A SIMULATION STUDY ON A QUEUEING SYSTEM AT PSYCHIATRIC AND MENTAL HEALTH OUTPATIENT DEPARTMENT OF A GENERAL HOSPITAL IN SOUTH PENINSULAR MALAYSIA

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DEDICATION

This thesis is specially dedicated to the youths and the community. May this research provide good input and help for future studies.

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ABSTRACT

The management of an outpatient department is quite difficult. Despite a shortage of doctors and nurses, the number of patients visiting the outpatient department increases year after year. Long wait times for treatment at the department are always a major issue for management and to make matters worse, the consultation time is always much shorter than the waiting time. Therefore, the purpose of this study is to simulate the queueing system in the Psychiatric and Mental Health outpatient department in a local hospital in South Peninsular Malaysia. Particularly, it aims to analyse the waiting time at the outpatient department and propose potential solution. The Arena simulation software is used to develop a simulation model that illustrates the outpatient department. Arena software is used because it provides graphical simulation-modeling and analysis modules that can be used to build a wide array of simulation models. In addition, data were collected at the outpatient department for a month due to the approval from the Ministry of Health. The data gathered was used in the model improvement process. Then, the data was analysed to present the actual and simulated results. The findings exhibit from the analysis show that long waiting time does exist in the queueing system where patients need to wait more than three hours to receive treatment and two hours just to take the medication at the pharmacy. Based on the analysis of improvement, a solution was proposed to reduce patient waiting time. The proposed improvement was to add a suitable number of servers at the consultation room and pharmacy so that it is possible to be implemented at the Psychiatric and Mental Health outpatient department. This research helped the outpatient department to analyse and evaluate the current queueing system so that the real occurrences would not be interrupted. In all, the study is expected to be helpful as a managerial reference for the administrator of the outpatient department, mainly in reviewing and upgrading the existing queueing system.

ABSTRAK

Jabatan pesakit luar adalah jabatan yang sangat mencabar untuk diuruskan. Walaupun kekurangan doktor dan jururawat, jumlah pesakit yang mengunjungi jabatan pesakit luar meningkat dari tahun ke tahun. Masa menunggu yang lama untuk rawatan di jabatan selalu menjadi masalah utama pengurusan dan menambah burukkan lagi keadaan, masa rawatan selalunya lebih pendek daripada masa menunggu. Oleh itu, tujuan kajian ini adalah untuk mensimulasikan sistem penggiliran di jabatan pesakit luar di sebuah hospital tempatan di Selatan Semenanjung Malaysia. Tujuan utamanya adalah untuk menganalisis masa menunggu di jabatan pesakit luar dan mencadangkan penyelesaian yang bersesuaian. Perisian simulasi Arena digunakan untuk membina model simulasi yang menggambarkan jabatan pesakit luar. Di samping itu, data dikumpulkan di jabatan pesakit luar selama sebulan. Data yang dikumpulkan digunakan dalam proses penambahbaikan model. Kemudian, data dianalisis untuk menunjukkan keadaan sebenar dan simulasi di jabatan pesakit luar. Hasil analisis menunjukkan bahawa masa menunggu yang lama memang wujud di dalam sistem penggiliran di mana pesakit perlu menunggu lebih dari tiga jam untuk menerima rawatan dan dua jam hanya untuk mendapatkan ubat di farmasi. Berdasarkan analisis penambahbaikan, satu penyelesaian dicadangkan untuk mengurangkan waktu menunggu pesakit. Penambahbaikan yang dicadangkan adalah dengan menambahkan bilangan kaunter yang sesuai di ruang rawatan dan farmasi yang mana dapat dilaksanakan di jabatan pesakit luar. Kajian ini membantu jabatan pesakit luar menganalisis keadaan semasa sistem penggiliran tanpa mengganggu keadaan semasa yang berlaku di jabatan tersebut. Secara keseluruhan, kajian ini bermanfaat sebagai rujukan pihak pengurusan pentadbir jabatan pesakit luar untuk mengkaji dan menaik taraf sistem penggiliran yang sedia ada.

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LIST OF SYMBOLS AND ABBREVIATIONS

μ	-	Average service rate
λ	-	Average arrival rate
n	-	Number of customers in the system (in queue plus in service)
λ_n	-	Arrival rate given n customers in the system
μ_n	-	Departure rate given n customers in the system
P_n	-	Steady-state probability of n customers in the system
L_s	-	Average number of customers in the system
L_q	-	Average number of customers in the queue
W_q	-	Expected waiting time in queue
W_s	-	Expected waiting time in system
M	-	Arrival rate distance; Poisson or Exponential rate
M	-	Service rate distance; Poisson or Exponential rate
c	-	Number of service channels
GD	-	Service discipline/general distance of service time
∞	-	Maximum number allowed in system
∞	-	Calling source/population size
N	-	System limit
λ_{eff}	-	Effective arrival rate
A	-	Consultation room A
B	-	Consultation room B
C	-	Consultation room C
D	-	Consultation room D
E	-	Consultation room E
F	-	Consultation room F
P1	-	Dispensing counter 1
P2	-	Dispensing counter 2
P3	-	Dispensing counter 3

LIST OF APPENDICES

LIST OF PUBLICATION

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CHAPTER 1

INTRODUCTION

Chapter 1 is the engine that drives the entire research documentation. Hence, this section covers and explains about the background of the study, problem statements, objectives, scope of the study, significance of the study, and lastly, this thesis organisation.

1.1 Background of study

The main function of a general hospital is to provide the most comprehensive healthcare services to the public, especially for those who cannot afford to go to the private hospitals. Thus, the general hospital has been the main attraction to the public to get their healthcare services, resulting in the ever-increasing number of patients and visitors coming to the hospital, at any time of the day.

The number of patients and visitors coming to the general hospital is always on the rise, but the efficiency of the hospital management has not improved. This is evident from the long waiting times which patients have to bear with, before they receive their health services, thus rendering it difficult for customer satisfactions to be achieved. Patient satisfaction is ranked among the most significant success measures for the quality of healthcare services (Zabada, Sanjay & Munchus, 2001). Overcrowding in outpatient departments and specialists' clinics in Malaysian public hospitals is quite a common sight, as found in a study by Manaf (2006), which reported that, outpatient clinics in Malaysian public hospitals are overcrowded with patients.

The government hospitals in Malaysia have been in a state of transition, where demands for health services are sharply rising, primarily due to better perceptions of patients who are well-informed, about diseases and possible therapies (Ismail *et al*., 2010; Pocock & Phua, 2011).

Over the years, hospitals in Malaysia, mainly those government-run, have to endure enormous challenges in delivering effective and adequate facilities with minimal resources (Zhu, Tang & Gong, 2013), with the number of patients increasing every year, while the number of key staff, such as doctors and nurses, significantly reduced. This problem has greatly affected several different departments, including the outpatient department, which queues for treatment may take hours. The development of faster services with a reduced waiting time for the outpatient department has also been the goal of many service providers in recent years (Garba, Ebenehi & Ademola, 2013; Singh & Gupta, 2014).

Long queues are symptomatic of inefficiency in hospital or clinical facilities. Unfortunately, this is the case in many public hospitals or health clinics in many developing countries. Many patients are received daily by the public outpatient clinics, which usually results in long waiting times (Afrane & Appah, 2014).

In the hospital, the nurses, trained counter personnel, including the Information Technology (IT) staffs and the entire equipment act as the servers in the queueing system, while clients who come to the hospital, including the walk-in patients, wait for the required services to be provided, before going to the pharmacy counter or to another department, for further treatments or services (Obulor & Eke, 2016).

This research was conducted to analyse the queueing issue at the Psychiatric and Mental Health outpatient department in a government hospital in Johor, and propose suitable solutions to improve it. It is critical to determine how long a patient must wait in line before being served and how this queueing time may be reduced. Patients tend to give up queueing, if it takes them too long to get their treatment. A simulation model, as developed in this study, would help in assessing potential improvements to the current problem. The average waiting time for each patient can be calculated using the simulation model. Since waiting time is crucial, it needs an adequate system component to be focused. Therefore, it is necessary to analyse and diagnose the waiting time consumed for each patient, in the outpatient department, so that this queuing issue can be resolved. The main aims of this study were to simulate

the current queueing system, to analyse the queueing problem and to propose suitable solutions.

1.2 Problem statement

Time is always a great concern for patients throughout their treatment, provided by any healthcare provider, either public or private. Despite being aware that, they need to wait to see a doctor, queueing for too long often creates uneasiness among the patients, and it wastes them their time, which could instead be used to accomplish other things beneficial. Researchers usually use simulation methods to help them visualise and understand the circumstances in their study, to improve the long waiting time (Ahmad *et al*, 2020). Previous research has shown that, a simulation modelling could be used to successfully overcome queueing system problems. Therefore, in this research, a simulation model was developed to simulate the current queueing system, to analyse the queueing problem and to propose suitable solutions to the issue of long waiting times in the Psychiatric and Mental Health outpatient department of a government hospital, in Johor. Arena, a simulation software, was used to create the simulation model because it is a software that include phases of simulation project starting from input data analysis to the analysis of simulation output data. The outpatient department was modelled, based on the current scenario, using the Arena simulation model and changes for improvements were made on the outpatient department, based on the trial-and-error method, to determine the optimum number of service counters, layout design and other factors to reduce the waiting time at the outpatient department. As far to our concern, this study was the first of its kind conducted at the Psychiatric and Mental Health outpatient department at a government hospital in Johor.

1.3 Objectives of study

The objectives of this study are as follows:

(i) To analyse the queueing data of the Psychiatric and Mental Health outpatient department of a general hospital in south peninsular Malaysia.

(ii) To propose a simulation model of queueing system for this department.

(iii) To propose suitable improvement solutions to the current queueing problem at the outpatient department.

1.4 Scope of study

To achieve the stated objectives, this study focused on one of the general hospitals in Johor. The collection of data only involved the outpatient department. Data was collected for twenty days, from Sunday until Thursday, 8:00 a.m. to 4:30 p.m. Through the daily records, data needed to be analysed, such as, arrival rate, service time, number of patients waiting and rate of departure was collected. Subsequently, a simulation of the queueing situation was established from the collected data, before the data was further analysed.

1.5 Significant of study

The significant benefit which can be obtained from this study is that, its results can be used as guidelines and references for the management of government hospitals, particularly, the hospital selected for this research, in terms of planning, organising and controlling for future benefits. This study can also be used to identify and improve weaknesses related to health services management, by recommending better alternatives.

1.6 Thesis organization

This thesis consists of six chapters, which start with the Introduction, followed by Literature Review, Methodology, Results and Discussions, Analysis for Improvement and lastly Conclusion and Recommendations.

Chapter 1, which is the Introduction, starts with the background of the study, where it leads to the problem statement, which determines the objectives of this study. Scope of study describes details about what were involved in this study while Significant of study shows the benefit gain from this study.

Chapter 2 consists of Literature Review, which summarises the previous studies and theories related to queueing and simulation. Meanwhile, Methodology in Chapter 3 explains about the workflow of this study, and the formulas and software used to obtain the results.

Chapter 4, Results and Discussions, discusses the simulation model and analysis of the results obtained from the simulation model. Analysis for Improvement, in Chapter 5, shows the analysis in proposing improvement, based on the existing problems. Lastly Chapter 6, Conclusion and Recommendations, concludes the whole study and suggests suitable ideas for future research work.

CHAPTER 2

LITERATURE REVIEW

A queueing study is a real-life situation application of the queueing theory to solve daily queueing in our daily lives, such as in hospitals, post office and banks. Following the basis of this study, this section presents the literature review of related works by some researchers, related to the healthcare. Thus, this chapter summarises information about queueing theory and modelling, basic queueing principal, queueing model description, multiple server queueing model, simulation, Arena simulation software, application of simulation in healthcare, and applications of queueing and simulation in Malaysian healthcare.

2.1 Queueing theory and modelling

The first ever queueing theory was developed by the Danish telecommunications engineer, Agner Krarup Erlang. Erlang single facility M/M/s queues, known as Erlang C mathematical model, was analysed, where customer arrivals were based on the Poisson distribution. David G. Kendall was another significant figure in the evolution of queuing theory. Kendall introduced the A/B/C notation, known as 'Kendall's notation', which portrays the characteristics of a queueing method that has become the standard in the classification of queueing theory (Afrane & Appah, 2014).

Queueing theory was then introduced to packet switching networks in the 1960s by Leornard Kleinrock, and this development contributed to the birth of the Internet. In 1969, Leornard's Host Machine became the first node on the Internet, and

the first message to travel across the Internet was sent from there. In reality, however, operations in services often display features that were not captured by early queueing models, such as those developed by Erlang and Jackson (Nick, 2012).

Ndukwe, Tayo & Sariem (2011) examined the relationships between the number of pharmacy staff, the drug dispensing procedure and the waiting time of outpatients. A mathematical queuing model was used in their study to estimate the probability that the waiting time would exceed the given value, when the prescription arrival and service rates and number of servers were known. It was found that, the key factors determining outpatient waiting time were, the pattern of prescriptions at the pharmacy, the sequence of work and the number of staff working at the workplace.

The application of queueing theory and modelling to the queueing problem in the outpatient department of AngloGold Ashanti Hospital in Obuasi, Ghana, was investigated by Afrane & Appah (2014) in this report. A descriptive, observational, and ex post-facto case study methodology was used, and it was demonstrated that, the device can operate optimally with eight physicians, effectively, as opposed to only five.

A cross-sectional descriptive survey was done to study the queueing system at the general outpatient clinic, in relation to time spent by patients on the queue, and patient satisfaction. Observations were also made on the queueing model and the service discipline at the clinic. Majority of the patients spent 2 hours or less on the queue, before being seen by a doctor and less than 1 hour to see the doctor. The queueing method employed at the clinic is a multiple single channel type and the service discipline is priority service (Babar, Mudey & Khot, 2016).

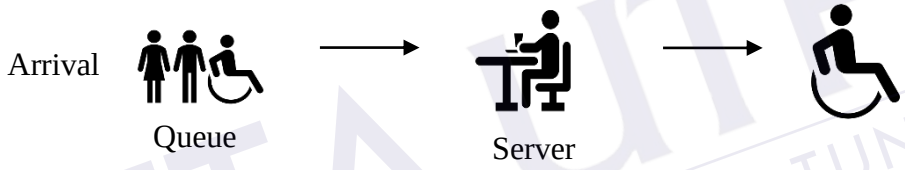
Lasisi & Abdulazez (2017) examined the reliability of the implementation of queueing theory in outpatient service delivery, at Abubakar Tafawa Balewa University Clinic, Bauchi. The results obtained have shown that, the traffic volume or likelihood that the system was found to be busy was about 81%, and that, patients were likely to have to wait on the queue for 36 minutes to be served. It was proposed that more physicians be hired, at the same time, as an initiative to minimise patient waiting time.

The Emergency service of a public hospital was examined in this work using queue definitions and relationships. The least squares method was used to validate the function that best fits the arrivals and services data. Based on the model's findings, it was concluded that, the Emergency Department lacks the minimum number of doctors needed for a continuous flow of patients. The model calculated the minimum number

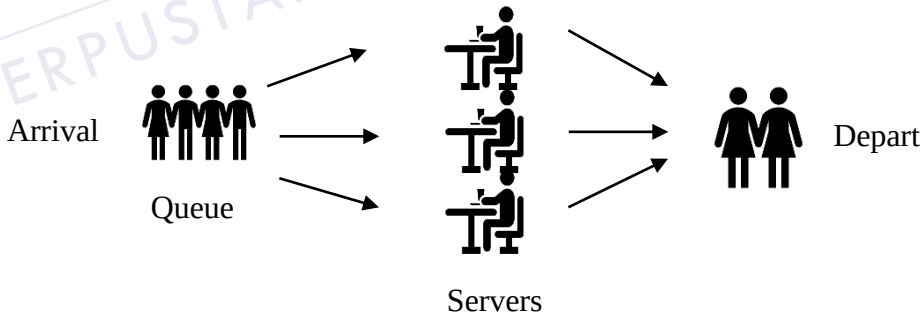
of doctors required to meet current and potential service demand, while maintaining the same service times and service disciplines. The analytical models allowed direct understanding of the current relationships, between service demand, number of doctors, and the attention priority of the patient seen, as a system of queues (Jauregui *et al.*, 2017).

2.2 Basic queueing model

A queueing system is known as a single server model, if the system has only one server, and a multi-server model, if the system has multiple parallel channels. A single server and multiple servers' systems are shown Figure 2.1 (a) and (b) (Shanmugasundaram & Umarani, 2015).



(a) Single server model



(b) Multiple server model

Figure 2.1: Comparison of single and multiple server models (Shanmugasundram & Umarani, 2015)

The queueing theory framework consists of three key concepts, namely, customers, servers and queues (Schwartz, 2016). Customers are running units that serve the network. An individual can be a client or whatever which a system needs to process and finalise; a web application, a database inquiry and a component to be

milled via a machine. Servers are the entity that provides the service. It may be a cashier in the store, web server or database server or a browser. Queues are working units which wait, if the server is busy, and cannot do the work as it happens.

According to Koka, Badshah & Shah (2017), single server and multiple models are based on certain assumptions about the queueing, which are as follows:

i. Arrivals are defined by Poisson probability distribution and come from an infinite population.
ii. Single waiting line and each arrival waits to be served, regardless of the length of the queue, with no balking and reneging taking place.
iii. The queue discipline is first come first served
iv. A single server and processing time follow exponential distribution.
v. Average service rate is higher than average arrival rate, $\mu > \lambda$

2.3 Simulation

Generally, simulation is a very powerful and widely used management science technique for the analysis and study of complex systems. A simulation model usually takes the form of a set of assumptions about the operation of the system, expressed as mathematical or logical relations, between the objects of interest in the system (Winston, 2004). Simulation is a viable replication of the performance of a real-world process or system over time, while queueing theory uses mathematical analysis to evaluate the system's measure of effectiveness. Each queueing system is a typical problem of a discrete event system and simulation is a very effective technique of addressing queueing problems, as well as analysing their effectiveness, in a practical way (Fadhil & Saad, 2011).

A simulation model is built on a set of assumptions about the system's behaviour. The mathematical, logical and symbolic relationships of system values between entities or objects express these assumptions. After the model has been validated and confirmed, it may be used to address 'What If' questions in the real-world system and is valuable for anticipating future system changes after validation and testing. Simulation is useful in the system design process, since it can save money and time, while also giving strategic decision knowledge (Hernandez, Morales & Rodriguez, 2016).

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