Review on Queueing Problem in Healthcare

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Abstract

This article shows the application of queueing, simulation and scheduling used in the field of healthcare. A summary of queueing, simulation and scheduling theory used in waiting time, appointment system and patient flow are summarised in this article. Different departments in the healthcare system are also considered in this article such as emergency department, outpatient department and the pharmacy. The aim is to provide the reader a general background into queueing, simulation and scheduling in the healthcare.

Keywords: Healthcare; Scheduling; Simulation; Queueing.

1. Introduction

Patients are expected to receive treatment and services from specialized staff and equipment from the main healthcare facility centre which is the hospital. However, the queueing in many hospitals has been a big issue to the public. This is due to the long waiting time to receive health services. Furthermore, the very long waiting time for treatment results in boredom and can cause a patient's health status decline and hence, reduce the treatment efficiency due to patients may not be attended and end up going home without receiving attention.

The long waiting problem is caused by the increasing number of visitors and patients attending to the hospital while the services system remains unchanged. There are lot of complain has been reported due to queueing problem such as, lacking beds in the hospital, long queue at the pharmacy department and reduced number of equipment. The seriousness of this problem is often featured in the news report through the mainstream media.

In the hospital, the nurses, trained counter personnel including the IT staff and the entire equipment act as the servers in the queueing system while clients who come to the hospital include the walk-in patients, wait for the necessary service, obtain it and then leave upon completion of service or walk to another department expecting supplementary service [1].

2. Queueing

A study on the application of queueing theory and modelling to the queueing problem at the outpatient department at a hospital in Ghana is investigated. The method used are descriptive, observational and ex-post facto case study approach. The analysis came out with a result stated that optimum performance can be achieved with eight doctors compared to five doctors. Therefore, applying queueing theory and modelling to queueing can enhance decision making with regards to what will provide optimal performance [2]. As the solution to long waiting time, an efficient queueing model for proper appointment system is proposed. A series of interviews are carried out to get the general overview on the factors affecting patients waiting time. Hence, the appointment queueing system provides better utilization of resources and reduces patients waiting time in the outpatient department [1].

A survey on patient’s satisfaction at the emergency department has been done which evaluated 2195 questionnaires for a period of three years to plan the capacity of emergency department in Mures County, Romania to manage in optimal way to patient’s flow. Queueing models are used to provide reasonable accurate evaluations for the system’s performance and as a useful tool for decision making [3]. In this research, queueing theory has been used as the first tool to view patient waiting time on each server and the results show that the appointment system should be change for physicians. Through this research, recommendation on the best strategy to improve the appointment system and a study of the major causes of patients’ length of time for medical treatment could be provided [4]. A descriptive analysis was conducted to develop a suitable model for determining waiting arrival time and service time of patients at the outpatient counter. This study included the arrival rate and service rate of patients at the outpatient counter for the analysis. The result shows that multiple server channel model was developed for the outpatient department with the focus on the patient waiting time to have the treatment [5].

3. Simulation

A simulation study to replicate patient movement flows in an emergency department (ED) of a general hospital in north Peninsular Malaysia has been conducted [6]. This study was carried out to evaluate resource utilization among personnel and physical resources. Then, a hybrid simulation method combining discrete event simulation and system dynamic modelling approach was proposed to better understand emergency department operations from a whole system perspective [7].
In this study, an improvement of discrete event simulation model for modelling outpatient pharmacy workflow queueing system has been done in an outpatient pharmacy in Riyadh. The intention of this study was to explore the possible options in designing efficient queueing system. The data were collected using stopwatch. Based on the analysis of the data which involved various scenarios, the result found from the simulation model shows that long waiting time exist in the system and simulation model basically helps to reduce the patients’ waiting time and improve the service quality [8]. A suitable queueing theory and simulation technique has been developed in this study to optimize the management of studied outpatient pharmacy.

A descriptive analytical study was conducted with a sample of 220 patients involves in this study. The simulation results showed that reducing staff in the morning would not change the performance but increasing one staff may change the queue performance. Hence, by using queueing theory and simulation techniques, the patients’ waiting time and number of waiting patients could be reduced [9]. In this research, a queueing model is developed using discrete event simulation where the healthcare centre at Mississippi State University (MSU) is selected as case example. The aim is to reduce patient waiting time and improve throughput of the system. The results suggest that 90% of patients should follow normal route in the blood lab and another 50% should reroute to other lab [10]. In reducing average waiting time for outpatient section, a simulation for number of patients attending the outpatient section was simulated. Patient’s arrival time, service time and average waiting time were calculated by simulating the number of patients. The results show that the average waiting time can be reduced by 40.97% if another doctor allocated to provide the services and the extra doctor must be present at least in the peak hours between 9 a.m. to 12 noon [11].

This study of [12] had proposed a new method for surgical scheduling which based on duration groups and level of variability for scheduled procedures in the operating theatres. A discrete event simulation was used to model and validate the daily surgical schedules. Based on the analysis, the result shows that how a can a method improves the surgery scheduling but additional factors such as considering accurate estimations for variability of surgeons and system for managing emergency should be included into the analysis [19-24].

4. Scheduling

In the research of [13] modelled the patients’ flow using discrete event simulation where many appointment scheduling is analysed and evaluated with an attempt to address the appointment scheduling problem for appointment systems which involved multiple classes of patients having different mean service times, punctualities, no-show probabilities and service time variability. Thus, it is found that significant performance improvements may be achieved through classification and sequencing of patients [25-27]. A research was developed to schedule the working shift of the nurses so that the availability and equality of the nurses were ensured. This research used goal programming method to develop the work shift schedule. The results show that the hard constraints were satisfied compared to the current scheduling work shift for the nurses in the hospital [14]. A real scheduling problem was used in this study to develop a mathematical model to schedule the operation theatre during peak and off-peak time. Integer Linear Programming and Linear Programming techniques were used for the analysis of this study. The results show that linear programming technique able to obtain optimal schedule which meet the aim to develop a mathematical model for the operation theatre scheduling and the related constraints [15]. A model was proposed for the scheduling entry of the non-critical patients into the Emergency Department which may be helpful for the management service. The data were extracted from the hospital historical data and the model was based on the patient scheduling algorithm. The results show that overall mean of 31% of the patient waiting time able to be reduced and proved that the model is efficient for the application within the service provided in the emergency department [16]. A mathematical programming model was proposed to generate physician schedules which satisfy physicians’ preferences and their duty requirements. The constraints were collected and included into the analysis which results in the automated schedule provide fairness and more effective among the physicians [17].

In the research of [18], a stochastic integer programming was developed for multiple operating room to minimize the costs from both health care providers and patients. Synthetic data was used to test the performance of the proposed model and experiments were conducted to show the effectiveness of the proposed model. The results show that approximately 27% of the cost can be reduced by using the proposed stochastic integer programming model. The variables and constraints are introduced as follow:

\[
\sum_{i \in I} y_{it} \leq 1 \quad \forall i \in I, \quad y_{it} \leq x_{it} \quad \forall i \in I, \quad t \in T
\]

\[
y_{it} \in \{0,1\}, \quad \forall i \in I, \quad t \in T, \quad \text{representing patient } i \text{ is assigned to the } r^{th} \text{ OR. The basic model includes:}
\]

\[
\text{Min} \quad \sum_{i \in I} \alpha_i x_i + \sum_{i \in I} d_i \left(1 - \frac{1}{2} \sum_{t \in T} y_{it}\right) + \sum_{i = 1}^{\sum_{k \in K} q_k} \sum_{i \in I} \sum_{t \in T} W_i W_i^{k,i} + \sum_{i \in I} \sum_{t \in T} \Omega_i^{k,i}
\]

### Table 1: Summary of Previous Study

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Title</th>
<th>Research Problem</th>
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<tbody>
<tr>
<td>Nor Azati &amp; Nur Salsabilah</td>
<td>2018</td>
<td>Application of Queueing Theory Model and Simulation to Patient Flow at The Outpatient Department</td>
<td>To determine the waiting arrival time &amp; service time of patients at the outpatient center also to model suitable queueing system using simulation. Arena student version unable to develop more than 150 entities waiting &amp; simulate complex model. Only simple flow can be developed.</td>
</tr>
<tr>
<td>Afrane &amp; Appah</td>
<td>2014</td>
<td>Queueing Theory and The Management of Waiting-time in Hospitals: The Case of Anglo Gold Ashanti Hospital in Ghana</td>
<td>To investigate the application of queueing theory and modelling to the queueing problem at the outpatient department at AngloGold Ashanti hospital in Obuasi, Ghana. This study however did not consider costs and it would be interesting to include the cost dimension in another study in future.</td>
</tr>
<tr>
<td>Obulor &amp; Eke</td>
<td>2016</td>
<td>Outpatient Queueing Model Development for Hospital Appointment System</td>
<td>To propose and efficient queueing model for proper appointment system as the solution to the long waiting times. Queueing model seems difficult to implement due to the increase in the calling population.</td>
</tr>
<tr>
<td>Lade, Chowriwar &amp; Sawantil</td>
<td>2013</td>
<td>Simulation of Queueing Analysis in Hospital</td>
<td>To reduce the average waiting time of patients for OPD section. There would be more profits made and more time to carry out business to improve</td>
</tr>
</tbody>
</table>
Table 1 shows the summary of previous study on the application of queueing, simulation and scheduling in healthcare. However, there is a few parts that need to be improved. Further contributions are listed in Table 2. Both scheduling and simulation can be implemented in queueing system. Scheduling helps in arranging and optimizing processes while simulation is an innovative approach to imitate the real-world operation process and improve system performance. Therefore, both scheduling and simulation are important to ensure queueing problem can be overcome based on what is the problem circumstances.

5. Discussion

Table 1 shows the summary of previous study on the application of queueing, simulation and scheduling in healthcare. However, there is a few parts that need to be improved. Further contributions are listed in Table 2. Both scheduling and simulation can be implemented in queueing system. Scheduling helps in arranging and optimizing processes while simulation is an innovative approach to imitate the real-world operation process and improve system performance. Therefore, both scheduling and simulation are important to ensure queueing problem can be overcome based on what is the problem circumstances.

Table 2: Recommendations of the Research

<table>
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<th>Contributions</th>
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<tbody>
<tr>
<td>i. To analyse the current queuing problem in the healthcare.</td>
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<td>ii. To study the waiting times for the health services.</td>
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<td>iii. To simulate the healthcare system.</td>
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<td>iv. To validate the best decisions for the healthcare system.</td>
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<td>v. To reduce the waiting time during peak hour.</td>
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6. Conclusion

Queueing, simulation and scheduling are combinations of powerful management tool which often applied in many different areas which now has been applied in the medical sector. Proper implementation of these powerful management tool may lead to an effective and efficient management system.

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References


