AMSI VACATION RESEARCH SCHOLARSHIPS 2020–21
Get a Thirst for Research this Summer

Optimisation of Surgical Waiting List Management

Jack Powers
Supervised by Associate Professor Paul Corry & Professor James McGree
Queensland University of Technology

Vacation Research Scholarships are funded jointly by the Department of Education, Skills and Employment and the Australian Mathematical Sciences Institute.

AMSI AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE
Australian Government
Department of Education, Skills and Employment

Abstract

Patients awaiting elective surgery in Australia can often experience long wait times to receive care due to high demand and limited capacity of the health care system. Currently in Australia, patients are placed on a waiting list and assigned a nationally defined classification indicating the urgency of the surgery, determined from a range of clinical factors. However, this classification process can be subjective and up to the discretion of the treating health professional, leading to potential inequities in waiting times. This project investigated prioritising patients through use of a scoring system, incorporating clinical factors and time spent on the waiting list to determine a priority score. Patients are admitted to surgery in descending order of this score, which is updated regularly. Limited summary statistics were able to be collected due to lack of comparable patient data (which was randomly generated), however it was found that the priority score model fundamentally changed patient ordering and the behaviour of basic summary statistics were similar to that found in existing literature. Further research would be required to determine the magnitude of additional fairness and equability, if any, this novel system would provide over that of the current ranking system.

1 Introduction

In the Australian public health system, there is often a long waiting list for patients to access elective surgeries due to high demand and limited capacity of the health system. Currently in Australia, after a general practitioner (GP) referral to a specialist, patients are placed on a waiting list and assigned a nationally defined classification indicating the urgency of the surgery. This urgency classification is derived from the clinically recommend time within which a patient should receive surgery based on a variety of clinical factors, such as the patient's need, likelihood of deterioration and benefit from surgery (Australian Institute of Health and Welfare 2013). This prioritisation model ensures that patients with greater clinical need or higher potential to benefit from the surgery receive the service first. In Australia, there are three national categories for surgery prioritisation:

- Urgent (Category 1) — surgery recommended within 30 days of being added to the wait list
- Semi-urgent (Category 2) — surgery recommended within 90 days of being added to the wait list
- Non-urgent (Category 3) — surgery recommended within 365 days of being added to the wait list (Queensland Health 2015)

However, this system has been a point of contention and dissatisfaction for health care providers, politicians, policymakers and especially, patients. This classification process can be subjective as definitions for "patient's benefit of surgery" and "likelihood of deterioration" used to determine the patient's urgency category are not clearly defined and up to the discretion of the treating health professional (Curtis et al. 2010). Due to this, there can exist disparities, discrepancies, and potential bias relating to where exactly a patient is on the waiting list and when they can expect care.

There is also an expectation that, while priority patients should spend a lesser amount of time waiting for surgery, similar patients with similar conditions should experience similar wait times. With no clear guidelines to distinguish patients in these situations, factors such as socioeconomic status of the patient, cost-effectiveness of the procedure, or potential patient health deterioration may influence patient priority, leading to an inequitable access to service (Breton et al. 2020).

To solve this problem, there have been proposals to implement a single waiting list, where patients are ranked according to both clinical factors and time spent on the waiting list. This would ensure that semi-urgent and non-urgent patients do not wait exceptional amounts of time for care. This system has the potential to revolutionise the field of surgical waiting list management by utilising modular, transparent, and defensible weightings in a mathematical formula to obtain a priority score.

This project will focus on the investigation and modelling of the current three category system for ordering elective surgery patients, as well as the feasibility of a novel patient ranking system. A literature review will be conducted to gain an understanding of the current patient ranking environment and methods used around the world to rank patients on the basis of clinical factors. Specifically, through the weighting of a range of relevant clinical criteria as well as consideration of time spent on the waiting list. A preliminary simulation model will be developed to analyse waiting list behaviour and collect data on waiting times for both the current system and an alternate system. This model will then be used to verify alternative ranking systems that already exist around the world. It should be noted that due to the scope of this research, it is in no way an accurate model and represents a proof of concept.

1.1 Statement of Authorship

Initial project idea formulated by Associate Professor Paul Corry and Professor James McGree in association with Sunshine Coast University Hospital. Background research, model development and analysis performed by Jack Powers. General guidance and supervision provided by Associate Professor Paul Corry and Professor James McGree. Project funding provided by AMSI and the Australian Department of Education.

2 Literature Review

There has been some work on the topic of explicit ranking of patients awaiting elective surgery outside that of a prioritisation model. Most of the literature focused on the policy and systematic use of centralised waiting lists, as opposed to explicit score based ranking of patients. However, there has been substantial work in the aspects that would be required to support such a project in Australia, such as weightings for certain clinical criteria, as well as the acceptability of waiting lists in general.

Oudhoff et al. 2007 investigated the acceptability of waiting lists in a health care model through survey of patients, surgeons, GPs, and occupational physicians. The majority of GPs and surgeons surveyed as part of the study accepted the existence of waiting lists in health care. In contrast, patients responded negatively to the existence of waiting lists, as it was believed that when needed, patients should not have to wait for care. This belief is of no surprise, as when a patient is in a situation where elective surgery is required, they may already be suffering from a variety of symptoms such as pain or dysfunction, where untreated could potentially be life threatening. However, while patients detested waiting lists (in that the existence of such lists resulted in potentially delayed treatment), the use of waiting lists, and especially the prioritisation of patients based on individual symptoms and degree of suffering, was not see as inequitable.

In terms of patient prioritisation, it was found that surgeons preferred individual management of the prioritisation process and thought it was best systematically to leave individual patient prioritisation to the treating physician. In contrast, the majority of patients, GPs, and occupational physicians favoured a nationally agreed system for prioritising patients, which may allow for increased transparency and equitability.

The current prioritisation system in Australia categorises patients into three urgency groups based on the clinically recommended time in which they should receive treatment, which is based on a range of explicit clinical and social criteria such as pain, disease progression, and disability. An alternative approach to the current system would be the use of a single waiting list where patients are assigned a score based on a variety of relevant clinical factors and time spent on the waiting list. This approach was investigated by Testi et al. 2008 and utilised a prioritisation formula in the generalised form of $P_i = \alpha_i t$, where P_i is the prioritisation score of patient i, α_i is the urgency coefficient of patient i, and t is the time spent on waiting list (in days). The magnitude of this score provides an indication of the urgency of care. Patients with the highest priority score are admitted first, regardless of the initial urgency assessment or any other factors (unless of course the need for emergency surgery develops).

The urgency coefficient (α_i) is determined from clinical judgment of the patient's condition according to a set of predetermined criteria, where these criteria may be weighted by a number of other factors (where weightings for certain factors would be contrived in conjunction with health professionals). The value of the urgency coefficient is calculated when a patient is first placed on the waiting list and is constant, only being reassessed if the patient's condition improves or worsens.

The patient prioritisation formula used in the work of Testi et al. 2008 utilised three clinical criteria developed and weighted in conjunction with surgeons participating in their study. The three criteria used are numerical values indicating disease progression or deterioration (r), pain or dysfunction (p) and disability (d), where $0 \leq r, p, d \leq 4$. The priority score for patient i (P_i) is then calculated by the following formula, where t is time on waiting list in days:

$$P_i = \begin{cases} 3r_i^2 t, & r > 0 \\ (1 + 0.5p_i^2 + 0.5d_i^2)t, & r = 0 \end{cases}$$

The rationale of this prioritisation formula is that there exists a hierarchy of need, where if there is a risk or evidence of disease progression, other criteria become irrelevant. In contrast, when disease progression is not evident, the criteria for pain or dysfunction (p) and disability (d) are weighted equally. Hence the range of P_i is $0 \leq P_i \leq 48t_{max}$, where t_{max} is the value of the longest waiting patient.

The criteria and weightings utilised by Testi et al. 2008 can be seen to be relatively limited and simple. Alternative clinical criteria and weightings was further investigated by Solans-Domènech et al. 2013, with the aim of developing a universal priority scoring system that could be applied to all patients with standard criteria

Dimension	Criteria	Weighting
Clinical-functional impairment	Disease severity	23%
	Rate of disease progression	15%
	Pain (or other main symptoms)	14%
	Difficulty in doing daily life activities	14%
Expected benefit	Probability and degree of improvement	12%
Social role	Limitations in the ability to work, study, or seek employment	9%
	Limitation to care for one's dependents (if relevant)	8%
	Being dependent with no caregiver	5%

Table 1: Criteria and weights of the universal priority scoring system for patients on waiting lists for elective surgery (Solans-Domènech et al. 2013)

for all conditions. In this study, it was intended to identify and develop a range of relevant, objective, and defensible criteria and weights which could be applied to a range of patients awaiting elective surgery.

This was carried out through a nominal group process, where a range of multidisciplinary participants were selected with backgrounds related to all aspects of waiting list management. The members of the group responded to a variety of questions relating to what criteria should be included and the relative weights of the included criteria. The participants then ranked the suggestions of the group, to develop and achieve a consensus of relevant clinical criteria and weights for elective surgery waiting list management. The summary of the results can be seen in Table 1.

Utilising aspects of the work mentioned above, Siddins et al. 2012 proposed a system to rank elective surgery patients, from the initial specialist consultation to waiting list management. The proposal of a mathematical formula with specific criteria and weightings to calculate a priority score is similar to that of Testi et al. 2008, however includes specialised booking forms for individual conditions. An urgency category system is still used (in terms of the clinically recommended time treatment should be received), however its use is intended to supplement other clinical factors instead of being the sole metric of prioritisation. The surgery booking forms are tailored for each elective surgery procedure with the inclusion of relevant clinical criteria, as well as optional additional weightings for psycho-social factors that may be difficult to quantify.

In terms of the accrual of priority scores (termed P-scores), an example of this process can be seen in Figure 1, demonstrating how different urgency coefficients and waiting times interact to produce a single waiting list. In this instance, P-scores accumulate non-linearly, however this behaviour is fully determined on the weightings of various clinical factors as well as the relationship relationship between time and the urgency coefficient.

A priority score based ranking system for elective surgeries has the potential to revolutionise waiting lists. Waiting list reports could be generated instantly, providing patients with a better understanding of their rank on the list, as well as ensuring an increased degree of trust and confidence in the health system. Health professionals

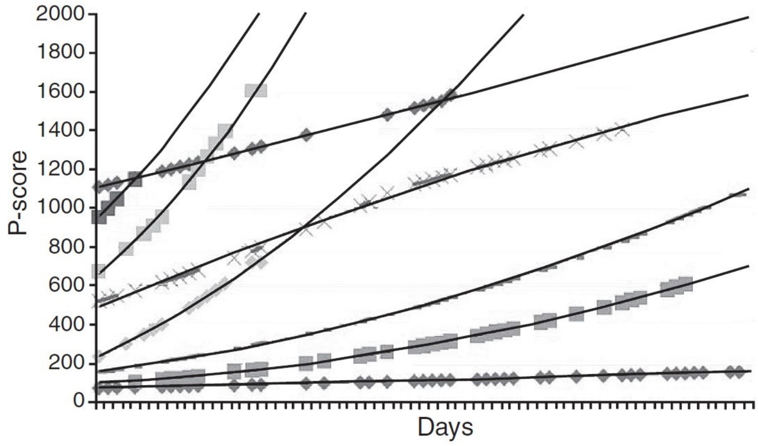

Figure 1: Example of variation in the accrual of P-scores (priority scores) over time for individual patients (Siddins et al. 2012)

would be able to focus more on the patient and less on administration, as tailored booking forms for specific conditions and procedures would streamline the booking process, removing irrelevant criteria and unnecessary administration work. The use of clearly defined and defensible criteria and weights would also provide a more transparent and equitable system. The above literature has demonstrated that supporting work for this type of project does exist, and the development and implementation of a priority score based system is very much feasible within the Australian health system.

3 Method

To develop a discrete event simulation for both the existing three category system and the proposed priority scoring system, the programming language Python, along with the simulation package SimPy was used. From these models, summary statistics were collected and used to assess the performance of each model.

3.1 Three Category System

Firstly, a three category simulation was developed based on available knowledge on how the current system is implemented in the Australian public health system. This simulation will provide baseline data points that can be used as a comparison for the ranking system. The simulation flow chart detailing patient behaviour can be seen in Figure 2. Patients arrive to the simulation according to an exponential distribution and the priority category (category 1-3) were assigned according to a uniform distribution. A variety of metrics at a patient and operating theatre level were collected, such as average patient queuing time by priority and summary statistics of operating theatre efficiency, which can be seen in the Results section.

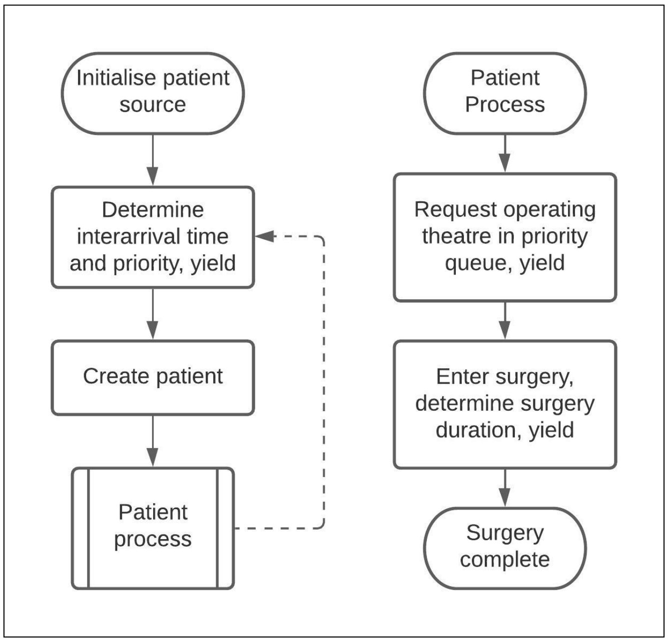

Figure 2: Three category priority system based discrete event simulation flowchart

3.2 Priority Score System

Next, using the weightings as developed by Solans-Domènech et al. 2013 and the prioritisation formula principles of Testi et al. 2008, a novel prioritisation formula is proposed:

$$P_i = \begin{cases} 3(0.6r_i^2 + 0.4s_i^2)t, & r > 2 \\ (1 + 0.23s_i^2 + 0.14p_i^2 + 0.15r_i^2 + 0.14l_i^2 + 0.12i_i^2 + 0.05d_i^2 + 0.08c_i^2 + 0.09w_i^2)t, & r \leq 2 \end{cases}$$

where the clinical criteria used are disease severity (s), pain (p), rate of disease progression (r), difficulty in doing daily life activities (l), probability and degree of improvement (i), being dependent with no caregiver (d), limitation to care for one's dependents if relevant (c), and limitations in the ability to work, study, or seek employment (w), where $0 \leq s, p, r, l, i, d, c, w \leq 4$. Hence the range of P_i is $0 \leq P_i \leq 48t_{max}$, where t_{max} is the value of the longest waiting patient. The rationale for this formulation is that if there exists disease progression, all other criteria should be disregarded and ranking should be done on the basis of disease progression and disease severity, weighted 0.6 and 0.4 respectively.

A discrete event simulation model was then developed in SimPy using the above prioritisation formula. To calculate performance metrics for this model, algorithms which continually updated each patient's P-score and rank in the system were implemented. This is detailed in the simulation flowchart, which can be seen in Figure 3 and provides detail on the patient creation process and the patient behaviour process.

Similarly to the base model, patients arrived to the simulation according to an exponential distribution and individual clinical scores (such as disease severity (s), pain (p), rate of disease progression (r), etc.) were assigned according to a uniform distribution on the range $[0, 4]$. A range of summary statistics were collected. It

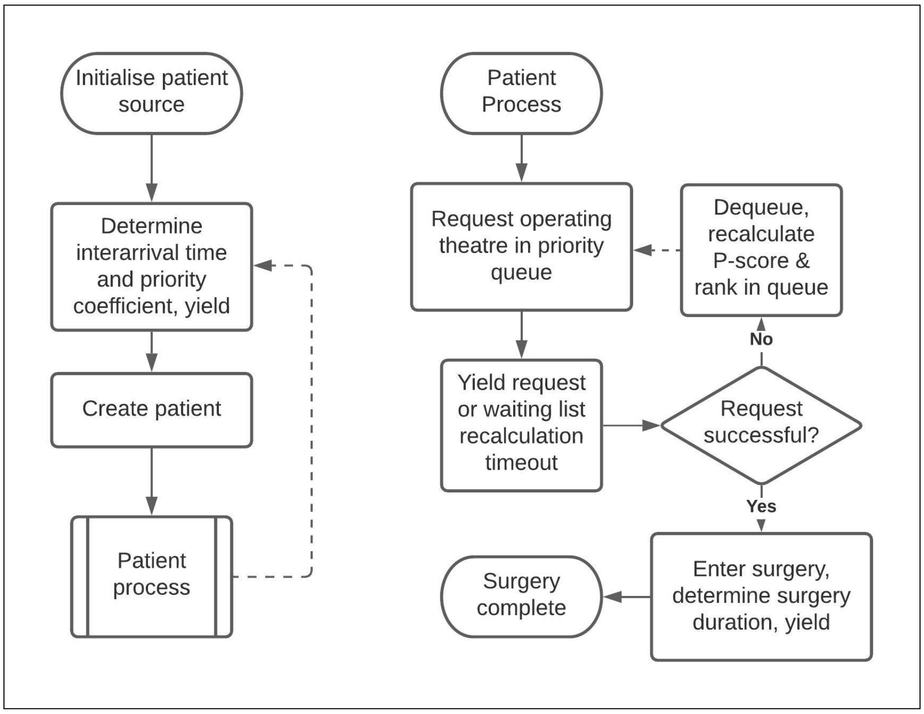

Figure 3: P-score based discrete event simulation flowchart

should be noted that if the patient clinical scores were not randomly generated and characterised real patients, there may be some correlation between certain criteria. However, because the criteria scores were randomly generated, there would exist little or no correlation between them.

3.3 Simulation Parameters

In its current form, the simulation utilised arbitrary time units with a compressed time horizon, and represents a proof of concept instead of a full-scale waiting list model. This was to ensure that simulation behaviour was correct with easier output graph interpretation, as well as due to patient data being randomly generated. An initial patient backlog was also implemented to provide some aspect of reality in the simulation.

To ensure a degree of comparability between the three category model and the P-score model, the same simulation parameters were used where relevant. These parameters can be see in Table 2. It should be noted that only a single simulation replication was conducted for both simulation models, and therefore more simulation replications would be required to obtain results with a certain level of statistical confidence.

Under classical queuing theory, this model under the given parameters can be described as a two server queue. Queuing theory concepts can also be applied to calculate the system utilisation parameter, ρ. This measure is calculated as the arrival rate to the system divided by the service rate, and indicates the average proportion of time each server is occupied. In this instance, with the parameters listed in Table 2, patients arrive to the simulation according to an exponential distribution with mean interarrival time of 11 time units and are serviced by two operating theaters with constant surgery length of 20 time units. Hence, the system

Parameter	Value
Simulation length	3000 time units
Surgery length	20 time units
Average patient interarrival time	11 time units
Number of operating theaters	2
Initial patient backlog	20

Table 2: Simulation Parameters

utilisation parameter can be calculated to be $\rho = \frac{\frac{1}{11}}{2\times\frac{1}{20}} = 0.\overline{90}$, which is less than one, indicating that the system can operate under steady state conditions and the queue length will not infinitely increase.

3.4 Treated in Turn Proportion

A metric that will be used to compare the models, as well as ensure general alignment with the real world is the treated in turn proportion. This is a metric used by Queensland Health to ensure that patients are not waiting past the recommended time within they should receive surgery. It dictates that:

> Within each urgency category, a minimum of 60% of elective surgery patients should be treated in the same order as they are added to the waiting list (Queensland Health 2017)

It is designed to minimise queue jumping and ensures that the surgery system somewhat represents a first in, first out queue. It is a measure of the proportion of patients that were disadvantaged by queue jumping due to being a lower priority category. For the purposes of calculating this value in the models, a patient was classified as treated in turn if they entered surgery in the same order or sooner than the order they arrived to the system, otherwise they are classified as treated out of turn.

4 Results

4.1 Three category system

The simulation was run according to the parameters in Table 2 and modelled after the current three category system for elective surgeries. The output of this simulation can be seen in Figure 4, plotting patient waiting time by urgency category as well as the number of patients waiting throughout the simulation, also by urgency category. In the first subplot of Figure 4, there can be seen to be distinct groupings of priorities, especially at the start of the simulation, in terms of queuing times. As the simulation progresses, the groupings diminish, however are still present across the vertical axis. At the start of the simulation, when there exists a backlog of patients, queuing times are relatively high, decreasing as this backlog is cleared. Depending on the patient

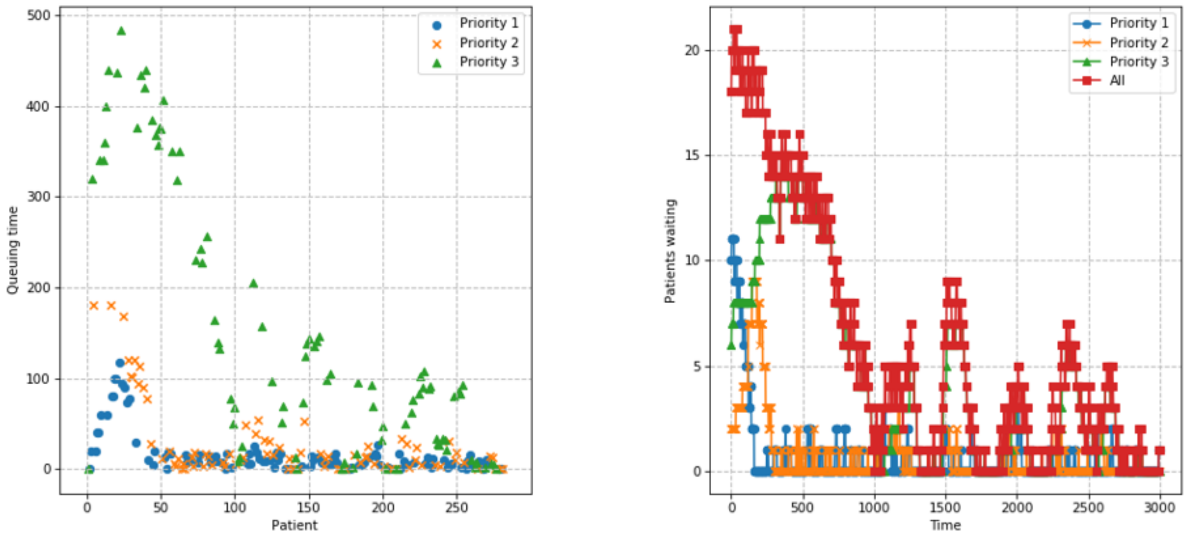

Figure 4: Three category priority system model plots

interarrival rate, the queuing time groupings may change, however as currently set, the system is operating under a steady state, and it is expected that the queue will not infinitely increase.

In the second subplot of Figure 4, it can be seen that the total number of patients queuing fluctuates throughout the simulation time horizon. The queuing numbers of priority 1 and 2 patients appears to be relatively consistent, with main fluctuations occurring in the case of category 3 patients, creating a significant impact on the total number of patients queuing.

The summary statistics of this simulation can be seen in Table 3, where it is evident of the differences in queuing time between the different priorities, especially in category 3 patients. As expected, category 1 patients queue the least amount of time, with a mean of 16.83 time units. Category 2 patients queuing time is close behind with a mean of 27.1 time units. Interestingly, category 3 patients queue for a much longer time than category 1 and 2, with a mean queuing time of 145.23 time units. In all instances, the standard deviations of each patient category are rather large, demonstrating the spread of waiting times between urgency categories, as well as the disadvantage faced by category 3 patients. For comparison purposes to the P-score model, the overall average patient queuing time was 60.99 time units with a standard deviation of 104.45 time units.

Statistics relating to average resources occupied and treated in turn proportions were also collected. Throughout the simulation, the average operating theatres utilised was 1.795, which yields an average system utilisation of $\frac{1.795}{2} = 0.8975 \equiv 89.75\%$. This is very close to the theoretical system utilisation parameter of $\rho = 0.\overline{90}$. The treated in proportion was calculated to be 73.5%, indicating the proportion of patients that were treated as expected or earlier, based on the rank in which they entered the system.

	Time in queue		
Priority	Mean	Median	SD
1	16.83	8.79	24.8
2	27.1	12.1	41.35
3	145.23	90.64	146.27
Aggregated	60.99	14.17	104.45

Table 3: Three category system simulation metrics

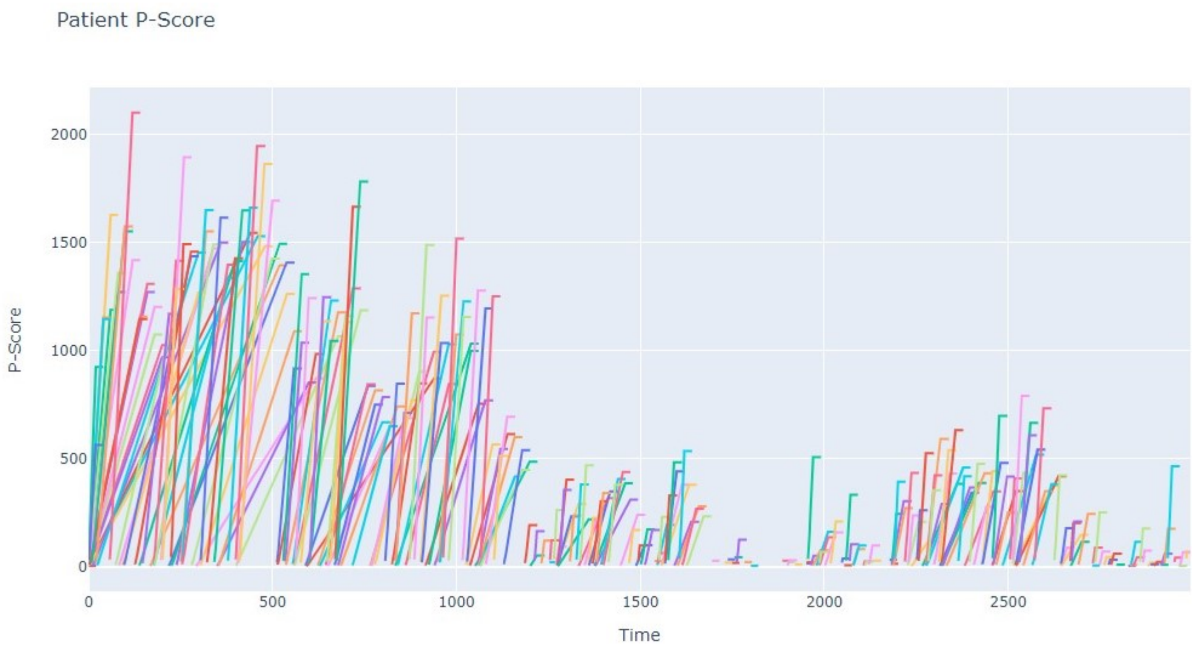

Figure 5: Patient P-score plot

4.2 Priority score system

Using a priority scoring system allows a single waiting list to be implemented, where patients ascend in score according to their clinical factors and subsequent priority coefficient. The resulting P-score plot can be seen in Figure 5. It can be seen that the P-score of each individual patient (represented by a differently coloured trace) increases at different rates, according to that patient's P-score coefficient. This allows higher priority patients to move through the waiting list faster. The plateau on each trace represents when a patient enters surgery, with the line terminating when surgery is complete. At the start of the simulation, when there is a patient backlog present, there is a higher density of traces where patients require higher P-scores to receive treatment, as compared to later in the simulation when patients receive treatment with considerably smaller P-scores.

How a patient's P-score value affects their ranking in the waiting list system can be seen in Figure 6. As a patient progresses on the waiting list, they may be overtaken by an another patient of higher priority. For

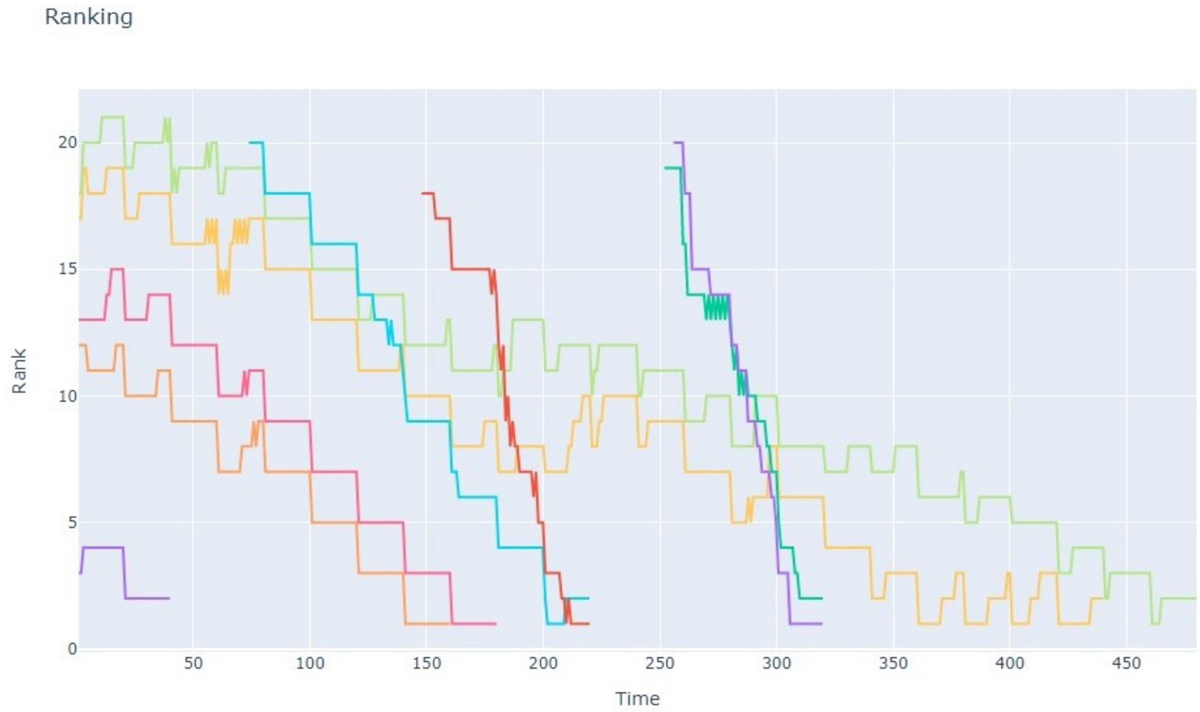

Figure 6: Ranking of selected patients at the start of the P-score simulation

example, there are some instances where a higher priority patient quickly descends in rank in a short period of time with little rank fluctuation, while there are other instances where patients fluctuate in rank over a longer period of time, with a tendency to decrease in rank, indicating a less urgent case. To ensure equity in care, the ranking of all patients throughout the simulation should have a tendency to decrease, so that all patients eventually receive treatment.

Gathering summary statistics for the priority scoring model was more difficult and abstract compared to the category ranking system, due to the continuous and unbounded nature of P-scores. It also posed difficult to make direct comparisons between the two models due to different patient populations, as it was not possible to accurately generate an urgency category which mapped to correctly scored clinical criteria without expert opinion. As a result, the two models would not be directly comparable on a per patient basis, however general model behaviour and statistics can be compared.

The summary statistics generated by the P-score model can be seen in Table 4, detailing statistics relating to time in queue as well as P-score information. It can be seen that average queuing time in this model is 68.82 time units with a standard deviation of 82.99. In terms of the P-score statistics, it appears that the mean value for both patient P-score on admission and P-score coefficient are rather small in compassion to the overall range of the values. In contrast, both metrics have very large standard deviations indicating a large spread on the collected values. In all metrics, the median demonstrates that there are a number of extreme values present in

	Time in queue	P-score on admission	P-score coefficient
Mean	68.82	628.94	14.79
SD	82.99	534	10.76
Median	40	438	9.58

Table 4: P-score summary statistics

the simulation.

In terms of average resources utilised, 1.82 operating theaters were occupied throughout the simulation, yielding an average system utilisation parameter of $\frac{1.82}{2} = 0.91$, which is equal to the theoretical measure to two decimal points. This is a good indication for verification of correct model behaviour. The treat in turn proportion was lower compared to the three category system, with 68.21% of patients being treated in the order they were added to the list.

4.3 Comparison

A comparison table detailing the overall queuing times mean and standard deviation can be seen in Table 5. It is evident that the average queuing time for patients in the three category system is smaller than that of the P-score system, by approximately eight time units. In contrast, the standard deviation of P-score model is smaller than the three category system by approximately 22 time units. This indicates that, while patients waited longer on average in the P-score system, variance in queuing time decreased. This perhaps is indicative that equity of the overall system has been improved, as waiting times between patients is no longer as extreme, however at the expense of larger queuing times.

The treat in turn proportion for the P-score system also decreased compared to the three category, with a decrease of approximately 5%. This may be expected as, in a sense, the P-score system utilised continuous categories, as opposed to three distinct categories. Hence, the treat in turn proportion may not be a suitable metric for a P-score system, as less queue jumping may occur when there are a smaller amount of discrete categories as there are fewer categories to jump to. Nevertheless, the metric is useful to determine the proportion of patients that are disadvantaged by queue jumping.

The average system utilisation values for both models was also very close to the theoretical value of $\rho = 0.\overline{90}$, indicating the correctness in the behaviour of the developed models. However, only a single simulation replication was conducted, so the calculated system utilisation parameters are only representative of a single random number stream. If more simulation replications were conducted, it would be feasible that the system utilisation parameters for both models would closer approach the theoretical value.

	Time in queue			
Model	**Mean**	**SD**	**Treat in turn %**	**Average system utilisation**
Three category system	60.99	104.45	73.5%	0.8975
P-score system	68.82	82.99	68.21%	0.91

Table 5: Model metric comparisons

5 Discussion

Testi et al. 2008 utilised the standard deviation of queuing times to assess equity of care, where it was argued that a lower overall variance between queuing times across all patients was an indicator of equity. In this work, it was also found that the standard deviation of queuing time under the priority scoring model decreased compared to a priority category system. Mean queuing time was not reported on, however unlike the results in Table 5, the standard deviation decreased by half - a much more substantial result (Testi et al. 2008). This is very similar to the behaviour of the two developed models, providing some aspects of verification.

A limitation of this work is that due to lack of access to real patient data, numerical values of clinical factors were randomly generated according to a uniform distribution. Due to this randomness, clinical factors that may be correlated in reality were not in the simulation. Additionally, there is a possibility that some clinical factor scores may contradict with each other or with that of a health professional's judgement.

Comparing the two priority systems using other metrics than that of queuing time also proved difficult as essentially, two separate and random populations were used for each model. For there to be comparability at a patient level between the two models, real patient data would be needed or generated under the guidance of a health professional. This is to achieve a mapping between a urgency classification (category 1-3) and clinical factor scores, so that the same patient population can be used in both models. With this data, analysis can be conducted to identify specific patients that benefited or were disadvantaged under the P-score system (besides an overall metric provided by the treat in turn proportion).

As previously mentioned, this work serves more as a proof of concept of a P-score waiting list system as opposed to realistic model. All simulation parameters were contrived arbitrarily on an undefined time scale. To achieve a higher degree of confidence in the collected statistics, multiple simulation replications would be required to achieve a neighbourhood of results, more diverse than that of a single random number stream. However, the behaviour of the model - particularly in comparison to the three category system - can be seen to be a somewhat accurate representation of what may be expected under such a system.

6 Conclusion

Long waiting lists for elective surgery have been a point of contention and dissatisfaction within the Australian health care system, with patients potentially waiting extreme amounts of time to receive treatment. Instead of a three category system to prioritise elective surgery patients, utilising a P-score model has the potential to revolutionise waiting lists in Australia, in terms of increased transparency, equity, and consistency. It was found that the proposed P-score ranking system fundamentally changes the ordering of patients. While patients on average queued longer, the standard deviation of queuing time decreased, perhaps indicating that equity may have improved by distributing excess queuing times across the whole patient population.

There were several limitations in this model which prevents it from being used for any rigorous analysis, and serves more as a proof of concept of an alternative patient prioritisation model. Future work in this field would involve exploring the existing literature from around the world deeper and establish a better understanding of all the intricacies required to develop a novel patient prioritisation system. Additionally, access to real world patient data would allow for more accurate simulations and analysis between the current and proposed ranking systems. Once this is complete and found to create an impact at a local level, the system could one day be adopted in Queensland and Australia.

References

Australian Institute of Health and Welfare (July 2013). *National definitions for elective surgery urgency categories*. Tech. rep. URL: https://www.aihw.gov.au/getmedia/509f8a18-73c9-416c-92a5-f5073201df46/15778.pdf.aspx?inline=true.

Queensland Health (2015). *Waiting lists*. URL: https://www.qld.gov.au/health/services/hospital-care/waiting-lists#:~:text=In%20Australia%2C%20there%20are%203,added%20to%20the%20wait%20list..

Curtis, Andrea J et al. (Feb. 2010). "Waiting lists and elective surgery: ordering the queue". In: *Medical Journal of Australia* 192.4, pp. 217–220. ISSN: 0025-729X, 1326-5377. DOI: 10.5694/j.1326-5377.2010.tb03482.x. URL: https://onlinelibrary.wiley.com/doi/abs/10.5694/j.1326-5377.2010.tb03482.x.

Breton, Mylaine et al. (Aug. 2020). "How the design and implementation of centralized waiting lists influence their use and effect on access to healthcare - A realist review". In: *Health Policy* 124.8, pp. 787–795. ISSN: 01688510. DOI: 10.1016/j.healthpol.2020.05.023. URL: https://linkinghub.elsevier.com/retrieve/pii/S0168851020301202 (visited on 12/27/2020).

Oudhoff, Jurriaan P et al. (Dec. 2007). "The acceptability of waiting times for elective general surgery and the appropriateness of prioritising patients". In: *BMC Health Services Research* 7.1, p. 32. ISSN: 1472-6963. DOI: 10.1186/1472-6963-7-32. URL: https://bmchealthservres.biomedcentral.com/articles/10.1186/1472-6963-7-32 (visited on 12/27/2020).

Testi, A. et al. (Jan. 2008). "Prioritizing surgical waiting lists". In: *Journal of Evaluation in Clinical Practice* 14.1, pp. 59–64. ISSN: 13561294. DOI: 10.1111/j.1365-2753.2007.00794.x. URL: http://doi.wiley.com/10.1111/j.1365-2753.2007.00794.x.

Solans-Domènech, Maite et al. (Nov. 2013). "Developing a universal tool for the prioritization of patients waiting for elective surgery". In: *Health Policy* 113.1-2, pp. 118–126. ISSN: 01688510. DOI: 10.1016/j.healthpol.2013.07.006. URL: https://linkinghub.elsevier.com/retrieve/pii/S0168851013001954.

Siddins, Mark T. et al. (2012). "Achieving waiting list reform: a pilot program integrating waiting time, category and patient factors". In: *Australian Health Review* 36.3, p. 248. ISSN: 0156-5788. DOI: 10.1071/AH11997. URL: http://www.publish.csiro.au/?paper=AH11997.

Queensland Health (2017). *Treated in turn*. URL: https://clinicalexcellence.qld.gov.au/resources/service-delivery-models/treated-turn.