to the outpatient capacity.

The importance of this work is that, unlike most SD models, this model is not derived from a functioning system. Rather, it is derived from the architects' plans for Alfred Centre and is designed to test "best-case" scenarios of how the Centre could operate. There is a strong conviction with The Alfred Centre will stand apart as a quarantined facility so that no emergency and unpredictable care will be provided in this facility.

The main reason for the development of this model was to test and develop the configuration of beds and theatres in Alfred Care Center against its main objectives as an elective 'walk-in, walk-out' investigative, diagnostic and treatment facility.

The purpose of the model was to predict problems so that management actions could be taken early. At the time of writing, the process of scenario planning with a range of project groups within The Alfred Centre had just begun. This paper highlights the areas that will be of interest to these groups and the scenarios that will need to be developed. It demonstrates the application of the model and shows in a dummy simulation the range of options open to the planners.

Literature review

There has been extensive use of System Dynamics (SD) modelling in the health sector. Dangerfield and Roberts (1999) in their introduction to the Special Edition of the SD Review on healthcare argued for models to help decision makers with operational models. More importantly they argued the role of SD for policy guidance at strategic and budgetary levels where the tensions between management and clinician roles are always acute.

Gallivan (2005) puts a different case and argues for "back of the envelope" mathematical methods rather than the use of proprietary software packages. Such an approach runs the risk of excluding valuable feedback mechanisms common in hospital systems as well as precluding the use of micro-world simulation for managers to explore scenarios. Given the complex managerial and social structures involved in hospital administration and planning, techniques such as group model building (Vennix, 1996) provide an opportunity for consensus building around decision process.

There is a range of cited examples of the benefits of SD modelling approaches. The most important is possibly that of feedback systems emphasised by Taylor, Dangerfield and Legrand (2005) who reported on modelling cardiac catheterisation services in the UK. They observed that a desire to alleviate pressure on hospital systems through a number of measures including day surgery. Amongst their conclusions

> "Appreciating the wider consequences of shifting the balance of care is essential if services are to be improved. The underlying feedback mechanisms of both intended and unintended effects need to be understood" (pg 196)

Such feedback mechanism often produce counter-intuitive and "distant-in-time–and–place" effects. Lane, Monefeldt and Rosenhead (2000) examined in the factors that contributed to delay in Accident and Emergency units. One finding suggested that reductions in bed numbers did not increase waiting times for emergency services but did sharply increase the number of cancellations for elective surgery.

In addition to these feedback effects, there are the effects of the fundamental flow dynamics of the systems. It is not infrequent for policy makers to focus on the provision of extra capacity (stocks) as a first strike policy solution rather than address problems of patient flow. Wolstenholme (1999) studied the NHS in Britain and modelled major new structural initiatives. One of his conclusions was that there was a

> "clear demonstration that adjustments to flow (throughput) variables in a system provide significantly more leverage than adjustments to stock (capacity) variables." (pg 253)

Brailsford, Lattimer, Tarnaras and Turnbull conducted a whole-system review of emergency and on demand health care. They concluded that admissions (a flow) from general practice had the greatest influence on occupancy rates. Their modelling indicated a range of undesirable outcomes associated with continued growth in demand for emergency care, but observed that managing demand flow modelling indicated considerable potential to intervene to alleviate these problems.

The dynamics of waiting lists and the perceptions of wait lists have a significant impact on demand. Van Ackere and Smith (1999) examined waiting lists for elective surgery in the UK. They highlighted waiting lists as a rationing device to dampen down demand. The model examined both supply-side and demand side for elective surgery. They also commented on the extent to which sections of both the demand and supply chain affect the nature of the waiting lists. They also stressed that the pathway of care was critical to the dynamics of the model, Walker and Haslett (2003) simulated the impact of perceptions of waiting list length on referrals to a Sub-Acute Care facility.

Taylor and Dangerfield (2004) sound a warning in observing that the shift in the balance of health care, through such mechanisms as bringing services 'closer to home' or the establishment of day surgery centres is motivated by the desire to improve the provision of services. The unintended consequence is that these improvements in access serve to stimulate demand. This underlying positive feedback mechanism may prove that these interventions only have a limited effect.

Hirsch and Immediato (1999) outlined the advantages of micro-world learning environments for health-care providers in the development of new delivery systems. They also stress the advantages of simulation including feedback over spreadsheet projections because of the complex interactions and feedback mechanisms between decision-making consequences.

The Alfred Hospital

Founded in 1871, The Alfred is Victoria's oldest hospital operating on its original site and concentrates on specialist "high tech" services including Cardiovascular Medicine, Heart-Lung Transplant, Trauma Care, Oncology and Respiratory Medicine.

The Alfred has a staff of 3500 and treats more than one quarter of a million patients annually. It provides the most comprehensive range of specialist medical and surgical services in Victoria and accommodates six directorates comprising 42 clinical units, offering every form of medical treatment with the exception of obstetrics and paediatrics.

The State Government has recently allocated $60 million to this project in its 2004/05 Budget which adds to separately funded car park costs and an additional $8m of funds raised for equipment costs. (Source: The Alfred website http://www.alfred.org.au)

The Development of the Alfred Care Centre

In July 2000, the board of The Alfred Hospital approved a model of care for the delivery of short stay elective services. This model of care was based on a plan for a purpose-design facility for elective activities. This model was developed following extensive research, which examined day surgery centers based in the USA and UK (National Health Service, 2001). Fundamental to this plan was a new "culture of care" that would establish a point of difference between traditional in-patient services and ambulatory \ short stay care services (Antioch et al 2001). This was to be achieved through increased efficiency and convenience of the finished clinical intervention and a streamlined service provision based on principles of multipurpose areas and multi-disciplinary teams. Essentially, the new Alfred Centre was to provide ambulatory and short stay care that would enable The Alfred to maintain its services as an emergency and general hospital.

The Alfred Centre was designed to separate short-term elective surgery from emergency surgery and separate short-term recovery cases from the long-term complex cases.

It was anticipated that approximately 80% of elective services from the Alfred could be moved to the new Alfred Centre.

The Project Brief

The team developing the plans for the new Centre had to deal with a number of complex technical issues in relation to the design of the Centre. The new Model of Care, the new technologies and the scheduling of all day surgery from The Alfred meant that old performance data, and indeed old performance standards, would not be relevant for the new design. It was expected that a large number of process, both administrative and surgical would be improved. However the down-stream effects of these improvements were not known. There were three fundamental questions related to the input and output aspects of the process.

1. What were the likely dynamics of the operating theatres, cardiac catheter labs and endoscopy labs to ensure that the predicted and desired patient flow?

2. What is the correct capacity configuration of Post Anaesthetic Care Units (PACU) to deal with the patient flow?

3. Does sufficient capacity exist in PACU 2 and 3 to deal with all contingencies?

While it was expected that admission and operating times would improve, it was certain the patient recovery times would not.

The brief was to build a simulation model from the architects' plans to run scenarios involving a range of day surgery operations and procedures, with estimates of improvements in through-put, and to examine the ability of the PACU system to deal with the accelerated through-put.

The modelling was focused specifically on testing the plans and assumptions that had already been made. The centre was designed around a detailed service plan that measured the facility requirements including theatres and recovery beds. The simulation was required to model how it would work, to provide some clues on pressure points that might exist and to assist in any ideas to manage problems before they occurred. Later in the paper the issue of recovery beds is a case in point. Once pressure points had been identified, it was possible to use the flexible design to deal with insufficient stage 1 or stage 2 or stage 3 beds because it was possible use stage 2 for stage 1 or even stage 3 for stage 1.

The model was designed to test patient flow scenarios against the planned capacity of the Alfred Centre. The patient flow was generated by the scheduling of patients through four operating theatres, two endoscopy labs and two cardiac catheter labs (later changed to 6 operating rooms). The capacity was determined by the theatres and labs, PACU, short stay recovery and medi-hotel.

The model needed to allow 24 hours-a-day, seven days-a-week scheduling of 29 operating procedures through any of four theatres, five procedures through both cardiac catheter labs and six procedures through both endoscopy labs.

At the interface level, it was possible to schedule:

- All procedures by day of the week and by lab or theatre
- Proportions of operations being done under local anaesthetic
- Times for all procedures
- Recovery times for PACU 1 and 2 and short stay by procedure

The simulation was to show:

- Theatre utilisation
- PACU 1, 2 and 3 utilization
- Stay-time utilisation
- Transit times and queues for any part of the system
- The impact of bottle-necks on operating theatres

The planned capacity of the hospital was as follows: a pre-admission clinic, four operating theatres, three of which had pre-anesthetic rooms, two cardiac catheter labs, and two endoscopy labs (later changed to 6 operating rooms). There was an initial Post Anesthetic Care Unit (PACU 1) with 12 beds, two second stage PACUs with 19 recliners and six trolleys respectively, and 18-bed short stay unit and a six bed. The flows between these elements are shown in Figure 1.

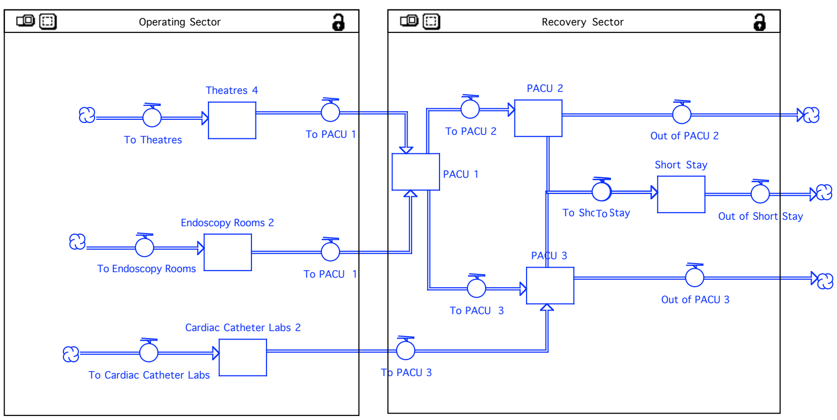

Figure 1: Simplified Model

The diagram highlights the important balancing the capacity of the Operating and Recovery Sectors. With the existing procedures in the Alfred Hospital both the operating theatres and the labs had separate recovery functions. In the Alfred Centre these would be combined. While both the Endoscopy Rooms and the Theatres flow patients to PACU 1, the Cardiac Catheter Lab patients go directly to PACU 3. PACU 3 is also on the pathway for some PACU 1 patients

The Client's Model Requirements

The client wished to know which procedures could be scheduled to maximise total throughput, theatre and lab utilization while ensuring that all procedures designated for the Alfred Centre were scheduled during a 4-week period. One complication in scheduling was the lack of a direct correlation between operating and procedure times in the labs and theatres on one hand and recovery time in the various PACU stages on the other. In addition, the PACU pathways that patients would take varied.

The client also needed to know the impact of process improvements in the new system. It was anticipated that there would be marked improvements in operating times and lab procedures. In the latter case this would be as a result of greatly improved technology in the new centre.

The initial model simulated the impact of the catheter labs, which were later replaced with operating rooms. This dynamic was not simulated in the original model. Given the recovery pathway for the patients from these labs, this would have a significant impact on the use PACU 2 and 3.

Initially, the model was populated with historical data from the Alfred Hospital. This data was for operating times for the surgical procedures, procedure times for the endoscopy and cardiac catheter labs, recovery times at all stages of PACU and short stay, percentage of procedures with local anaesthetic and discharge rates. In addition, the recovery pathways through the PACU stages were based on those of The Alfred.

User Interface: Main Controls

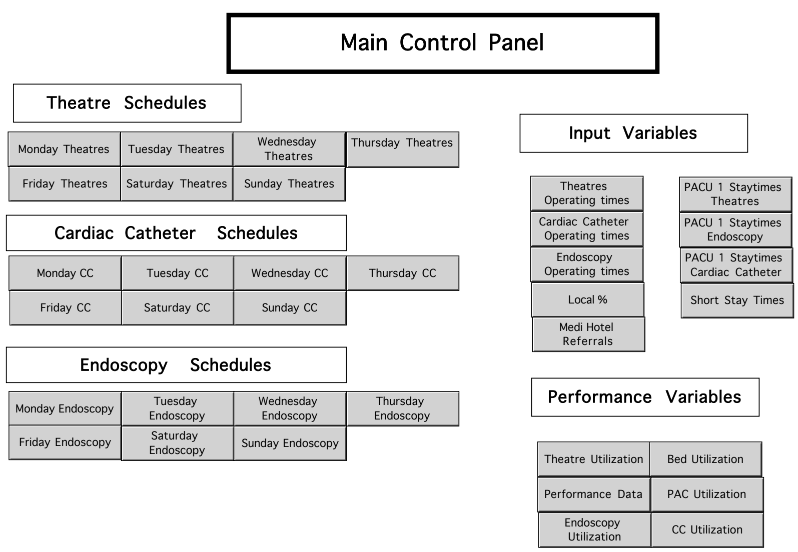

Figure 2: Theatre and Lab Schedules

This section of the interface allows the scheduling of operations. Here three hand and wrist operations have been scheduled for 8am and 1pm respectively and two tonsillectomy have been scheduled each hour between 8am and 3pm

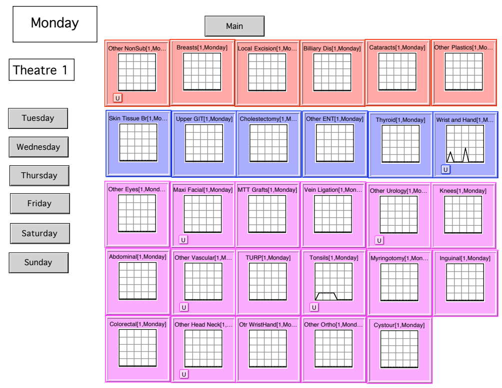

Figure 3: Theatre Scheduling Interface

This section allowed navigation to other weekly schedules.

Figure 4: Example of Schedules

Similar set-ups existed for Cardiac Catheter and Endoscopy labs.

Input Variable Controls

The model was populated with historical data and there was an expectation that many performance variables would improve significantly. It was therefore necessary that the model be able to run scenarios for projected improvements. Completion times for every procedure that was to be scheduled through the new centre could be varied for simulation.

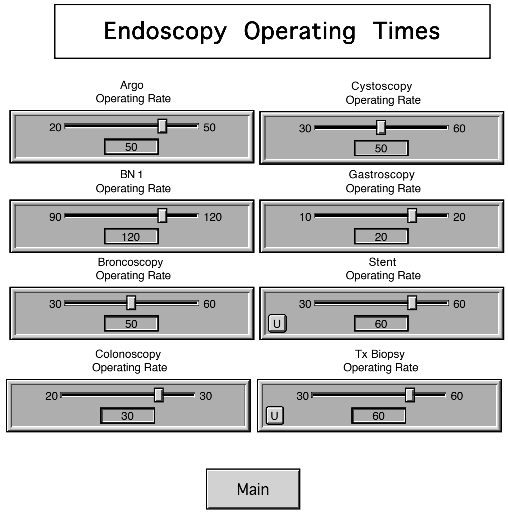

Figure 5: Interface for varying Endoscopy procedure times.

The interface also provided for variation in level proportions of operations conducted under local anaesthetic. These operations have the advantage of shorter recovery times and patients require less time in the PACUs.

Performance Variables (Sample Output from Simulation 1)

The aim of this simulation exercise was to test for optimal design combinations in the plans for the planned Alfred Centre. The simulations were also designed to test for optimal scheduling and performance. These performance figures would provide Alfred managers with advanced indications of whether the Centre as configured, would meet State Government performance targets.

Simulation 1 was run with a random sample of operating schedules in four theatres, two Endoscopy labs and four Cardiac Catheter labs across a week. The simulation is run using historical performance data, rather than the projected improved performance standards that the new centre was designed to meet. The simulation is indicative of the types of scheduling and input performance data that managers can use in deciding the configuration of a new centre such as the Alfred.

Performance data for theatre utilizations and bed utilization for Scenario 1 was captured. Figure 6 shows the utilization of Theatre 1 across a week. Total operating hours were 35.7. For Simulation 1 this was representative of the utilization in other theatres. This level of utilization is for public patients and does not include private patient operations that many surgeons perform at the Alfred. Nor does it include weekend operating schedules.

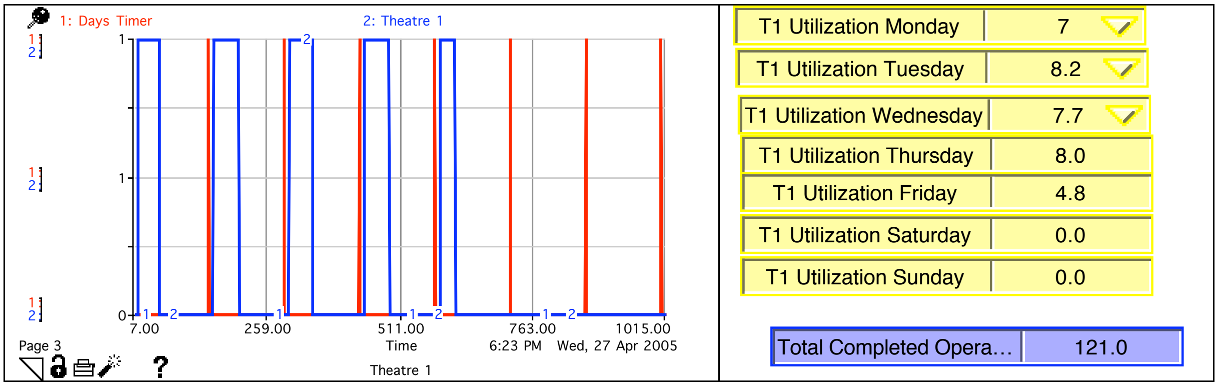

Figure 6: Theatre 1 utilization for a 5-day week

The simulation showed some complications for bed utilization in PACUs. Figure 9 shows bed utilization in PACUs and short stay overnight accommodation. Resources in PACU 1 are more than adequate for the Scenario 1 scheduling. PACU 2 has queues every day of the week. This is a result of Endoscopy and Cardiac Catheter patients flowing into PACU 2. PACU 3 (recliners) is under utilized. The impact of the removal of the Cardiac Catheter labs would change this dynamic and the 6 new operating rooms would change the patient flow through PACU 1 and through a flow-on effect to PACU 2 and 3.

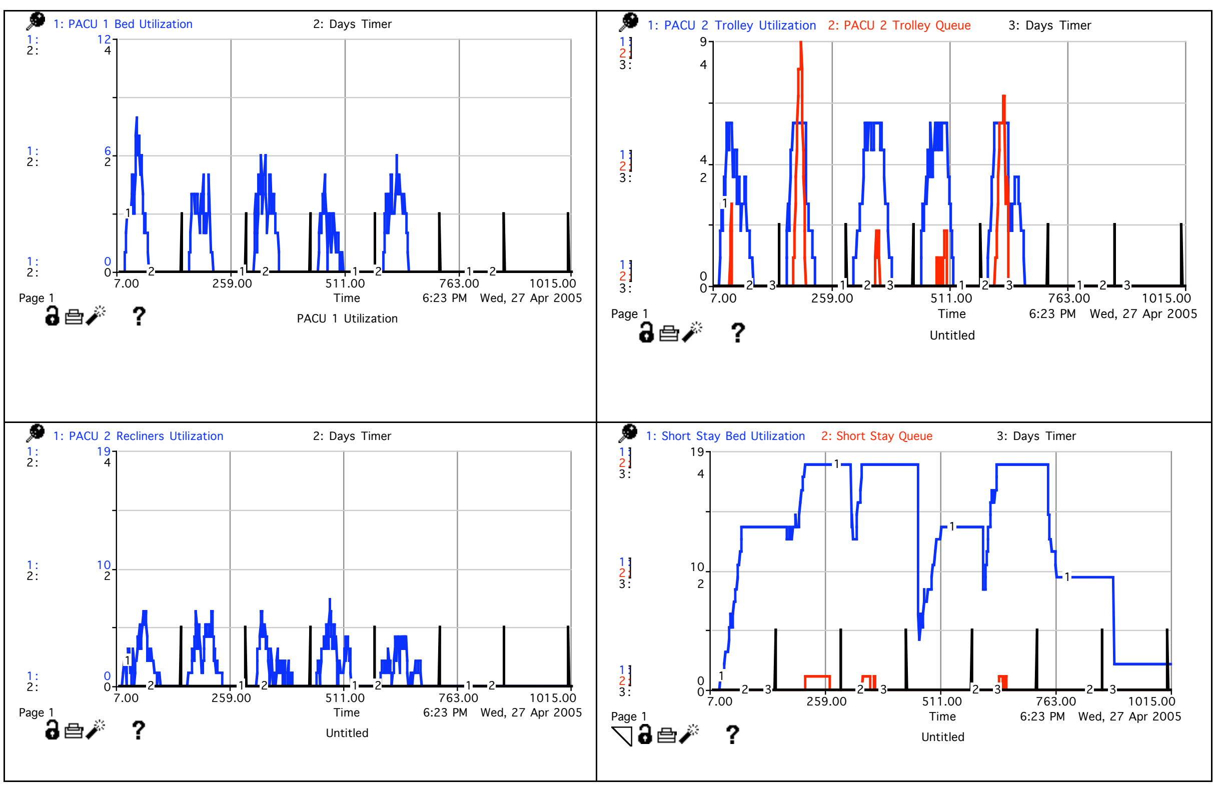

Figure 7: PACU bed utilization

A more important aspect of this scenario is that the queuing in PACU 2 would flow back into PACU 1 or could use the excess capacity in PACU 3. It is likely that the 12-bed PACU 1 could hold patients until space becomes available in PACU 2. This is a less desirable solution than using PACU 3 as it uses a more highly intensive resource than is needed. This is important because any flow back into the operating theatres would mean holding patients in the theatres and disrupting the operating schedule. The central question is whether this contingency should be included in the initial design or whether the possibility should be designed out of the system.

Scenario 1 also indicates that the possibility of re-allocating resources between PACU 2 and PACU 3 should be considered in the light of future simulation runs. It also serves to indicate that multiple scenarios are needed to mimic the Centre operating at full capacity.

Scenario 1 also indicated that PACU patients would be cleared by between 7-8pm each day and that the short stay facility was operating close to capacity every day except Thursday. This capacity constraint has important implications for the scheduling of private surgery after 5pm.

Future scenarios would also need to look at different mixes of surgical procedures and at close coordination between the labs and theatres.

Conclusions

The simulation of the architects' plans for the new Alfred Centre demonstrated the potential for advanced planning of complex hospital patient flow dynamics. Evidence from one scenario alone raised a number of questions on process management and design that could be tested in future simulations. Future scenarios testing would include examining a range of questions.

- Would there be a need to readjust the PACUs?
- Would the system be able to balance the needs for improved throughput with the need to provide access for a wide range of operations within the Alfred Centre?
- Would there need to be constraints on the range of operations that could be transferred from the Alfred to the Alfred Centre?
- Would preference be given to the quicker local anaesthetic procedures?

The simulations also identified the issue of the appropriate performance data to be used in base runs of the simulations. The current model uses historical data that does not give an accurate estimation of what are likely to be greatly improved procedure times. However, opportunity was there to simulate different processes, which enabled an examination of how the new centre would operate. Data on recovery times is likely to be more accurate, given the nature of the process. The accuracy of this data is central to the accuracy of the simulation. It is difficult to gain accurate estimates of the extent of the possible improved performance of a new high-tech facility when the base data comes from a large multi-purpose hospital. The best case is that a number of performance indicators can be established around a scale of improvements in patient flow processes. Despite these limitations simulation still provides a valuable perspective on the design dynamics of new hospitals. In particular, it provides an opportunity to re-assess some of the more traditional patients pathways and processes. Without simulation, the impact of performance improvement in the complex dynamics between theatres and labs and the recovery systems will never understood.

A final caveat: The Alfred Centre will effectively relocate a significant number of operations away from the main Alfred hospital. Many of these will consist of patients whose operations will less complex, less traumatic and require shorter recovery times. This will leave the larger and older Alfred hospital to deal with the longer, more complex procedures with extended recovery times, particularly those from arising from the increase capacity of the Emergency and Trauma Centre. It will also provide the opportunity for much greater capacity in dealing with the Alfred's complex and unpredictable emergency work. As this shifts occurs, the Alfred will increasingly be caring for a different mix of patients. This will create new dynamics in occupancy rates and the cost and resources required to run the hospital. However, this study did not extend across whole of Alfred so was unable to deal with the question of impacts across hospital.

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