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Discrete Simulation on Elective Surgery Wait Line Using Arena Simulation Software

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***Abstract*—Medical professionals and patients have struggled with long elective surgery waiting line for decades. Hospitals across the world, especially in countries with universal healthcare, struggle with balancing the heavy demand from elective surgery waiting line and allocating enough resources for emergency patients. Patients must rely on private hospitals or going abroad to get faster health care, but poorer patients do not have this privilege. In this research, we investigate whether moving surgeons across hospitals within a local health district can improve the elective surgery waiting line. For the scope of this research, only 3 types of surgeries, Urology, Ophthalmology, and Orthodontics, are considered. In order to implement the simulation process, 3000 dummy patients, 2000 old and 1000 new patients, were created for each urgency type in each surgery category. The data was fed into a new model in the Arena Simulation model as input. Poisson and Triangular distribution were applied in this model for assigning the surgery and observation duration. Our model scenario contains 2 large hospitals and 1 small hospital. In the experiment model, one surgeon was moved from both large hospitals to the designated small hospital, and we analyzed the 90th percentile of the output. We noticed that the 90th percentile duration in the waiting line decreased for both small and large hospitals after moving one surgeon from each large hospital. Therefore, we can conclude that temporarily transferring surgeons from one hospital to another can be beneficial to the elective surgery wait line. By moving surgeons instead of patients, patients can also choose a hospital nearer to their home for their elective surgery.**

***Index Terms*—Analysis, health care, modelling, simulation.**

I. Introduction

Countries with universal health care system have struggled with the elective surgery waiting line problem for decades. Especially in the first world countries, as population increases, the number of patients requiring health care increases. Unfortunately, in most countries, the increased in demand is not balanced by a proportional increase in supply. Patients nowadays must wait longer than before due to the shortage of medical professionals and facilities. Thus, they must rely on private hospitals for quicker service or wait in the long queue in public hospitals. This is dangerous and disadvantageous to the patients as their conditions can worsen when they are waiting to be admitted into surgery, or if there is any underlying worse condition that is harder to detect outside of the operating room. Medical professionals around the world strive to seek a more efficient solution for the elective surgery problem but continue to struggle with the increasing demand and patient's dissatisfaction towards the long elective surgery wait times.

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Many researchers have attempted to tackle the elective surgery waiting line problem for decades. Min uses a stochastic optimization model with considering SICU capacity constraints [1]. Marques uses integer programming approach to schedule elective surgeries [2]. Yip and his team investigated moving surgeon schedules within a hospital to optimize observation bed usage [3]. Nevertheless, none of the articles provided insight on moving surgeons or any other resources to different hospitals to accommodate temporary spikes of demands.

Like other countries, Australia has been struggling with the long elective surgery waiting line problem. Although the annual national report shows that majority of the patients are admitted on time according to the recommended schedule, it still takes 268 days for 90 percent of the patients to be admitted and complete their necessary surgeries in 2018. This is an increase of 5 percent since the year 2013-2014 and a 2 percent increase compared to 2016-2017.

In 2017-2018, 873,993 patients were added to Australian hospitals' elective surgery wait line. This is a 9.1 percent increase from 2013-2014's total of 794,401 patients. However, the increase in resources still cannot counteract with a significant increase in the number of patients in this decade. In 2017-2018, there are 2.5 public hospital beds per 1000 population. Although this is an increase from 1.18 beds in 2012-2013, the increase in resources is still significantly less than the increasing rate of patient admission [4].

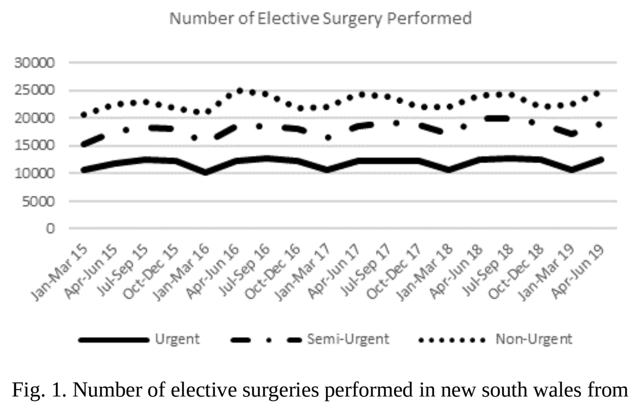

Fig. 1. Number of elective surgeries performed in new south wales from 2015 – 2019.

Fig. 1 shows the number of elective surgery patients who had to undergo their necessary surgeries in the past 4 and a half years. In 2018, although 873,993 patients were added into the elective surgery wait line in Australia, only 748,778 patients completed their surgery in the same year. This proves that not all patients complete their surgery within the recommended period as the maximum wait time recommended for a non-urgent patient is 365 days [4].

Furthermore, this statistic does not include the wait times to see a specialist before they are added to the elective surgery wait line. It could take up to a year for the patients to get an appointment with the necessary specialist which could be a major issue for patients whose daily tasks are affected due to their condition [5]. Hence, elective surgery wait times is a very controversial problem within Australia, due to its many unsatisfied patients. Medical professionals and government officials strive to come up with an optimal solution to this long waiting time problem. In this research, we analyze the New South Wales's elective surgery wait line statistics and investigate whether temporarily transferring surgeons across local health districts will improve the elective surgery waiting line. To decrease the scope of this research, we only look at the data from 2015 to 2018.

II. New South Wales Elective Surgery Performance Analysis

The Bureau of Health Information of New South Wales government publishes the New South Wales elective surgery performance every quarter in the Healthcare quarterly reports. However, only the overall summary is provided. The public does not have access to any data aside from the median, 90 percentile and performance percentage for each hospital [6].

In New South Wales, elective surgery patients are categorized based on how urgent their condition is and how fast they need to be operated on. The first category, Urgent patients, are critically conditioned but non-life-threatening patients who need to be operated within 30 days.

The second category is Semi - Urgent patients who are recommended to be operated within 90 days. The last category, called Non-Urgent, includes patients that need to be operated to improve their condition, but their condition is not life-threatening. Patients in the Non-Urgent category are recommended to undergo the necessary operation within 365 days [7].

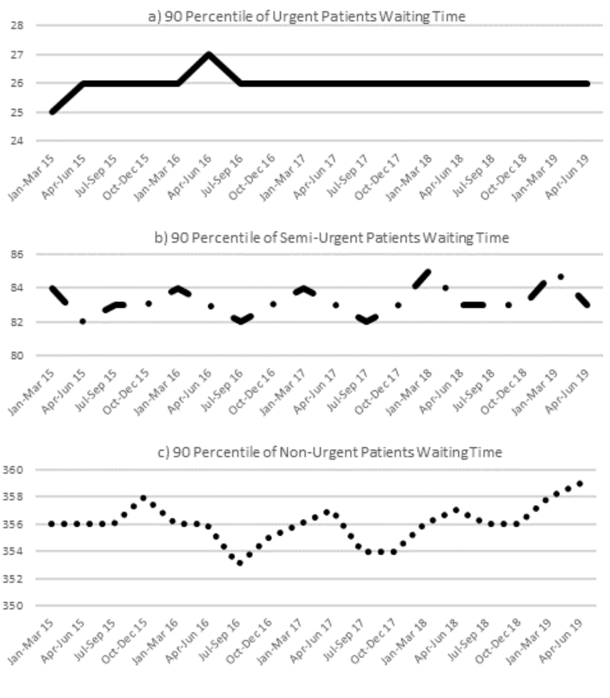

Fig. 2. 90th percentile of urgent, semi-urgent and non-urgent patients waiting time.

Fig. 2 shows a steady trend of the waiting times for urgent patients in New South Wales. On the other hand, semi-urgent patients' waiting times fluctuate every quarter, creating a wave pattern in Fig 2 part b. However, there is a gradually increasing trend for waiting time of the non-urgent patients in New South Wales as shown in Fig 2 part c [6].

III. Discrete Event Simulation Model For Elective Surgery

Since this research involves the lives of real patients, a real experiment to determine the outcome is too risky for the patients. Therefore, a simulation was done to predict the outcome of the model. We use Arena Simulation software for this purpose.

Arena Simulation software is a Discrete Event Simulation (DES) software that was created by Rockwell Automation. It is compatible with most Microsoft Windows operating system and is fully compatible with Microsoft software such as Excel and Access. This software was preferred over other simulation software because of its entity modelling. In the model, each entity is treated individually, which means the researcher can look at individual entities in their model rather than treating them as a large group [8]. Arena also provides picture icons and graphics to represent each entity and the process. The users can see each entity icon moving through their model, thus following the flow process. The Arena Simulation software is widely used in military branches and varies industries including airlines, manufacturing and supply chain industries nowadays for simulating workflow and process [9].

In this model, the patients are divided by their clinical urgency, hospital and surgery categories before being placed in the queue for their surgeries. Each patient's record through the simulation is recorded on an output file and analyzed after the simulation completes.

First, we identified necessary components that affect elective surgery waiting line. To decrease complexity, this research will only focus on the waiting time for a patient after their specialists have confirmed the need for surgery and place them into the elective surgery queue. Due to the recent backlash by the media about hospitals letting private patients jump the elective surgery queue, private and public patients are treated equally in this model. The goal of this research is to optimize the elective surgery waiting line in order for patients to complete their necessary surgeries as soon as possible. [10] This research will focus on investigating whether moving resources within the same district will improve the elective surgery waiting line. To simplify the model, the following surgery categories are selected as the primary focus:

- Orthopedics
- Ophthalmology
- Urology

Since the New South Wales government does not publish elective surgery data, we had to create dummy data using the statistics provided for our model. For this research, we created a data set of 1000 old patients and 100 new patients, each randomly assigned one of the three surgery categories and a clinical urgency. The dummy inputs for this research is stored in a text file then inputted into the Arena simulation software.

To create the model, all aspects that affect patients waiting times in elective surgery were first considered. A priority point system is used in the proposed model to determine which patients need to undergo surgery before others in the queue based on their urgency. Prioritized patients are given a higher point than other less urgent patients. The most important specification is the patients' urgency. The patients in the Urgent category must be prioritized as they need to be operated within 30 days followed by the Semi-Urgent patients that are recommended to be operated within 90 days. The priority points are assigned before the patients are split into their designated categories, as shown in Fig. 3.

After assigning the corresponding priority points, the patients are separated by surgery categories since each has its own resources in their respective departments. This creates 3 different queues in our elective surgery waiting line model, which is shown as the 3 branches in the model in Fig. 3. After being separated from the model, patients are placed in the queue to wait for their turn to undergo surgery.

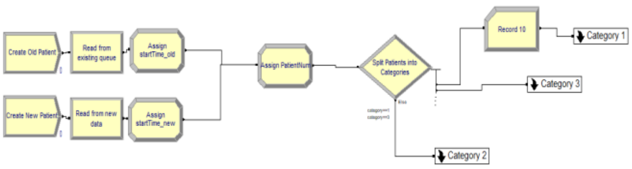

Fig. 3. Model outline.

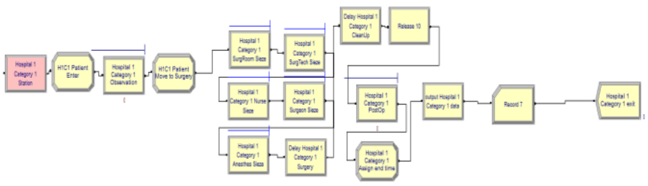

Fig. 4. Surgery model for a specific category in a hospital.

TABLE I: ASSIGNED NUMBER OF RESOURCES IN HOSPITALS

Resources	Large Hospitals	Small Hospitals
Observation Beds	10	4
Surgery Rooms	5	2
Nurses	12	6
Anaesthesiologists	5	2
Surgery Tech	6	3
Surgeons	6	3

The patients are processed in descending order of the number of points followed by the time of entering the queue. This will enable the Urgent category patients to precede their Semi-Urgent or Non-Urgent counterparts even if they enter the queue later than their counterparts, to ensure the Urgent patients undergo the necessary procedures in the necessary amount of time. Like Urgent patients, Semi-Urgent patients takes precedence compared to Non-Urgent patients. Therefore, they were given a higher point than Non-Urgent patients during the initial point assessment to ensure they can jump ahead of the Non-Urgent patients.

The amount of resources is an estimate as each hospital has a different number of surgery rooms and observation beds, depending on the size of the hospital and its surgery departments. The number of each necessary resources are stated in Table I. Since surgeries can have various duration, depending on the complexity of the surgery, Poisson distribution with a mean surgery time of 1 hour is applied in this simulation. We also assume the patients will be observed for at least 30 minutes, and at most 1.5 hours, before the surgery is performed so that the nurses and surgery tech can prepare the patients for surgery. When an observation bed is empty, the next patient in line will be assigned to that observation bed. The patients in the observation rooms will be moved into surgery once a surgery room is available. After their surgeries are complete, the patients will be moved to observation rooms again for post-surgery observation. Triangular distribution is used for the post-surgery observation, with a minimum of 30 minutes, mode of 1 hour and a maximum of 24 hours, and post-operation clean up to be 1/2 an hour.

Once the patients complete the surgery and finish post-surgery observation, they will exit the simulation. These patients' surgery details are recorded in a text file by the simulation. The data fields that are collected from the simulation are the patient's time of entering the queue, time of exit queue, surgery category, and urgency. A text file is chosen instead of CSV file because it does not contain any limitation to data file size, which enables us to run simulation will larger data set and combine simulation repetitions in one document.

For the second model, the same structure is applied but one surgeon each from Hospital 1 and Hospital 2 are moved to Hospital 3. As for the patients, instead of moving patients into the shortest queue, they are moved into their preferred hospitals. We want to investigate whether moving surgeons to smaller hospitals temporarily will improve the elective surgery wait line queue, and patients will not have to travel farther to larger hospitals for their procedures.

The model is simulated for 365.25 days at a time with 30 replications. Running the simulation for 365.25 days replicates the scenario for the entire year. Since there is no real data used in this model simulation, replications were needed to determine the precision of the simulation. Given the size of this research, only a small sample size is needed to validate the model, hence the simulation is run with 30 replications. The resulting statistics are the average of all replications of the simulation.

IV. RESULT

In the simulation, we designated 4 hours per day towards elective surgery to make way for the emergency surgeries admitted every day. 2000 out of the 3000 patients were already in the queue while the remaining 1000 is added later. The output of the simulation is analyzed to determine whether moving resources around a local health district make a difference in improving the elective surgery waiting line.

Since we did not use real data for this simulation, 30 repetitions of the simulation were done to ensure the precision of the result. In each simulation repeat, the average of maximum waiting time for each category under each urgency and hospital was calculated. After all of the 30 simulation repetitions completes, the average of each statistic is calculated and thus the result of this research.

From Table II, we notice that 5 out of the 9 groups of surgeries show a 1.5 – 2% decrease in the maximum waiting time period. The other increases can be explained by other factors that come in play with elective surgery, such as a shortage in other elective surgery resources or influx of patients coming into the surgery. The increases shown in Table II is assumed to be caused by the increase in the number of patients after patients are assigned to preferred hospitals instead of the hospital with the shortest queue.

TABLE II: HOSPITAL 3 (SMALL HOSPITAL) RESULT

Surgery Category	Urgency	Control Max	New Max
1	1	114	118
2	1	140	150
3	1	120	118
1	2	118	116
2	2	144	150
3	2	122	119
1	3	119	117
2	3	139	148
3	3	120	118

TABLE III: HOSPITAL 1 (LARGE HOSPITAL) RESULT

Surgery Category	Urgency	Control Max	New Max
1	1	7	7
2	1	10	5
3	1	34	41
1	2	10	12
2	2	6	5
3	2	37	43
1	3	13	11
2	3	11	4
3	3	45	47

TABLE IV: HOSPITAL 2 (LARGE HOSPITAL) RESULT

Surgery Category	Urgency	Control Max	New Max
1	1	52	54
2	1	52	51
3	1	49	46
1	2	12	14
2	2	52	51
3	2	47	47
1	3	54	55
2	3	50	51
3	3	46	46

Table III and IV show the change in elective surgery waiting time is not significant after moving one surgeon from each field in both hospitals. In fact, the decrease in the number of patients improved the elective surgery waiting for lines in some cases as there are not as many patients waiting in the same queue.

V. CONCLUSION

We conclude that transferring surgeon to another hospital temporarily can help decrease the elective surgery wait line, however, the hospitals will need to adopt an efficient elective surgery waiting line scheduling system to correspond with the increase in the number of patients. This will enable smaller hospitals to not have to recruit private surgeons to help perform the surgeries or moving patients from one hospital to another for specific surgeries. Moving surgeons instead of patients can also ease patients' travel before and after the surgery, especially if their surgeries can be done in a hospital closer to home or with a more convenient public transport. Thus, patients can choose their preferred hospital location without worrying about the comfort and convenience of travelling.

VI. FUTURE RESEARCH

We will also investigate the cause of improved outcome for Hospital 1 after losing one surgeon in our simulation. We could not use actual hospital data in this research due to waiting on the New South Wales health ethics application to be approved before receiving access to the data. Therefore, in the next step, we will apply actual data from a New South Wales health district to our model. Instead of dummy data, the next paper will contain elective surgery wait line patients and hospital administration details, including patients' intended surgery category, urgency, preferred hospital, preferred surgeon, and availability of resources needed for elective surgery, such as number of surgeons, nurses, surgery rooms, etc. from a New South Wales Local Health District. With real-life raw data, we will be able to accurately model our simulation since we will have the correct duration of pre-surgery and post-surgery observation periods and the duration of the surgery. If given the opportunity in the future, we will also investigate a cost-effective model for the elective surgery by assigning a cost to each aspect, including the additional cost for transferring surgeons, to the elective surgery process, but still try to optimize the patients' wait time.

If time permits, after the next paper, we will create a user interface software to incorporate with the Arena simulation. This will enable hospital administrations or local health district performance units can easily predict their wait line easily determine the effect of changing the availability of their resources. This software will most likely be written using Microsoft Visual Studio as it is the associated developing software with Arena simulation software.

Hopefully, this research will bring insight to not only New South Wales, but also countries around the world which are struggling with long elective wait lines, and the result being used in the health industry to improve elective wait lines and shorten patients' wait times for surgery.

CONFLICT OF INTEREST

The authors declare no conflict of interest

AUTHOR CONTRIBUTIONS

Dr. Jajo and Dr. Peiris provided background information and necessary resources for this research. Dr. Jajo and Ms. Leong conducted the research. Ms. Leong analyzed the data and wrote the paper. All authors had approved the final version.

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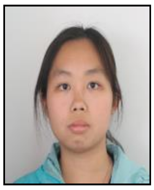

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Xing Yee is also part of Mathematical Association of America, and Australian Mathematical Society.